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ESG Economist

Technologies available to hit 2030 emission target

Casper Burgering – Senior Economist Sustainability Research | casper.burgering@nl.abnamro.com

- **We look at the emission reduction potential of current and future decarbonisation technologies for sectors of the Dutch economy to 2030 and then towards 2050**
- **In this publication, we focus on low carbon technologies in 21 sectors and outline our emission reduction scenarios by sector; click here for the individual sector notes**
- **For each of the 21 sectors – capturing more than 75% of all emissions – we build three emission scenarios: a base case and a passive and proactive pathways**
- **We use technological readiness indicators in order to identify the technologies that are ready to use and then estimate their emission-reduction potential for each sector**
- **Important low carbon technologies are energy efficiency measures, electrification, production of renewable energy, raw material substitution and building insulation**
- **With available decarbonisation technologies, the 2030 target could potentially be in reach if companies and sectors are proactive in implementing the available technologies**
- **However, in our base case, which assumes a less proactive approach and the existence of various bottlenecks, a large number of sectors would fall short**
- **Bottlenecks include the availability of qualified personnel and critical materials, but also the costs and availability of finance for the transition**
- **In highly energy-intensive Dutch industries, such as food, petroleum and basic metals, the challenge is still relatively high**
- **In transport sectors and in water & waste management, the number of radical low-carbon technologies is less or the terms and requirements are less available for the technology to break through or public policy is less stringent or transparent**
- **The success of climate measures taken in the short term – until 2030 – is going to determine largely the path to 2050**

In this publication, we answer the question of what the path of the Dutch economy and its sectors towards the ultimate 2050 climate-neutral goal might look like. In particular, we look here at the impact that low-carbon technologies can have on reducing greenhouse gases for 21 sectors in our so-called *Sector Technology Pathways*. What sectors are the heavyweights in the transition, where is reducing greenhouse gases most challenging and what are bottlenecks we need to overcome in the transition?

Our analysis shows that companies in many sectors often have ample opportunities to reduce their GHG emissions. Sometimes these are the 'low-hanging fruit' and relatively easy to implement. However often they are also complex adjustments in processes. Decarbonisation is thus always tailor-made. We start this publication with an introduction to our framework and scenarios, after which we dive deeper into the main conclusion. Finally we present the sector deep dives for 21 sectors of the Dutch economy and the low carbon impact going forward.

Framework for Sector Technology Pathways

With this publication, we provide insight into the trend in greenhouse gas (GHG) emissions by sector and what options or technologies companies in those sectors have to reduce GHG emissions from their economic activities. These are scope 1 emissions. These are the direct emissions from sources owned or managed by the company. We try to use this to identify the emission reduction potential of current and future decarbonisation technologies towards 2050. In this way, a GHG emission reduction pathway to 2030 and beyond to 2050 emerges for each individual sector.

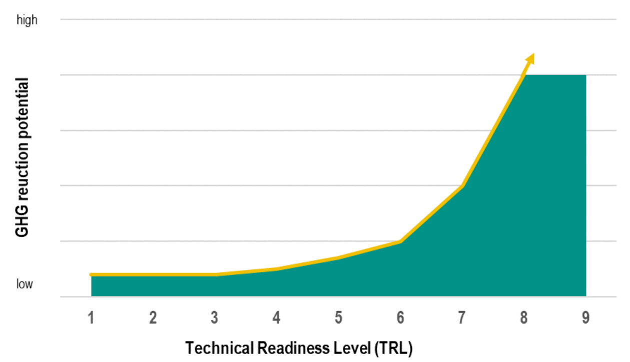
Our sector approach in this publication ultimately captures 75%-80% of total Dutch GHG emissions. However, understanding GHG emission reductions by sector is not enough. Although our exercise focuses specifically on the Netherlands and scope 1 GHG emissions, we note that making a climate-neutral pathway for an individual sector (and an individual country) has some challenges. It is often more effective to take a holistic view of the decarbonisation pathway, as sectors are interconnected and sometimes highly interdependent. Next to that, the world is highly globalised and sectors often have international value chains, especially in an open economy like the Netherlands.

GHG emissions can occur 'upstream' in the value chain through, for example, production of goods and/or semi-finished products and transportation. But GHG emissions are also realised 'downstream' through the use of products and their waste. To ultimately achieve climate neutrality, cooperation with partners throughout the value chain is often a more sensible approach. Moreover, this allows some sectors to have a much greater impact on GHG emission reductions from a much larger part of the economy, without themselves having a large share of GHG emissions from owned or controlled sources.

At different stages of decarbonisation technology development (Technical Readiness Level, TRL), a technology has a different level of impact on GHG emissions. The TRL scale (from 1 to 9) represents the stage in which a new decarbonisation or GHG emission reduction technology is positioned. Here, stage 1 represents the start of development and discovery. At this stage, it has relatively low GHG emission reduction potential. And stage 9 represents the commercial readiness of the technique and that the technique can be deployed on a larger scale. Then the GHG emission reduction potential is much higher and can also vary greatly from one technology to another.

Phase TRL and GHG-reduction potential

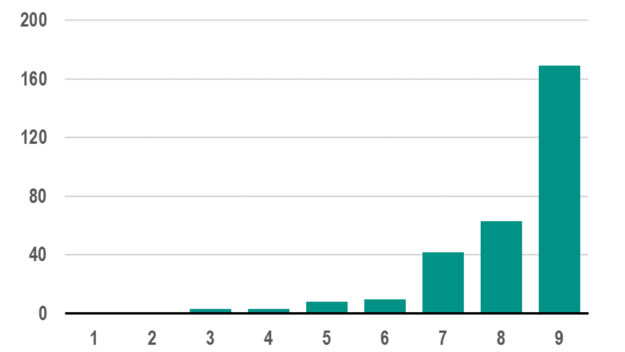
from low to high



Source: Climate-insiders, ABN AMRO Group Economics

Low carbon technologies in sectors by TRL

total number of low carbon technologies



Source: ABN AMRO Group Economics

Our research shows that sectors have many decarbonisation technologies available at the TRL-9 stage. This is positive, as it allows GHG emission reduction in the short term. On the other hand, there are few technologies in the blueprint and discovery phase (1 to 3). For the long term, not having breakthrough technologies (which are now in TRL phases 1 to 6) could be a drag on GHG emission reduction.

The analyses by sector – which can be found later in this publication – outline the options for companies to decarbonise. For each decarbonisation option, several variations are sometimes still possible to reduce emissions. All in all, making a good business case around decarbonisation for companies is always tailor-made. The (financial and technical) feasibility, but also the effectiveness of a technology, must be considered per company (and technology). Not every technology is applicable in every company - sometimes also due to insufficient network capacity - and some technologies are also mutually exclusive. Sometimes it is still very complex to make a good business case with decarbonisation technologies. It is necessary to have a good understanding of both the financial feasibility and the ultimate contribution to total GHG emission reduction. Accurate data on lead times, necessary investments, maintenance and operational costs, payback periods and possible subsidy schemes remain indispensable in making a sound business case.

Scenarios used in this publication

The choice of sectors is based on the share of the respective sector in the total GHG emissions of the Netherlands and/or the GHG emission reduction phase the sector is in and/or the availability of decarbonisation technologies in the sectors. In three pages per sector, we describe the current level of GHG emissions, what those GHG emissions are mainly caused by and what opportunities the sector has to reduce those GHG emissions. Then, using current decarbonisation technologies, we looked at what is a possible GHG emission reduction path between now and 2030, as well as in the path between 2030 and 2050. We developed this in three scenarios: a baseline path, a passive path and a proactive path.

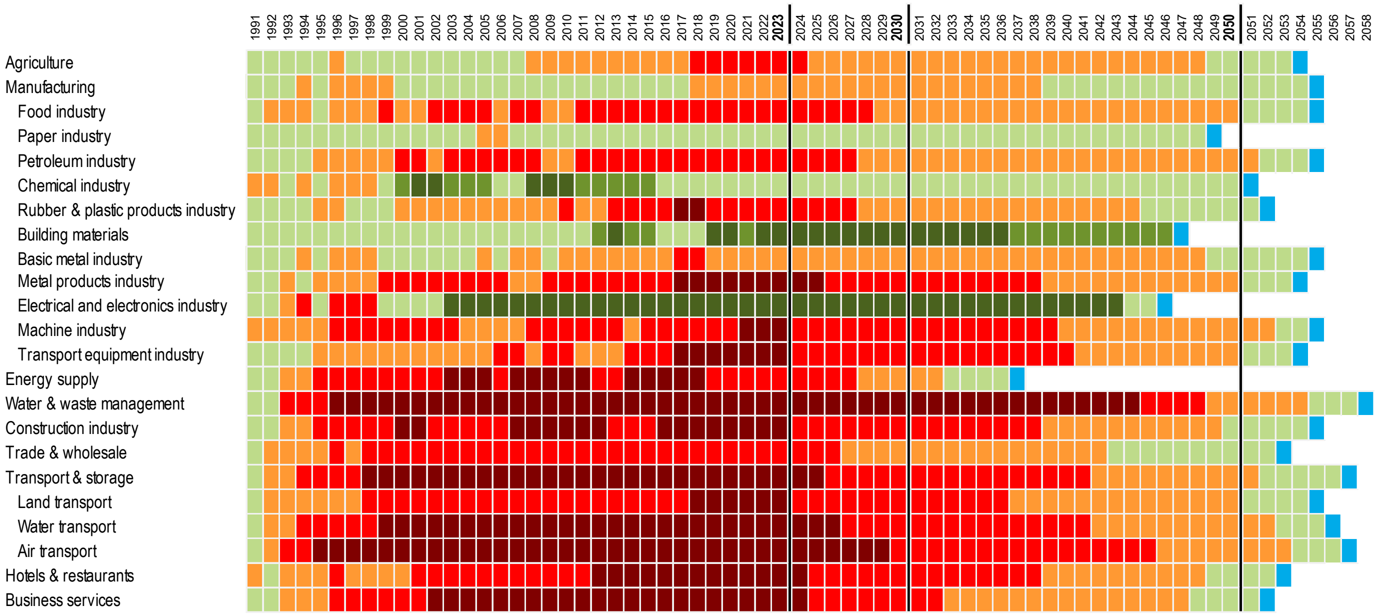
In the **proactive path**, emissions follow a pathway that is consistent with 1.5°C through strict climate policies, a significant acceleration in innovation and a high GHG emission reduction ambition among companies, achieving net zero GHG emissions around 2050. High value is placed in this path on decarbonising the electricity supply, increasing electrification, increasing energy efficiency and developing new technologies to tackle emissions that are difficult to combat. The **passive path** assumes that annual emissions decline at a much slower pace until 2030. In this scenario, many aspects go in slow motion. For instance, there is too little investment in new, cleaner energy technologies and GHG emission reduction ambition among companies is low. In our **base path**, technological progress is faster than in the passive scenario and a lot slower than in the proactive scenario. In this scenario, climate policy gradually becomes more stringent and the GHG emission reduction ambition among companies is medium.

Distance to climate targets in sectors

Many sectors have enough low-carbon technologies to achieve substantial GHG emission reductions between now and 2030. However, despite the current widespread availability of the technologies, breakthrough technologies often remain to be found. These breakthrough technologies should help clear the path between 2030 and 2050.

Our analysis shows - based on the baseline scenario - that a majority of sectors in the Dutch economy may not reach the climate-neutral target. For that, the challenges and obstacles mentioned earlier are too great. However, some sectors come close to the 2050 target and about four are capable of achieving climate neutrality before 2050. The vanguards are the paper industry, the building materials industry, the electrical industry and the electricity sectors.

Climate neutral path by sector towards 2050 (baseline scenario)



Source: ABN AMRO Group Economics

Note: The redder the colour, the greater the distance from the ideal trend line in GHG emissions in negative terms; the greener the colour, the more positive the GHG emissions trend. The blue block gives an indication of the year when climate neutrality could theoretically be possible.

In the goal of achieving climate neutrality by 2050 for the entire Dutch economy, the electricity sector has a leading role. After all, it is relatively easier to decarbonise the electricity sector than to phase out all fossil fuels in other sectors. The Climate Fund takes this into account. By subsidising this sector with the construction of new nuclear and low-carbon gas-fired power plants (including carbon capture and storage (CCS)), GHG emission reductions can be achieved sooner..

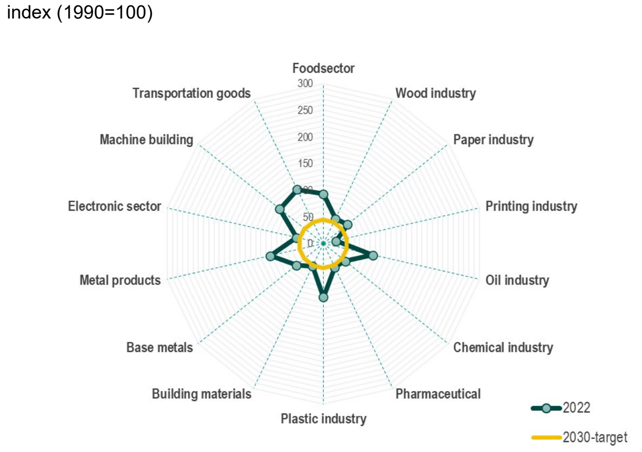
Distance to 2030 climate target

With current GHG emission reduction technologies, the 2030 climate targets are within reach for Dutch industry. This is a different story in other sectors, such as transport or water & waste management. This is apparent from the figure above, where these sectors haven a dark red indication, which signals that the distance and deviation from the trend line is still very far. There, the number of radical technologies to reduce GHGs is lower or the resources are not available for the technology to break through. For instance, electrification in the transport sector is the holy grail for a climate-neutral future, but its penetration is insufficient so far to meet the set 2030 target.

The following two figures each have the same starting point. They show the distance of the different sectors to the 2030 target. For simplicity and comparability, we have set it here at 55% of the 1990 GHG emission level (the EU target) for all sectors. There are of course sectors with different climate ambitions towards 2030. The two figures also have identical axes to further enhance comparability. The left figure shows industry and its subsectors, while the right figure shows the other Dutch sectors. It is immediately noticeable that the 2030 target for industry and its subsectors is not an unbridgeable gap. Some industrial subsectors are still relatively behind, but the stronger reduction in GHG emissions is achievable with available decarbonisation technologies. In the non-industrial sectors (right figure), the distance to the 2030 target is still challenging, especially for the transport sector and water and waste management.

Distance of industry subsectors to 2030 climate target

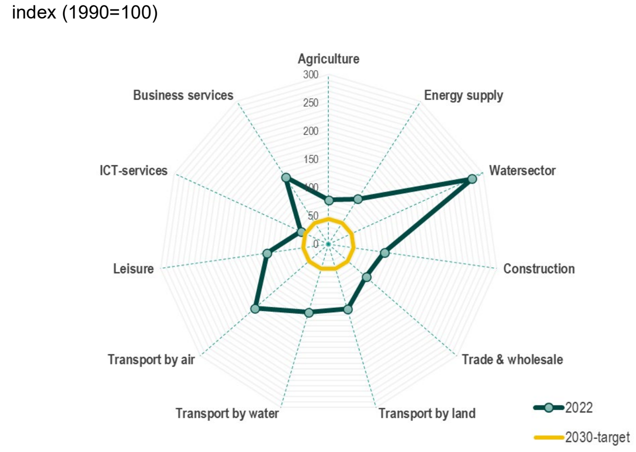
index (1990=100)



Source: CBS, ABN AMRO Group Economics

Distance of other sectors to 2030 climate target

index (1990=100)



Source: CBS, ABN AMRO Group Economics

For now, business investment in low-carbon industrial technologies remains a prerequisite for achieving GHG emission reduction targets. Government policies are going to help drive those investments in the coming years. To cost-effectively reduce GHG emissions from large companies within sectors, the EU has emissions trading (EU ETS) at its disposal as a policy measure. This is a powerful tool. Within this trading instrument - which trades emission allowances that give the right to emit a certain amount of GHGs - an ever-decreasing cap of allowances is available. This is the total allowable CO2 emissions. The level of the emissions cap is adjusted as the EU updates its targets. This ceiling will gradually go down in the future, reducing the number of available allowances over time. If sectors do not make sustainability improvements in time, the number of allowances will become increasingly scarce, increasing the price of CO2. This will incentivise companies to invest more in GHG emission reductions, ultimately reducing overall emissions. Towards 2030, many sectors covered by the EU ETS face a faster decline in the number of emission-free allowances. Some sectors already face a sharp reduction in this before 2030, but the phase-out continues after 2030 as well.

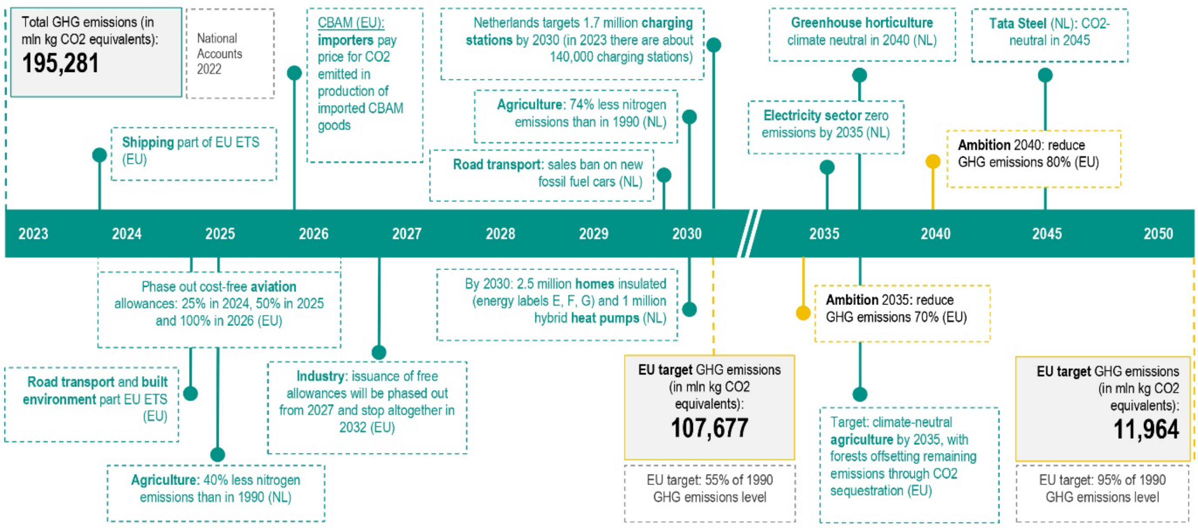
Reduction pathway in GHG emissions not without challenges

The Netherlands has more ambitious climate targets than the *European Commission's* (EC) July 2021 'Fit-For-55' targets. This 'Fit-For-55' package assumes a 2030 climate target, taking into account a 55% GHG emission reduction below 1990 GHG emission levels. For 2050, the EC targets a 95% reduction below 1990 levels. The 2030 target is slightly more ambitious in the Netherlands, aiming for a 60% GHG emission reduction below 1990 levels. For 2035 and 2040, it is 70% and 80%, respectively (though the European Commission has recently recommended an increase of the 2040 target to 90%). For these GHG emission reduction targets, the Netherlands has made a significant amount of funding available. For instance, the Climate Fund now contains almost EUR 38 billion for additional measures that contribute to achieving the reduction targets in the Climate Act. Of the resources in the fund, 85-90% have now been allocated to various climate measures. Together with the standardisation and pricing of CO2 in various sectors in the coming years, it should lead to more targeted climate investments.

For example, government investments through the Climate Fund should lead to emission-free electricity supply by 2035, more investments in the hydrogen sector, fighting energy poverty, more solar panels in the rental sector, making electric driving more attractive, more charging stations and the construction of small nuclear reactors. Many key milestones and climate goals are listed in the timeline below. Achieving these milestones, however, will not be without controversy, as there are still plenty of obstacles along the way to 2050.

Time line and milestones climate targets up to 2050

period 2023-2050



Source: ABN AMRO Group Economics
Note: the blocks framed in yellow represent outline targets and ambitions at EU level ('Fit-for-55'); the green blocks represent sectoral targets at EU and/or NL level.

In its global scenarios, the *International Energy Agency* (IEA) outlines ambitious targets for climate sectors. In doing so, the IEA urgently recommends setting milestones for each of the sectors to ensure that they are on track to meet the targets and remain on track to meet the targets in the longer term. Setting targets should ideally come from within the sector itself, but they should be ambitious enough. Governments play an important role here. With sector-specific and supportive policies, they can help achieve the various net zero milestones. For larger emitters of GHGs, the government also tries to achieve certain targets through tailor-made agreements. Ideally, it helps to make long-term climate targets concrete in short- and medium-term policies across sectors. These policies should be a co-creation between the government and the sectors. This builds confidence among companies in the sectors themselves, as well as investors, citizens and other countries.

Obstacles

Setting ambitious climate goals is positive, but achieving them is something else. The path to climate neutrality in 2050 will not be linear and/or flawless. Indeed, in reducing GHG emissions, there are still several challenges and bottlenecks. For instance, the **time** available until 2030 is relatively short. It simply takes a long time to implement decarbonisation technologies or transform our energy supply. In addition, the **availability of qualified personnel** falls short to install low-carbon technologies and build the necessary infrastructure nationwide. Currently, there is already a significant shortage of qualified people in the Netherlands and this will remain a delaying factor in the low-carbon transition for the time being.

Also, building many low-carbon technologies requires **critical materials** and metals that are increasingly considered strategic. On the demand side of these raw materials, we see an increase in demand in the coming years. For instance, metals such as rare earths and precious metals such as platinum and palladium are persistently consumed for batteries in electric vehicles. But demand for base metals and steel also remains relatively high for solar panel production and wind farm construction. At the same time, demand for raw materials such as maize and sugarcane/beet for ethanol (biofuel) production is also rising. There is no shortage of some of these raw materials now, but there will probably be in a few years if technologies do not change or evolve. Moreover, the supply chains of many raw materials are often controlled by a small number of countries (including China), making them vulnerable. Increased demand for these raw materials has already led to significant price increases, and if this continues for a long time, the prices of decarbonisation technologies will remain relatively high for the time being.

Cost and availability of finance also play a role in the transition. A lot is already possible in the technological field, but in practice, technologies sometimes still do not get off the ground sufficiently because the costs are simply not bearable and disproportionate to the returns. Electric vehicles or batteries for storage, for instance, are still relatively expensive. High prices for these are an obstacle to accelerating the transition. However, the good news is that technological development and innovation are continuing. This leads to possible cost savings and the emergence of new and better technologies. The price level also depends on the extent to which the technologies of the future continue to rely on critical materials and metals, and to what extent other - less critical - materials can be used for the production of low-carbon technologies.

Decarbonisation efforts by companies in sectors

Ideally, all climate change mitigation and adaptation measures and GHG reduction should be deployed across the value chain in a cross-sectoral manner. This is where the deployment of low-carbon technologies is essential. It is probably the most effective way to achieve scale in GHG emission reduction and keep the 2030 and 2050 targets within reach. However marginal the share of some sectors in total GHG emissions, it helps if all companies in each sector take responsibility.

Decarbonisation technologies by sector

Decarbonisation technologies		Agriculture	Food & beverages	Paper industry	Oil industry	Chemical industry	Rubbber- & plastic product	Building materials industry	Base metal industry	Metal products industry	Electrical engineering industry	Machinery	Transport goods industry	Energy supply	Water companies & waste	Construction	Retail & trade	Transport by land	Transport by water	Transport by air	Hotels & restaurants	Business services
Electrification	heat pump	■	■	■	■	■	■	■	■	■	■	■	■				■	■			■	■
	boiler		■	■		■	■															
	oven		■				■	■	■	■							■				■	
	electric propulsion	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■
	temperature control	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			■	■
Energy efficiency	energy management	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	residual heat	■	■	■																		
	digitalisation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	energy-efficient equipment	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	process optimalisation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Renewable energy	solar panels	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■
	wind turbines	■			■	■	■							■								
	geothermal	■	■		■	■	■	■	■	■	■	■	■	■	■						■	■
	aquathermal													■								
	biomass	■			■	■	■							■								
Building insulation & -sustainability	wall, floor and roof insulation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■
	pipe insulation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■
	double glazing	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■
	durable window frames/doors	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■
	sustainable property management	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■
Raw materials substitution & -transition	biofuels	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	
	power/sun-to-liquid	■	■	■		■	■	■								■	■				■	
	secundairy commodities		■	■		■	■	■	■	■	■	■	■			■	■					
	waste management	■	■	■		■	■	■	■	■	■	■	■		■	■	■				■	■
	circular/re-use/recycling	■	■	■		■	■	■	■	■	■	■	■		■	■					■	
Other combi-technologies	carbon capture storage(CCS)	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■			
	battery technologies	■	■	■		■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■
	carbon offset	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	fuel cell	■	■	■		■	■	■	■					■				■	■	■		
	heat	■	■	■		■	■		■	■			■	■								

Source: ABN AMRO Group Economics

In any case, **electrification** of processes can go a long way in the path to low carbon, provided the main obstacles are removed (such as limited grid capacity and infrastructure). Electrification in businesses has several advantages. Not only is electrically powered equipment slightly more energy efficient, but maintenance costs are often lower. In addition, regular maintenance of the electrical equipment (such as pumps, motors, fans, drying systems) improves energy efficiency and reduces emissions, at the time when the electricity used is low-carbon. Many companies in the industry have now taken steps towards electrification. For example, electric boilers have been implemented more widely, especially among SMEs. This is mainly due to the relatively low investment and operational costs.

For short-term results, companies can reduce their emissions by introducing **energy efficiency** measures. This is something almost all companies in sectors can do in the short term. It is low-threshold and, if implemented properly, also effective in reducing GHG. Examples include avoiding open refrigeration and freezer cabinets, reusing packaging, closed front doors in hot weather (air conditioning optimisation), energy management plans and cold weather (heat hedging), food waste prevention, more seasonal organic local produce, less meat products, LED lighting and smart sensors. But also automation (monitoring and measuring), process optimisation, sustainable design and solutions for inbound and outbound logistics fits in. In the machinery industry, for example, companies improve efficiency through higher levels of automation, with precision applications and connectivity between machine. Thanks to the use of advanced technologies such as GPS and smart sensors, machine builders are able to achieve ever higher accuracy in the working process, with a positive impact on efficiency and also GHG emissions.

Scaling up **renewable energy** is going to help decarbonise the power sector over time, for instance. This involves the deployment of solar, wind, hydro, biomass, nuclear and geothermal technologies on a larger scale. The growth of solar and wind power in particular has already increased sharply. But alongside the strong expansion of wind and solar capacity, improvements in grid infrastructure and efficiency are also needed. Underlying a rapid transition to the deployment of more renewable energy is strong political commitment, supportive laws and regulations and favourable financial conditions for renewable energy. More and more companies in sectors with physically owned shops and/or business premises are switching to rooftop solar panels to meet their direct energy needs.

With **building insulation & sustainability**, companies with their own business premises in all sectors (from retail shop to factory hall) will eventually have to get down to business. Many of the insulation measures - such as floor insulation, facade insulation, roof insulation or insulated double-glazing - require a lot of investment and are often radical measures. Incidentally, it also happens that the company has no direct influence on making premises more sustainable because, in many cases, the premises are not under its own management and ownership lies with a third party.

In the case of **commodity substitution**, the main issue is fossil fuel replacement. On balance, this provides the most reduction in greenhouse gas emissions. Replacing fossil fuels with fuels that produce fewer or no emissions seems simple. But in reality, this can be a complicated operation. For a start, there are many different types of more sustainable fuels. Each fuel has its own characteristics and therefore different fuels are suitable for different applications. But replacing the raw materials in the production process for more sustainable variants is also effective.

To further reduce carbon emissions and energy consumption at companies and achieve carbon-neutral sectors, low-carbon innovation in products, services and processes remains crucial. In the longer term, an acceleration of the transition is needed, especially for the period between 2030 and 2050. Then, further development of existing technologies with known operating principles will be needed, e.g. deployment of (green) hydrogen, green fuels, geothermal projects and/or carbon storage and use (Carbon Capture & Storage/Usage, CCS/U). But innovative breakthrough technologies also remain relevant for long-term.

Sector Deep Dives

In this section, we focus on low carbon technologies, trends and indicators in 21 sectors. In the various scenario's we calculate and estimate the potential impact of low carbon technologies on the GHG emissions going forward.

The following sectors are successively covered:

1. Agriculture
2. Food & beverage industry
3. Paper industry

4. Oil industry
5. Chemical industry
6. Rubber- & plastic products industry
7. Building materials industry
8. Base metals industry
9. Metal products industry
10. Electrical appliances & electrical industry
11. Machinery12. Transport goods industry
13. Energy supply
14. Water companies & waste management
15. Construction
16. Retail & wholesale trade
17. Transport by land
18. Transport by water
19. Transport by air
20. Hotels & restaurants
21. Business services

Important note:
*In this publication, we assume that the 2030 climate target for each sector is equal to the EU target of 55% below 1990 GHG emission levels. An exception applies to a few sectors here. These are the agriculture sector (2030 target here is 45% below 1990 GHG emission levels), energy supply (2030 target is 70%) and transport sector (2030 target is rounded 40%). For the industry climate sector, the 2030 target is 66% by 2030. However, this target for the climate sector industry includes construction and mineral extraction. Because of this difference and for simplicity and comparability with other sectors, we have retained the 55% target for 2030 for the manufacturing sector. For more background on the climate targets per climate sector, **click here**.*

This publication reveals the potential impact of decarbonisation technologies on greenhouse gas emissions by sector. As such, they are emission reduction pathways for sectors using low-carbon technologies and their potential impact ('Sector Technology Pathways'). There may be deviations in relation to other existing climate targets and strategies in sectors. The emission reduction paths we present here are the result of analyses and projections from external sources on decarbonisation pathways in sectors (both Dutch and international publications) and our own estimates, partly also based on available expertise within various departments at ABN AMRO. Emission reduction pathways of interest groups (national and international) in sectors are regularly included as a benchmark, where available.

*In appendix 1 of this publication you can find a headline overview of all the **decarbonisation technologies** available, including links to relevant publications. Following our list of sources consulted (appendix 2) at the end is a brief explanation of our **methodology**.*

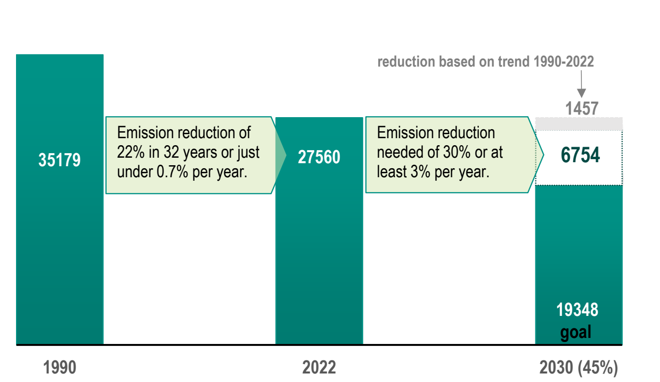
1. Agriculture

The industry's 2030 climate challenge

The agriculture sector must reduce at least 3% of the current level of greenhouse gases per year to meet the 2030 target of 55% of 1990 levels. The reduction rate increases by 1 percentage point once the 60% pathway is assumed. It works in its favour that the sector is currently leading the way in renewable energy production such as solar panels, geothermal, biomass plants, windmills, residual heat utilisation and manure digesters on a larger scale.

Sector greenhouse gas emissions and 2030 impact

mln kg CO2-equivalents

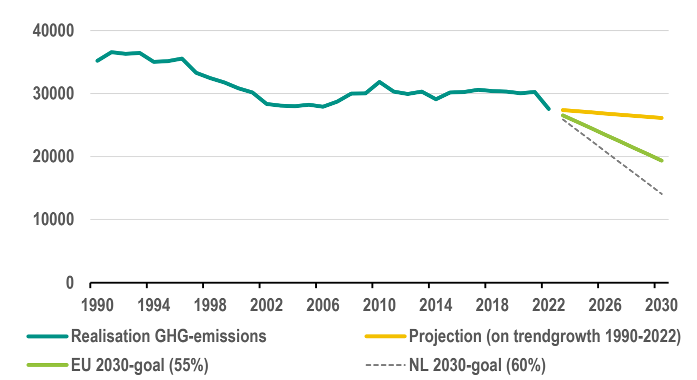


Source: CBS, ABN AMRO Group Economics

Note: The agriculture sector has an average share of 92% of total emissions from the agricultural sector (i.e. agriculture, forestry & fisheries). These total...

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

...emissions from the agricultural sector are shown in the figures above. In the analysis, however, we exclude forestry and fisheries.

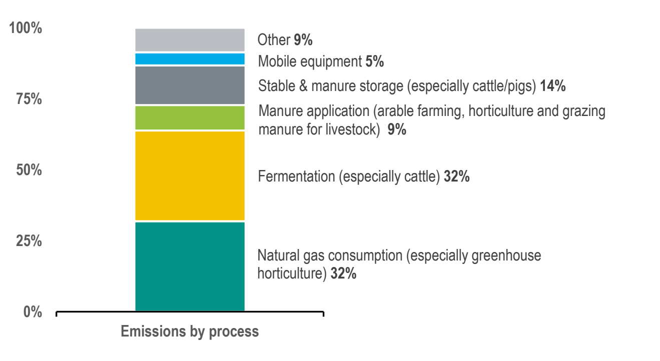
To keep up the pace in reducing greenhouse gases, it is about reducing direct emissions of CO2, nitrous oxide and methane and reducing fossil energy use. Each subsector has its own dynamics in this. Despite improved energy efficiency in recent years, it is still important to reduce energy consumption. Furthermore, in the transition to net-zero emissions, electrification will increase and the importance of fossil fuels will be further reduced.

Source of emissions

Cattle and livestock account for a significant proportion of the sector's greenhouse gases. This is done through fermentation, which releases a lot of methane. In addition, (greenhouse) horticulture is another major contributor to greenhouse gas emissions through natural gas consumption. Together, these two categories account for 64% (2021) of total emissions from the sector. A focus on these two categories with low-carbon technologies is going to provide the most reduction potential. In greenhouse horticulture, gas consumption will decrease, in livestock farming energy consumption and emissions from manure storage are important targets.

Agricultural GHG emissions by process (2021)

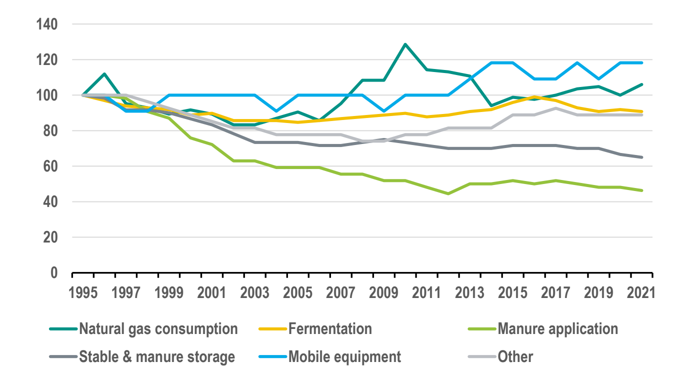
% share



Source: CBS, ABN AMRO Group Economics

Trend in GHG emissions agriculture by process

index (1995=100)



Source: CBS, ABN AMRO Group Economics

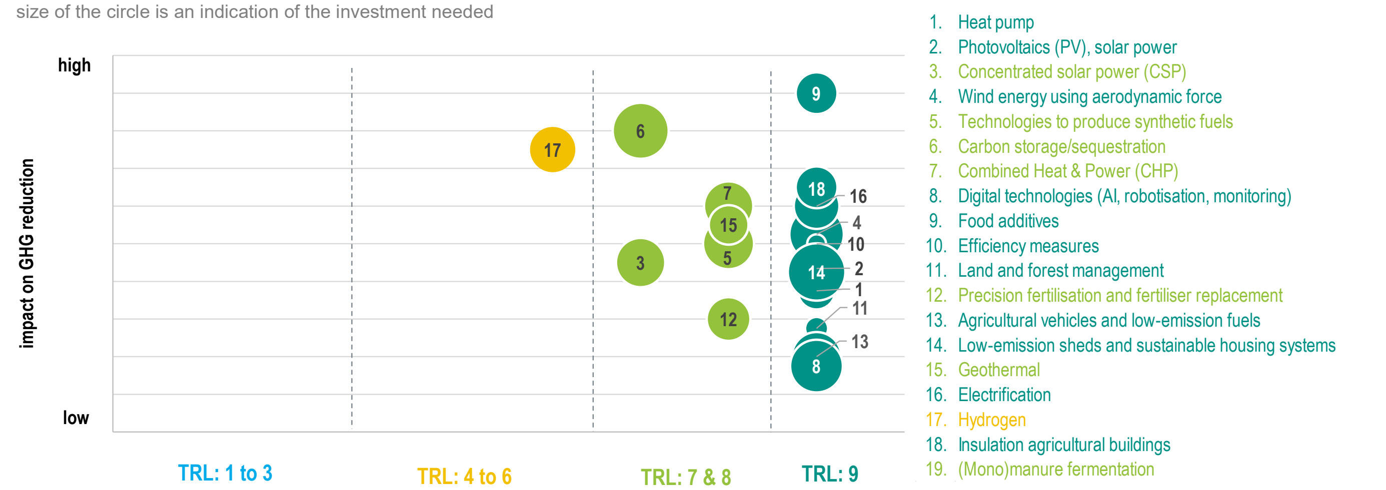
After peaking in 2010, gas consumption decreased annually in the sector until 2014. Since 2014, consumption has been at a similar level to 1995. Natural gas is widely used in boilers and combustion engines of cogeneration plants or combined heat and power (CHP) in greenhouse horticulture. The CHP is then used to generate electricity and heat and deliver CO2 from the flue gases to the plants. The trend in GHG emissions from fermentation parallels the trend in livestock. The use of feed additives can help reverse the trend. Emissions from stable, manure storage and manure application are much lower compared to 1995, while emissions from mobile farm equipment are actually higher than 1995 levels.

Reduction strategy for the sector with current and future available low-carbon technologies

Changes in average temperature and precipitation patterns, as well as more intense and extreme weather events, pose a major challenge to the sector every year. The sector therefore benefits from measures to reduce GHG emissions. Within the sector itself, there are numerous options for companies to reduce emissions. The matrix provides insight into the various options. The pace in overall GHG reduction will differ from other sectors in the coming years. This is mainly because the fragmentation of the sector is high, which then makes a more coordinated approach a lot more complex.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

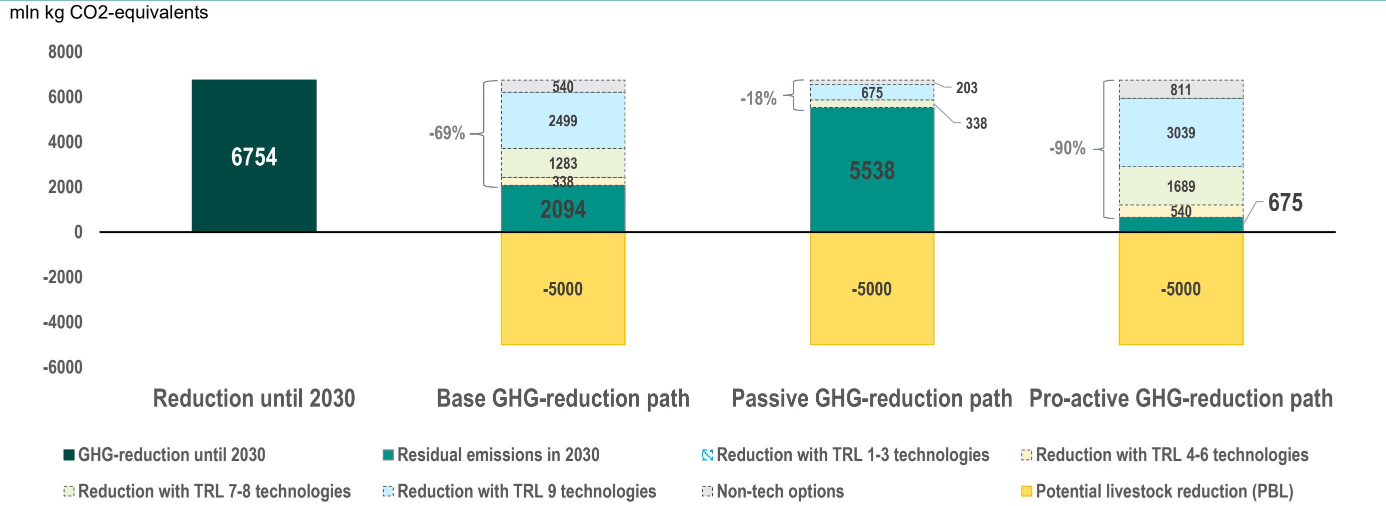
Note: TRL stands for *Technical Readiness Level*: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

The agriculture sector has been making efforts to reduce emissions for years and with success. Best practices are now well established in the sector. Agricultural farms are also ideally suited for low-carbon and renewable energy generating plants. In any case, it is clear from the matrix that many low-carbon technologies are at the commercially deployable stage (TRL 9) and a good number are soon to follow (TRL 7 and 8). There are still relatively few new technologies in the pilot and concept phase (TRL 1 to 6), to our knowledge. Electrification of machinery is a possible route for arable farming. Research by ABN AMRO (see here) shows that there is enough potential annually (especially from 2030 onwards) in green gas technology from (mono)manure fermentation.

Emission reduction potential up to 2030

The baseline scenario shows that the sustainability measures of companies collectively in the sector are not sufficient. About 69% of emissions 6,754 million kg CO2-eq. are reduced in this scenario with the available low-carbon technologies. All scenarios take into account further emission reductions of power generation (solar, wind and green gas), as well as regenerative agriculture (carbon storage in the ground). In the passive scenario, emissions decrease at a relatively low rate. On balance, only 18% will be reduced. In the proactive scenario, much more GHG is ultimately reduced than initially needed to meet the 2030 target. This assumes that there is also much greater demand from consumers and supermarkets for sustainable alternatives. There is growing interest in low-carbon agriculture where carbon is sequestered in the soil and/or in products. Soils high in organic matter are more resistant to drought and flooding and promote biodiversity. And with fibre crops, carbon production is sequestered over the long term, such as in insulation material.

Indicative impact of low-carbon technologies on the 2030 target



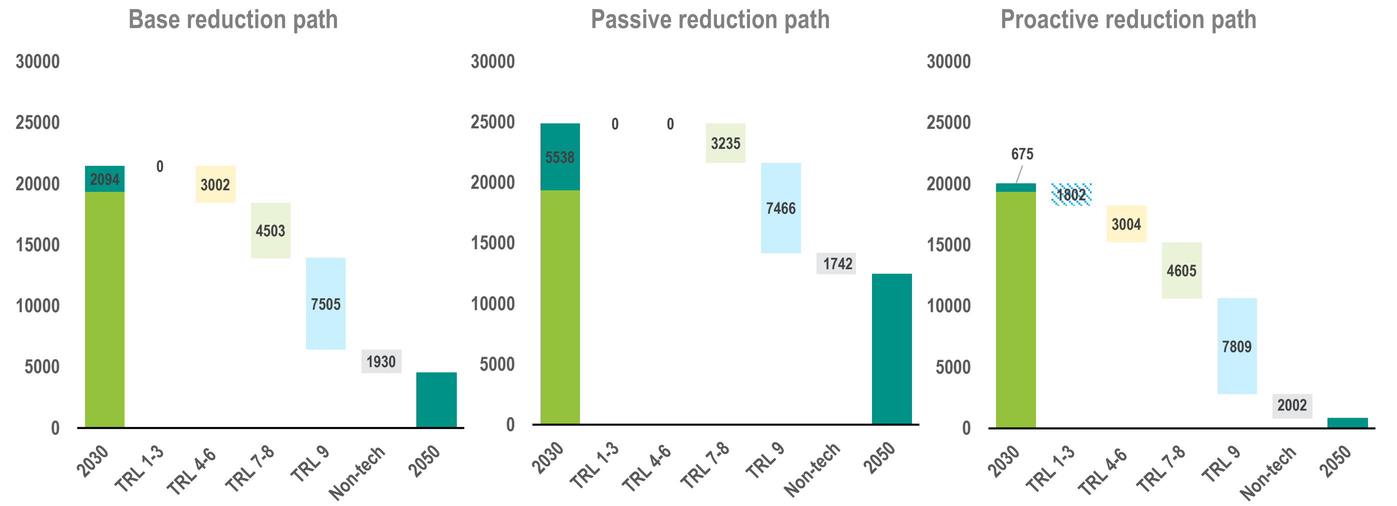
Source: CBS, ABN AMRO Group Economics

Emission reduction in the agricultural sector often involves the deployment of available low-carbon technologies. But sustainable methods that do not involve technology also have an impact in this sector. Think, for instance, of changing consumer behaviour, chain cooperation, reducing crop losses, food waste and waste management. The shrinkage of the livestock population could have a major impact on emission reduction in the coming years. From PBL calculations following measures proposed by ministries, GHG emissions could be 5.0 megaton CO2-eq. lower in 2030. Concrete policies are ultimately going to make the big difference in this sector. Only in our passive scenario will the 2030 climate target then not be achieved.

Emission reduction potential 2030-2050

Low-carbon agriculture is possible. In particular, it is driven by increasing resource productivity, increasing energy efficiency and increasing efficiency in the use of fertilisers. This requires investment in less energy-intensive machinery, modernisation of buildings, removal of obsolete machinery and the use of renewable energy sources (biogas, solar and wind power). The latter are of great interest to the sector because they are environmentally friendly and can be economically efficient. These are ways to keep the 2050 climate target in sight. However, the fact remains that this sector is also helped by breakthrough technologies that reduce GHG emissions on a larger scale.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)

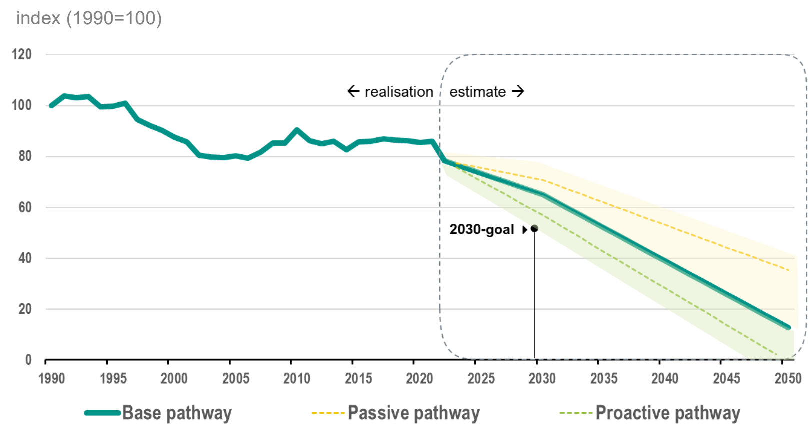


Source: CBS, ABN AMRO Group Economics

In the base path of GHG emission reductions between 2030 and 2050, the 2050 target is not achieved. For that, available sustainability measures fall short. In the proactive path, breakthrough technologies are available and the target is met by a fraction. In the most passive path, existing low-carbon technologies are nowhere near sufficient to achieve carbon neutrality in 2050.

If we assume the baseline scenario in terms of emission reduction and available net-zero technologies in the agriculture sector, our calculations show that the sector is not going to meet the set targets for 2030 and 2050. This path is still independent of breakthrough technologies that might be introduced after 2030.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the agriculture sector reaches carbon neutrality after 2050. This could be the case around 2054. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

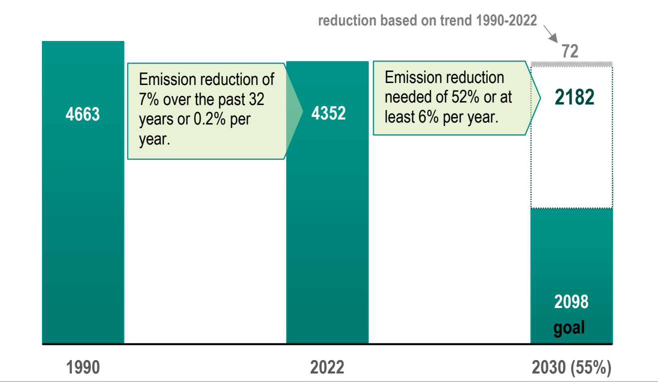
2. Food & beverage industry

The industry's 2030 climate challenge2030

The level of GHG emissions in 1990 and 2022 is almost the same. Historically, GHG emissions in the sector declined at an average annual rate of 0.2%. CO2 emissions from the Dutch food industry did decrease. In 2021, they were 12% lower than in 1995 and stood at 3.7 billion kilograms. However, this is still insufficient: an annual reduction in these emissions of at least 6% is actually needed. So the sector still has to bridge some 52% of the emissions it emits until 2030. Despite the fact that the feasibility of the 2030 target seems challenging, the sector is active with sustainability. From consumers, supermarket chains, government and NGOs, pressure is growing on the sector to further reduce GHG emissions.

Sector greenhouse gas emissions and 2030 impact

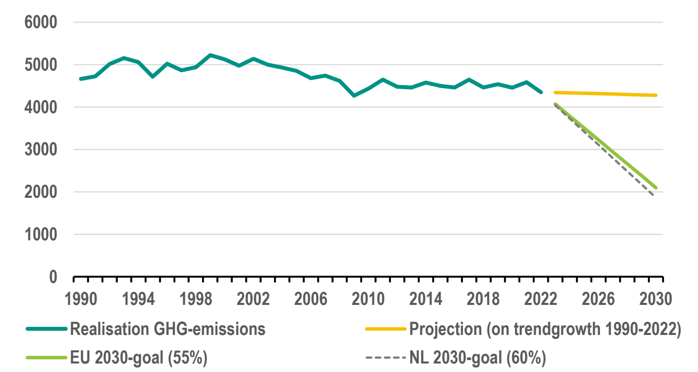
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

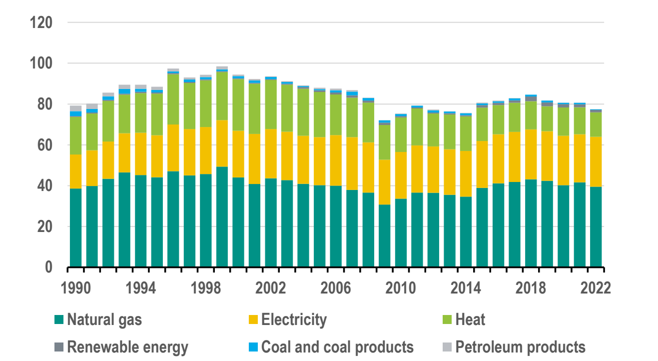
The sector still faces a big task to meet the 2030 emission reduction target. This will require the sector to invest heavily in the coming years. Again, the economic viability of decarbonisation technologies remains a key driver of investment decisions. Proven technologies (such as solar energy) have a reliable forecast to assess their viability. But for new and specific technologies it is much more complex to assess their business impact. Often there are greater uncertainties with such investments, such as: grid congestion for power connection, limited construction space and long payback periods.

Source of emissions

The Dutch food & beverage industry typically has a high demand for heating and cooling. For this, the sector mainly uses natural gas, electricity and heat. Energy consumption for heat has decreased in recent decades, while production has increased. This has been achieved mainly by improving energy efficiency. However, consumption of natural gas and electricity has remained almost constant.

Energy mix food & beverage industry

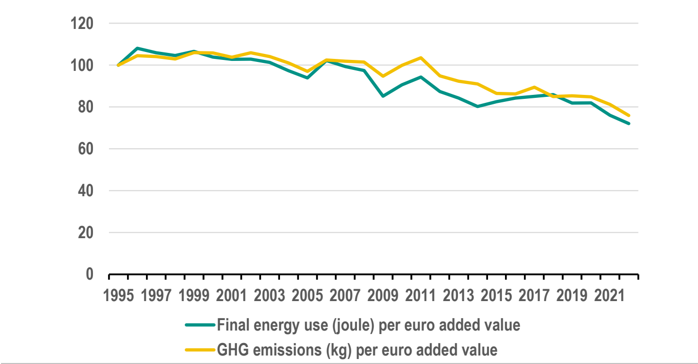
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy consumption

index (1995=100)



Source: CBS, ABN AMRO Group Economics

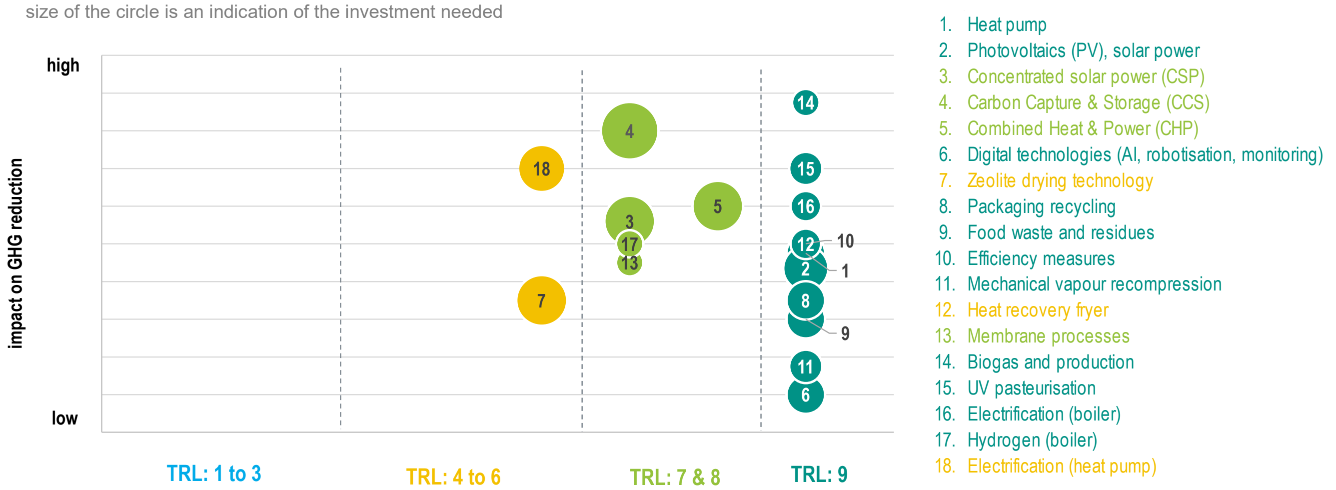
Energy consumption is the main source of greenhouse gas emissions in the Dutch food & beverage industry. In the figure on the right above, this relationship is evident. Energy in the sector is consumed as electricity or as heat and energy generated in on-site combustion units. Energy consumption in the various subsectors often depends on the type of product. Factors such as the age and size of plants also play a role here. Once investments are made in new equipment such as turbines, boilers or dryers, this results in higher energy efficiency and thus GHG emission reductions.

Reduction strategy for the sector with current and future available low-carbon technologies

The food & beverage industry has many low-carbon technologies and options available. Especially in the TRL-9 phase, many options are within reach. These options are the low hanging fruit. However, they also have much less GHG reduction potential than the seven technologies listed in the TRL 4-8 phase. The development of a technology in these phases can be slow. It sometimes takes a decade to scale up from a pilot plant (e.g. TRL 7) to commercial scale (TRL 9). Many subsectors mainly require heat (for steam, among other things) and fuel (for heating). In addition, much electricity is needed for cooling, freezing and for the necessary machinery and equipment. There are roughly three ways to accelerate decarbonisation in the sector's own production environment: energy efficiency, material efficiency or fuel substitution. For achieving energy efficiency, numerous low-threshold options are available. Material efficiency is mainly about reducing waste streams.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

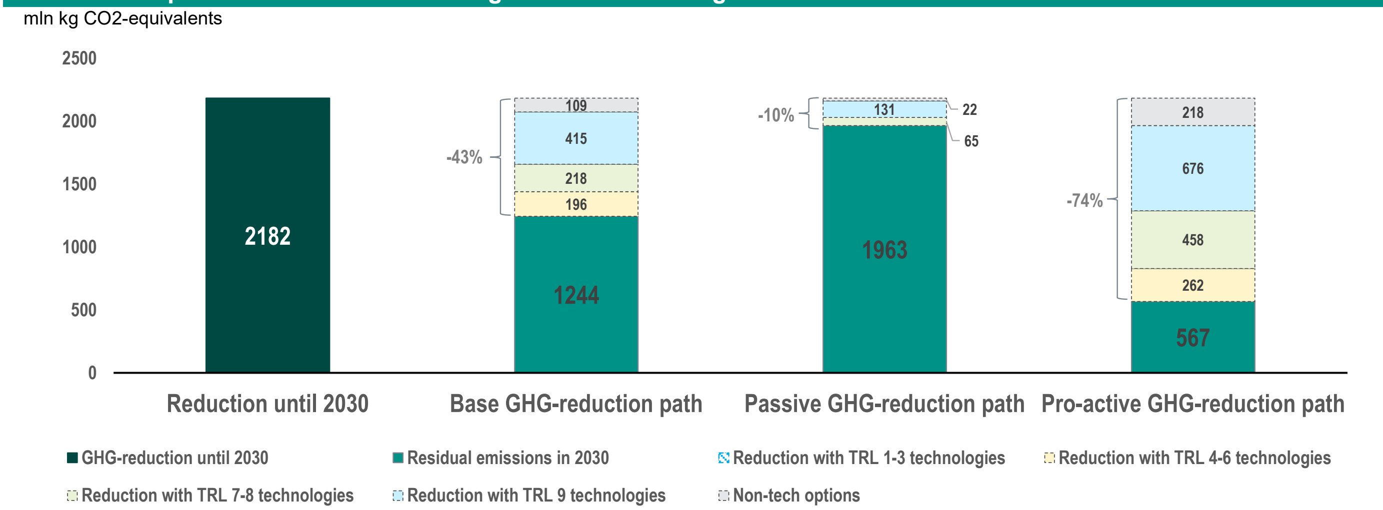
Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

Fuel substitution and process (re)design are often good starting points and have the potential to give rapid emission reduction results. Fuel substitution delivers the most in terms of GHG reduction. Furthermore, biogas, green gas, hydrogen or carbon-free electricity can be to provide heat and steam to the processing process. Biogas from residual waste (such as potatoes) can be produced via simple and commercially available technologies.

Emission reduction potential up to 2030

About 43% of the 2,182 million kg CO2-eq. is reduced in our baseline scenario with the available low-carbon technologies, as presented in the matrix above. It shows that all these sustainability measures are not enough. Emission reduction thus remains of great importance in this sector. The sector has barely gained pace in this area since 1990. In the passive scenario, emissions decrease at a relatively low rate. On balance, only 10% will be reduced in this scenario. This is mainly because the technologies already available to reduce emissions in TRL-9 have relatively low impact. In the proactive scenario, much more GHG is ultimately reduced than initially needed to meet the 2030 target. This scenario assumes companies continue to invest in sustainability and also actively seek new sustainable alternatives.

Indicative impact of low-carbon technologies on the 2030 target



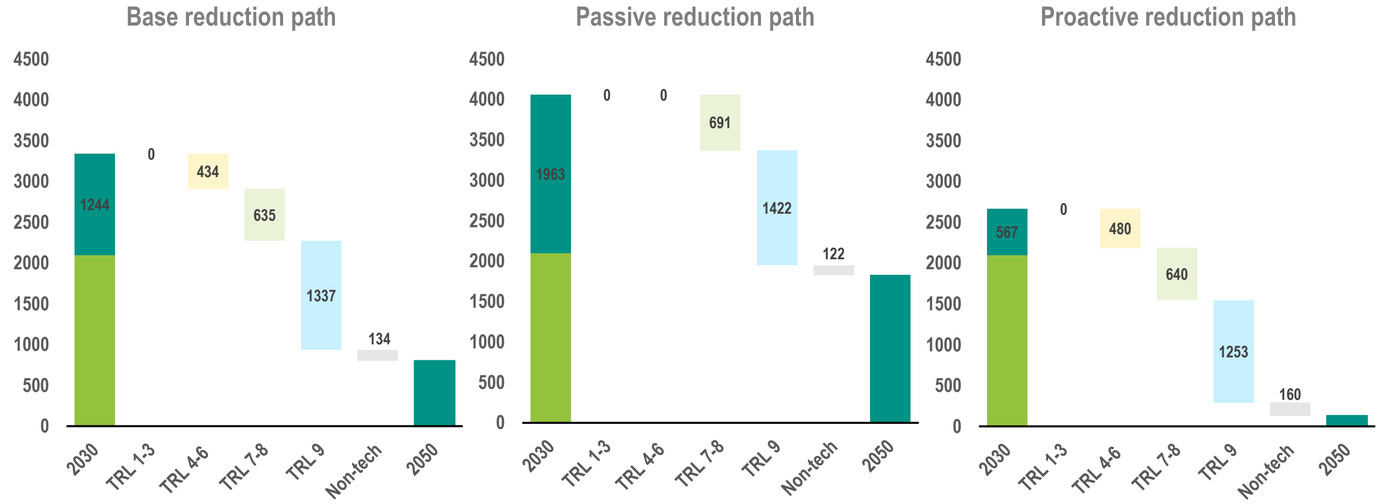
Source: CBS, ABN AMRO Group Economics

There is huge variation in emissions within the sector. Some subsectors of the food sector have a much bigger decarbonisation challenge than others. This may be because they are more energy-intensive in nature or because of the amount of heat they require. Here, the higher the temperatures that need to be reached, the more complex decarbonisation becomes. However, this sector also benefits from emission reduction methods that do not involve technology, such as changing consumer behaviour, chain cooperation, combating food waste and waste management.

Emission reduction potential 2030-2050

The food sector needs a lot of heat in its processes. In the base path, we assume that the generated heat comes from the use of clean fuels, renewables and electrification. These also play an important role in the most proactive scenario. However, despite having a wide range of decarbonisation options to its disposal, the sector also continues to need breakthrough technologies that reduce GHG emissions on a larger scale over the period 2030-2050. At the time of writing, breakthrough technologies at the TRL 1-3 stage have not yet been identified.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)

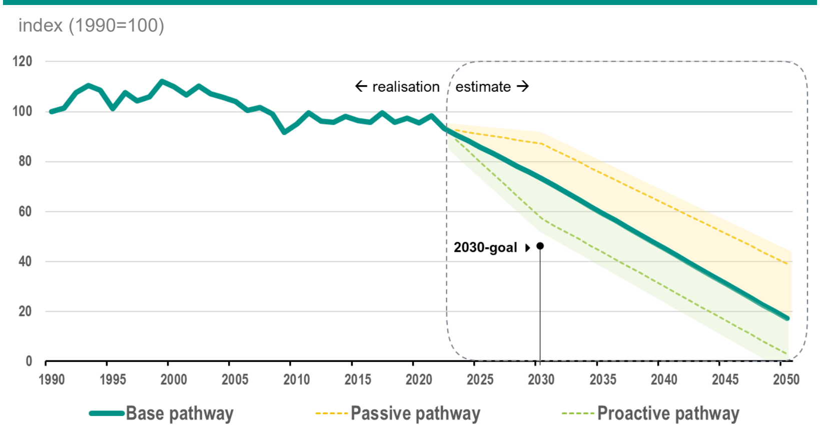


Source: CBS, ABN AMRO Group Economics

In the base path of GHG emission reductions between 2030 and 2050, the 2050 target is not achieved. For that, available sustainability measures fall short. In the proactive path, the target is met by a fraction. In the most passive path, existing low-carbon technologies are nowhere near sufficient to achieve carbon neutrality in 2050. Technologies in the TRL 4-6 phase are also not in full use or deployment.

If we assume the baseline scenario in terms of emission reduction and available net-zero technologies in the Dutch food & beverage sector, our calculations show that the sector is not going to meet the set targets for 2030 and 2050. However, this path is still independent of the breakthrough technologies that might be introduced after 2030.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

The Dutch food & beverage sector only reaches carbon neutrality after 2050 in our baseline scenario. According to our estimate, this could be the case around 2055. However, innovative net-zero technologies may well be successfully introduced in the coming years. These could greatly improve our emission reduction projection, achieving carbon neutrality for the sector much earlier. Much will depend here on developments in heat technology.

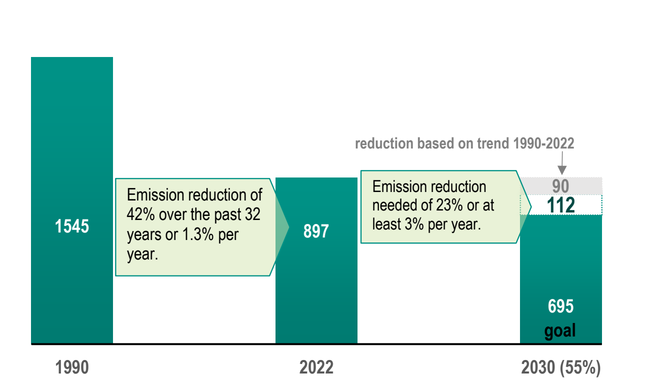
3. Paper industry

The industry's 2030 climate challenge

The paper industry is a relatively small industry in the Netherlands in several respects. The sector has a share <0.5% in both the economy and total greenhouse gas (GHG) emissions and around 1% share in total final energy consumption. However, it is the fifth-largest gas consumer in the sector. The paper industry needs to reduce at least 3% per year from current levels of GHGs to meet the 2030 target of 55% of 1990 levels. Since 1990, the paper industry has managed to reduce emissions by an average of 1.3% per year. However, this includes the disruption of the rise of digital working.

Sector greenhouse gas emissions and 2030 impact

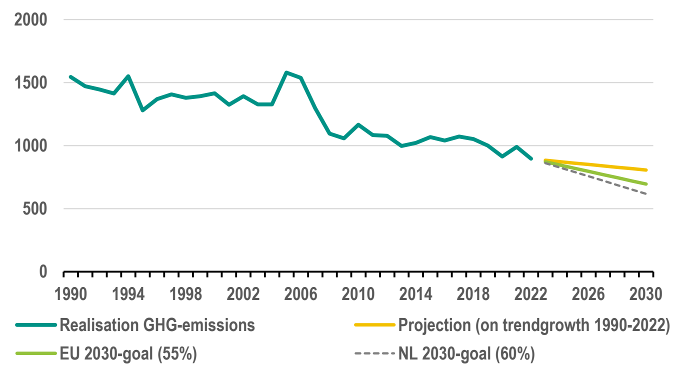
mln kg CO2-equivalenten



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalenten



Source: CBS, ABN AMRO Group Economics

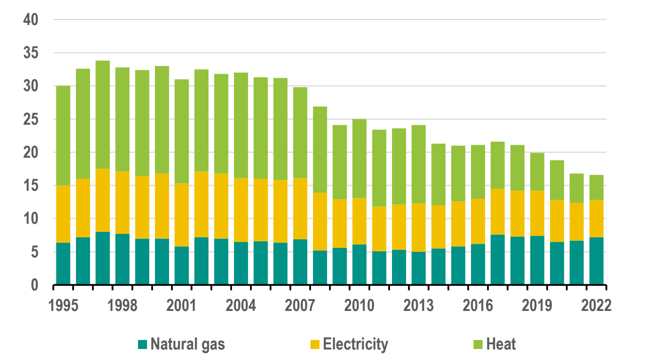
Based on the average GHG emission reduction of 1.3% over the period 1990-2022, the paper industry is capable of reducing at least 90 million kg of CO2 (eq.) through 2030. However, it is not enough to reach the 2030 climate target. For this, the sector needs to additionally reduce 112 million kg of GHG, or another 23% of the 2022 level. The feasibility of the 2030 reduction target thus still seems a tall order, but compared to other sectors, the final target is less far away.

Source of emissions

Processes in the paper industry can be very complex. To get from wood to the final product, several process steps have to be gone through, including wood preparation, pulp production (mechanical, chemical or pulp from recycled fibres) and pulp bleaching. The paper industry is a heat-intensive industry. The paper drying process consumes by far the most energy. The energy used for these processes comes mainly from natural gas, electricity and heat. Direct emissions come mainly from gas turbines and boilers. The boilers produce steam used in the process. Indirect emissions come from electricity from the grid.

Final energy use

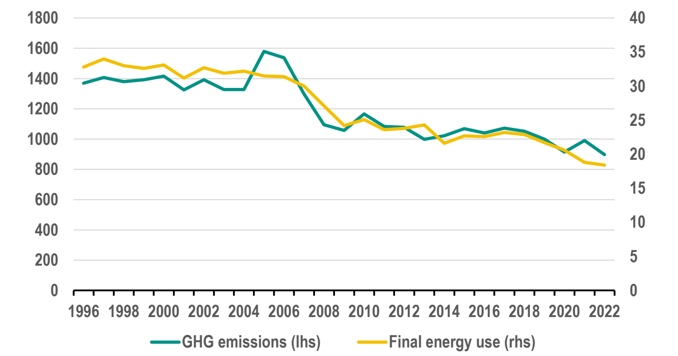
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy consumption

mln kg CO2-eq PJ



Source: CBS, ABN AMRO Group Economics

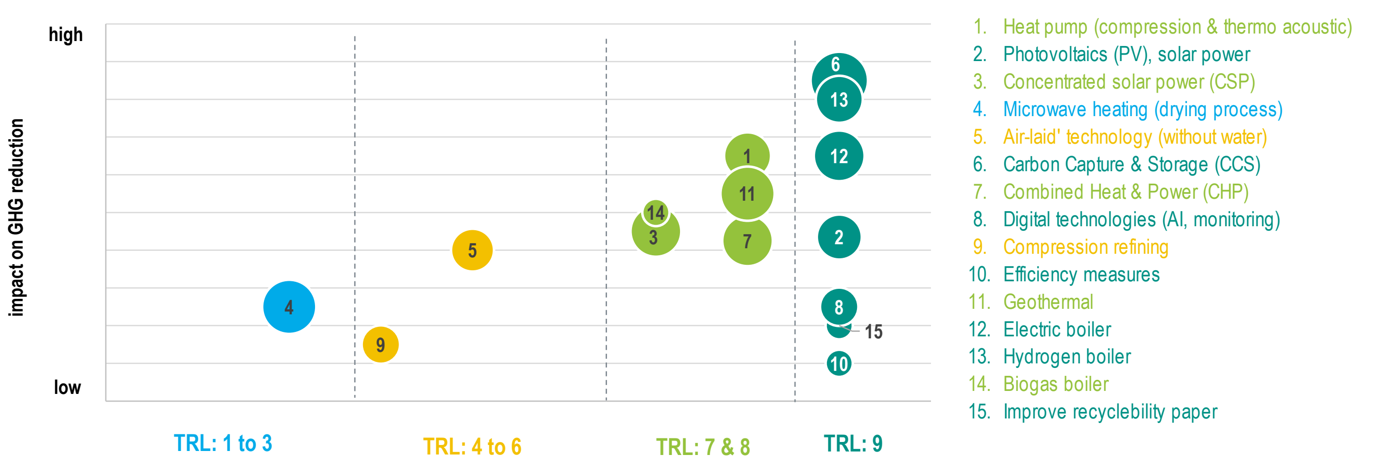
Energy consumption is the main source of greenhouse gas emissions in the paper industry. This connection is clearly shown in the right-hand figure above. However, over the years, the paper industry has implemented numerous emission reduction options - such as energy efficiency, waste heat reuse and fuel substitution - and these have contributed to the gradual decline in energy consumption and emissions since the 1990s.

Reduction strategy for the sector with current and future available low-carbon technologies

The paper industry is characterised as capital-intensive and mature, with long investment cycles and an increasingly globalised market with high price sensitivity. Paper products have a short life cycle and most carbon from paper production is released into the atmosphere within a year. Boilers are a major source of emissions. To a large extent, the paper industry produces its own generated energy, with which it can meet a large part of its energy needs. Furthermore, the paper industry can also play a role in encouraging forest regeneration, promoting forest growth and intensifying the use of non-wood pulp such as bagasse pulp, straw pulp, bamboo pulp and cane pulp.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

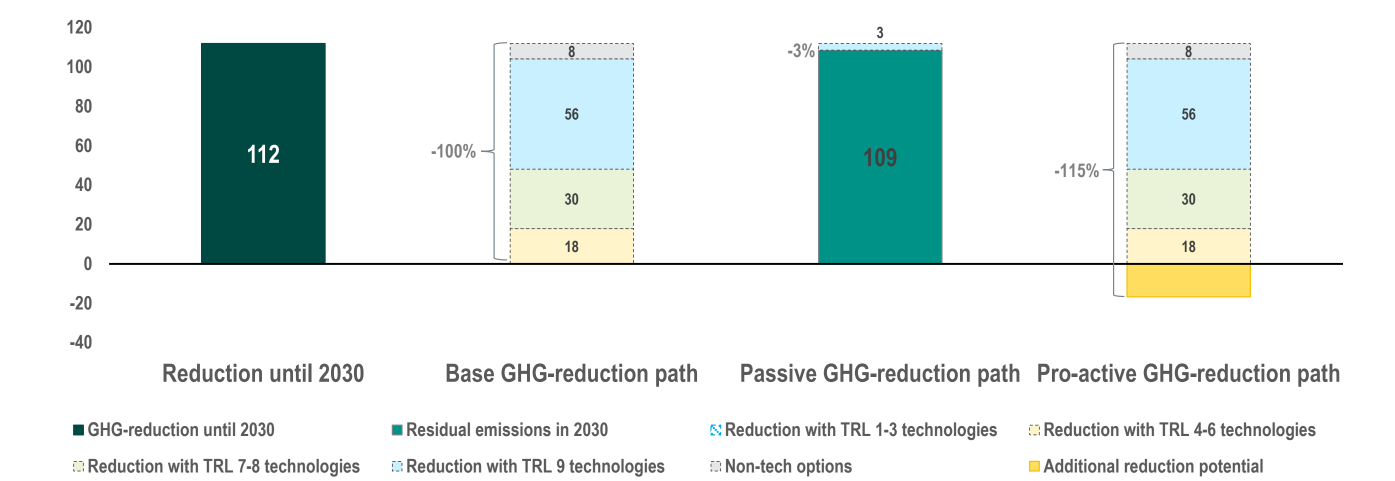
The above chart shows that many low-carbon technologies are at the commercially deployable stage (TRL 9) and a good number are soon to follow (TRL 7 and 8). There are still relatively few new technologies in the pilot and concept phase (TRL 1 to 6), to our knowledge. Although efficiency measures have a relatively low impact on CO2 reduction, this is one way of reducing emissions that is always economically feasible. An energy management system, such as monitoring steam, electricity and gas consumption lines, can improve the control of energy flow throughout the system and the measurement of energy efficiency. Also, regular maintenance, especially on electrical equipment (such as pumps, motors, fans, drying systems) can improve energy efficiency and reduce emissions.

Emission reduction potential up to 2030

Because the paper industry has a large number of decarbonisation technologies at its disposal that are not only at the TRL-9 stage but also have a relatively high CO2 reduction potential, our baseline scenario shows solid reductions up to 2030. In this scenario, the available low-carbon technologies have the potential to reduce 112 million kg CO2-eq to reach the 2030 target. The passive scenario assumes that the sector does not do much more to reduce emissions, than they have done in the past. In this scenario, a significant amount of CO2-eq. remains in 2030. Finally, in the proactive scenario, emissions in the paper industry decrease much faster and the 2030 target is almost certainly met, with only a small uncertainty factor. Here, an additional reduction in GHG emissions is certainly also plausible.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents

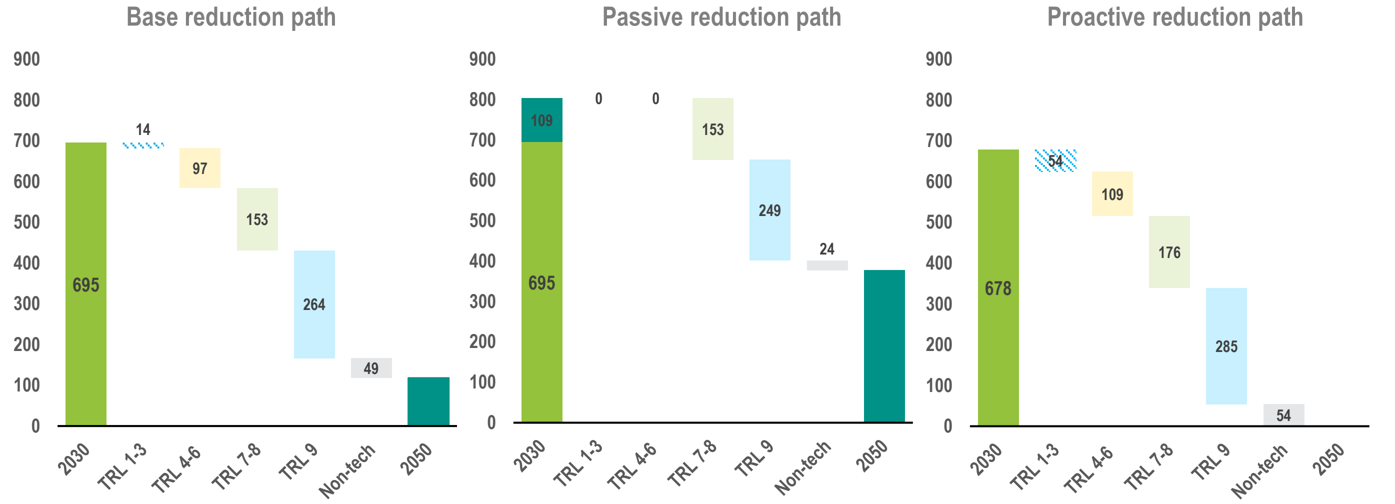


Source: CBS, ABN AMRO Group Economics

Emission reduction potential 2030-2050

With investment in and further development of existing technologies, the 2050 target seems attainable. It does require all industry operators to invest in less energy-intensive machinery, removal of obsolete machinery, improving the energy label of buildings and using renewable energy sources. More efficient use of resources remains an important aspect for the paper industry. This is good for reducing waste and increasing energy efficiency. These are all ways to keep the 2050 climate target in sight. For the path between 2030 and 2050, additional low-carbon breakthrough technologies are highly desirable.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)

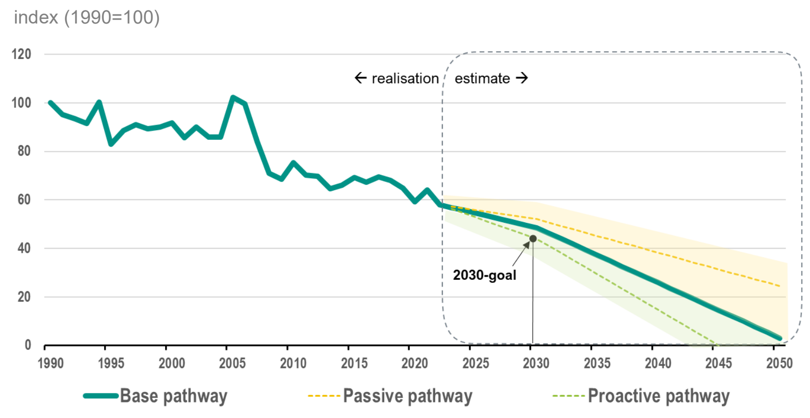


Source: CBS, ABN AMRO Group Economics

In the base path of GHG emission reductions between 2030 and 2050, the targeted 2050 goal is not fully achieved. A delay in the further development of low-carbon technologies in TRL stages 1 to 6 is one reason for this. Once that development is slower than expected, currently available sustainability measures fall short. In the proactive path, breakthrough technologies do become widely available and the target is met. In the passive path, existing low-carbon technologies are not sufficiently exploited and carbon neutrality in 2050 remains a long way off.

If we assume the baseline scenario in terms of emission reductions and available net-zero technologies in the paper industry, our calculations show that the sector is going to fall short of the set 2030 target by a fraction and reach the 2050 target (95% of 1990 levels) some two years earlier than 2050. Moreover, this path is still independent of any other breakthrough technologies that may be introduced after 2030 that we have not (yet) identified for our analysis.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

It is quite possible that in the coming years, innovative net-zero technologies will be successfully introduced or existing technologies will be effectively further developed. These trends could greatly improve our GHG emissions projection.

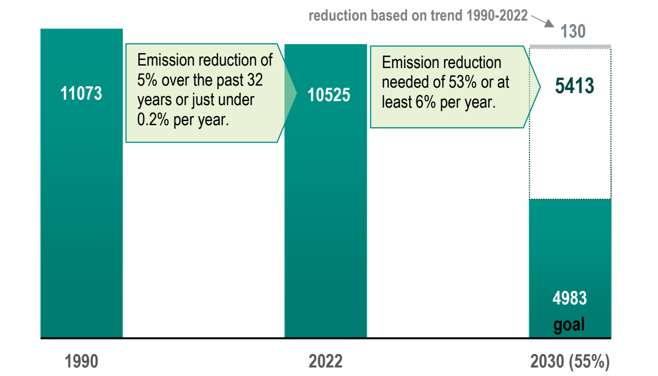
4. Oil industry

The industry's 2030 climate challenge

Despite its high emissions and energy intensity, the sector has only managed to reduce GHG emissions to a limited extent over the past 30 years, in a very erratic path from 1990-2022. It indicates that the sector is not yet making significant structural efforts to reduce GHGs and that there is a big challenge ahead for the sector between now and 2030. For instance, the sector still needs to reduce about 53% of the 2022 emissions until 2030, or at least 6% per year. With the sector's past emissions reduction experiences, that is a very big task.

Sector greenhouse gas emissions and 2030 impact

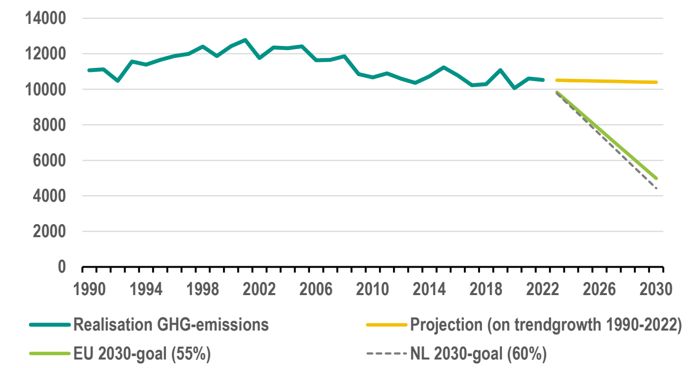
mln kg CO2-equivalenten



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalenten



Source: CBS, ABN AMRO Group Economics

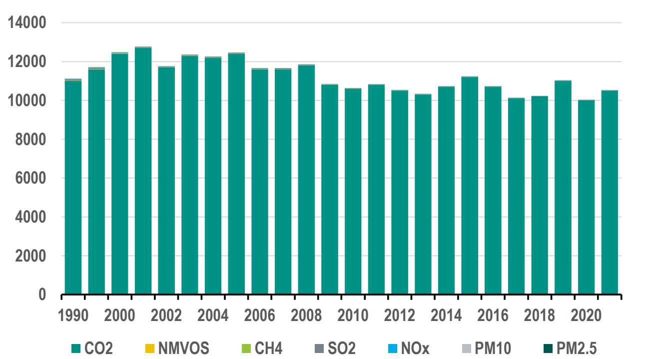
The sector additionally still needs to reduce 5,413 million kg of GHG in the next seven years. The feasibility of the 2030 reduction target is therefore still a tall order. However, many companies in this sector fall under the ETS trading system and are therefore more or less forced to step up their efforts to reduce GHG emissions in the coming years.

Source of emissions

The sector consumes a lot of energy every year. Extracting oil and gas from underground requires large amounts of energy to power and heat drilling rigs, pumps and other process equipment. Most oil is refined for further use and this requires large amounts of energy, especially to produce the hydrogen used to upgrade and treat the crude (source: IEA). Besides petroleum products, by-products such as fuel gas, petroleum coke and fuel oil are also produced during the refining process. These are used at the refinery as a source of energy (source: VNPI). Most of the CO2 emissions at a refinery are related to gas-fired process heaters, the on-site facilities for power and steam generation, gas-fired furnaces and hydrogen production (source: PBL). CO2 emissions are the bulk of all greenhouse gas emissions (see left figure below).

Emissions GHG oil industry

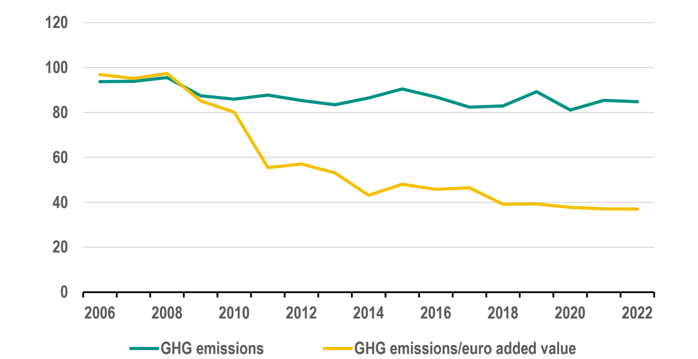
mln kg



Source: CBS, ABN AMRO Group Economics

Sector trend emissions GHG and output oil industry

index (2005 =100)



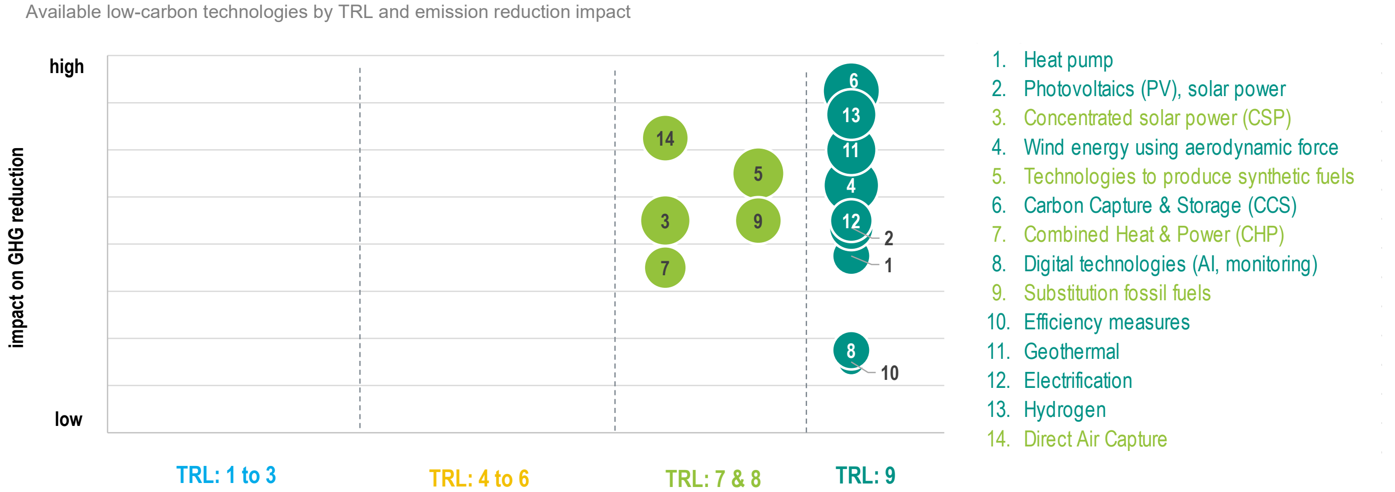
Source: CBS, ABN AMRO Group Economics

Refineries in the Netherlands differ in age, structure and location. This difference ensures that decarbonisation issues are almost always tailor-made. It can be seen from the right figure that GHG emissions from refineries in the Netherlands broadly follow the industry's production trend. This gives refiners the opportunity to address the problem of GHG emissions through their process operations. To do so, the industry has several decarbonisation technologies at its disposal.

Reduction strategy for the sector with current and future available low-carbon technologies

According to the International Energy Agency (IEA), there are five ways to achieve reductions in emission intensity within the petroleum industry. These include 1) addressing methane emissions, 2) eliminating all non-emergency flaring, 3) electrifying upstream activities with low emission intensity, 4) equipping production processes with CCUS (Carbon Capture Utilisation & Storage) and 5) expanding the use of low-emission hydrogen electrolysis in refineries. The following matrix plots some of the techniques (in outline) available for this purpose.

Available low-carbon technologies by TRL and emission reduction impact



Source: ABN AMRO Group Economics

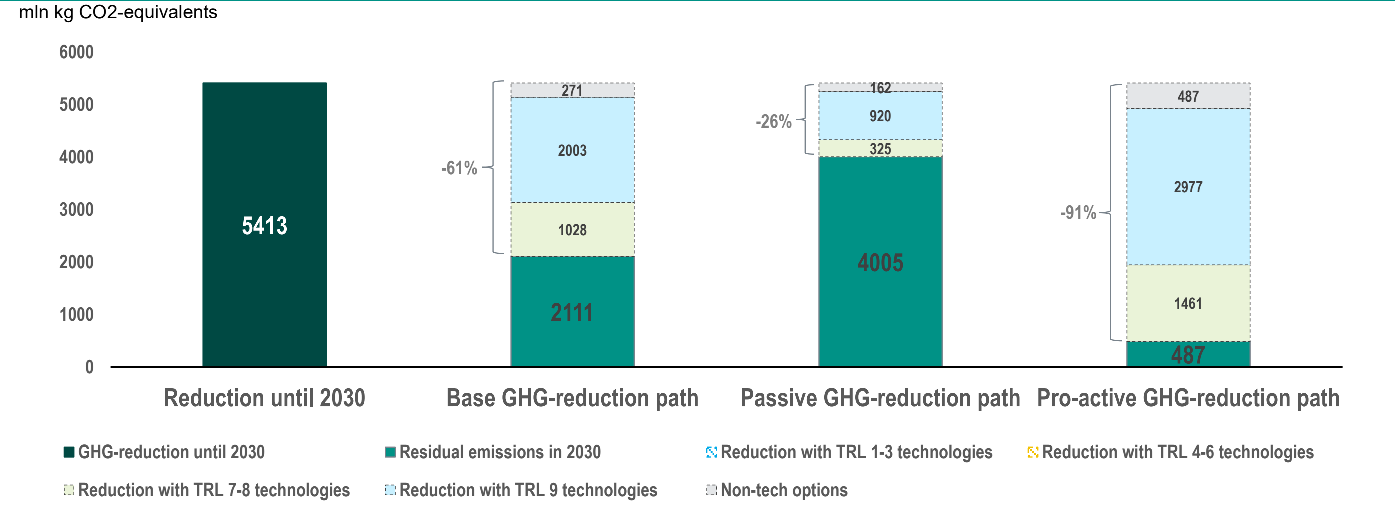
Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

The oil industry also supplies raw materials for the production of basic chemicals. Alternative products for these applications, such as biobased and synthetic hydrocarbons, are currently on a small scale, but this may change in the coming decades (source: PBL/TNO). In particular, success in external factors such as carbon transport and storage infrastructure, green electricity and hydrogen supply, and biomass availability play a major role in the petroleum industry's decarbonisation transition. Best practices for decarbonisation are well known in the industry. Improving energy efficiency is seen by many as a cost-effective and low-cost option, although it may only achieve modest GHG emission reductions. The matrix further shows that many low-carbon technologies are at the commercially deployable stage (TRL 9) and a good number are soon to follow (TRL 7 and 8). The pilot and concept phase (TRL 1 to 6) still contains relatively few new technologies, to our knowledge.

Emission reduction potential up to 2030

The baseline scenario shows that the sustainability measures of companies collectively in the sector are not sufficient. About 61% of the 5,413 million kg CO2-eq. is reduced by available low-carbon technologies in this scenario. In the passive scenario, emissions decrease at a relatively low rate. On balance, only 26% will be reduced. This assumes that companies invest much less in implementing low-carbon technologies. The right incentives for this are lacking. The proactive scenario ultimately reduces more GHGs than the other scenarios, but more is needed to ultimately achieve the 2030 target.

Indicative impact of low-carbon technologies on the 2030 target

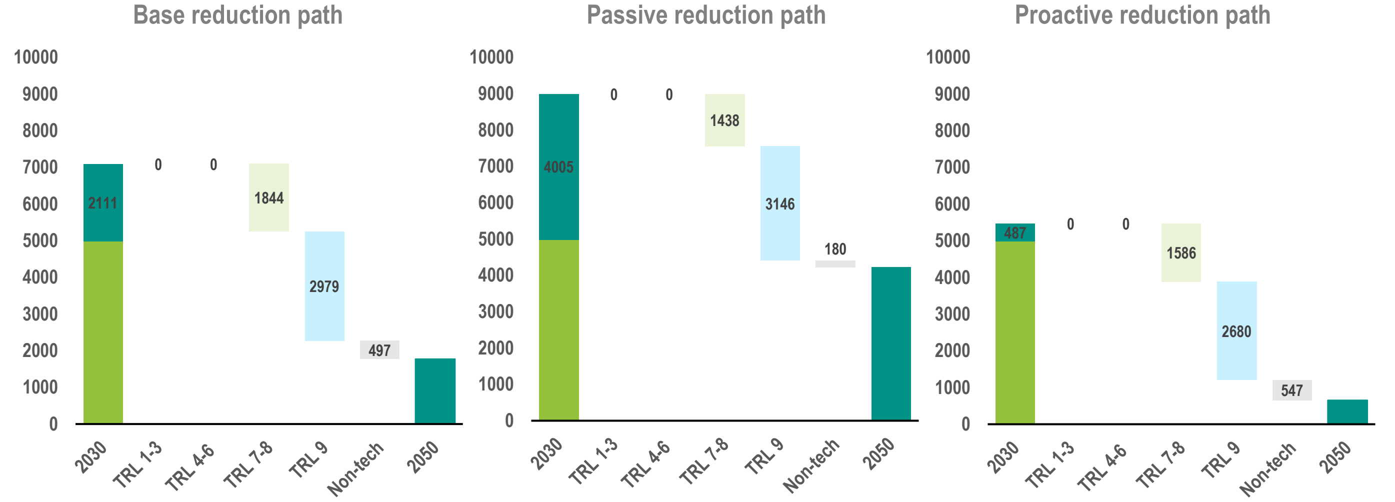


Source: CBS, ABN AMRO Group Economics

Emission reduction potential 2030-2050

Despite the fact that the sector has enough technologies at its disposal to effectively reduce GHG emissions, external factors also play a role. On these, the sector itself has little influence and it has an impact in the pace of future emission reduction. For instance, infrastructure investment for carbon transport and storage is key and, the sector depends on the supply of green electricity and hydrogen. The availability of biomass can also play a role for the sector. However, the fact also remains that this sector is helped by breakthrough technologies that reduce GHG emissions on a larger scale.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)

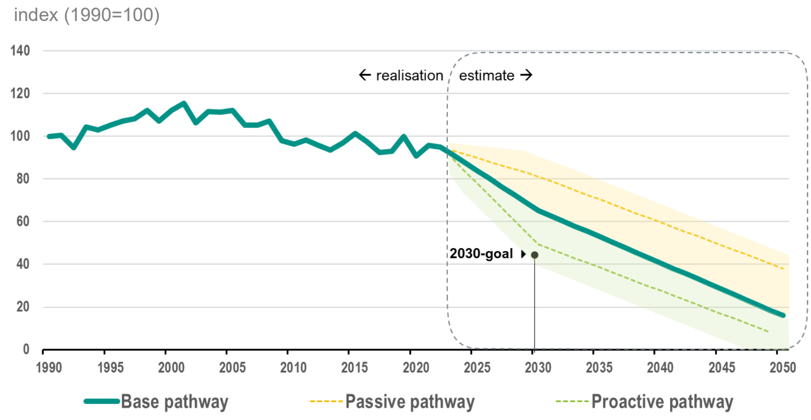


Source: CBS, ABN AMRO Group Economics

The petroleum industry operates in a highly competitive market. The industry faces high maintenance costs and significant investments, which translates into relatively low profit margins (source: VNPI). This calls for a search for a cost-effective emission reduction strategy. Here, CO2 capture and storage (CCS) plays an important role. Fuel substitution and the use of renewable energy sources can also form the basis for such a strategy.

If we assume the baseline scenario in terms of emission reduction and available net-zero technologies in the petroleum industry sector, our calculations show that the sector is not going to meet the set targets for 2030 and 2050. For that, available sustainability measures fall short, although they are hopeful. In the proactive path, decarbonisation technologies are utilised to a higher extent, but the 2050 target is not met. In the most passive path, existing low-carbon technologies are nowhere near sufficient to achieve carbon neutrality in 2050.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the petroleum industry only reaches carbon neutrality after 2050. This may be the case around 2055. But again, nothing is set in stone. However, the scenarios outlined here are still separate from the breakthrough technologies that may be introduced after 2030. It is quite possible that innovative net-zero technologies will be successfully introduced in the coming years, which could greatly improve our emissions projection.

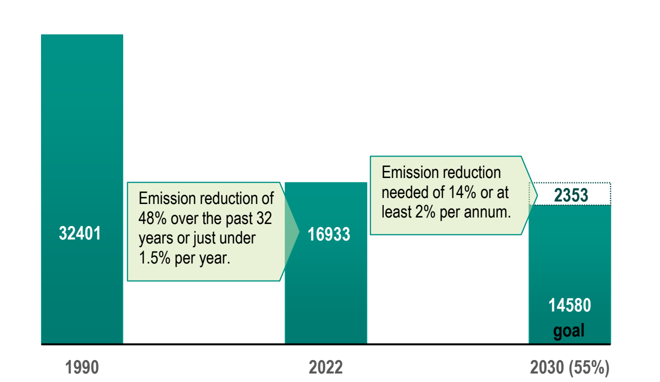
5. Chemical industry

The industry's 2030 climate challenge

Through the Dutch *Chemical Industry Covenant* of the 1990s, the industry managed to significantly reduce GHG emissions to air and water, among others. This has reduced GHG emissions by almost 48% over 32 years, or an average of about 1.5% per year. To reach the 2030 target - 55% of 1990 GHG emissions levels - the sector still needs to reduce 14% of GHG emissions from 2022 levels, or at least 2% per year.

Sector greenhouse gas emissions and 2030 impact

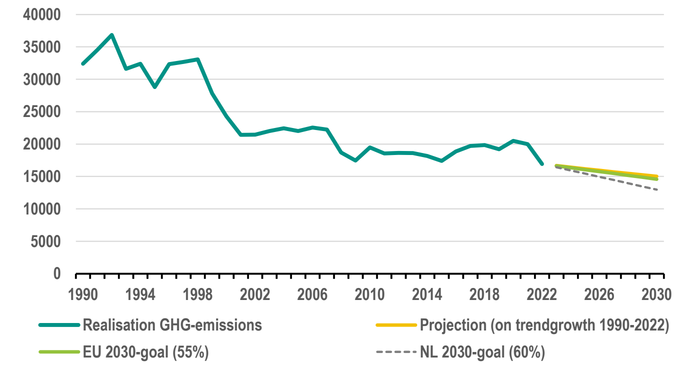
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

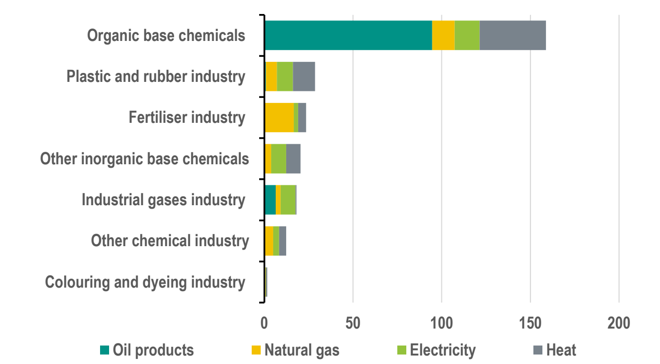
Despite there being a difference in the GHG emission reduction rate from the past and that which is needed, in our view, the 2030 target for the chemical sector is within reach. Not only because of the ample opportunities available in the sector to reduce GHGs, but also because this sector has many large companies which have to participate in the EU-ETS (emission trading system in Europe). In order to meet the requirements of the EU-ETS, emission reduction in this sector will increase relatively more in the coming years.

Source of emissions

The chemical industry has a multitude of subsectors, which can generally be divided into the organic chemical industry (such as refining and biofuel production) and the inorganic industry (such as the production of industrial gases and the chlor-alkali industry). Most energy is consumed in the manufacture of basic chemicals - these are the basic chemical raw materials that are further processed in other chemical subsectors - and the making of fertilisers, plastics and synthetic rubber. In particular, the processing of naphtha and ethane in crackers are important processes in the production of plastic resins and other chemicals, among others. These plants account for a large share of GHG emissions, consuming a lot of natural gas. Base organic chemicals in particular consume a lot of energy for their processes.

Final energy use by subsector chemical industry

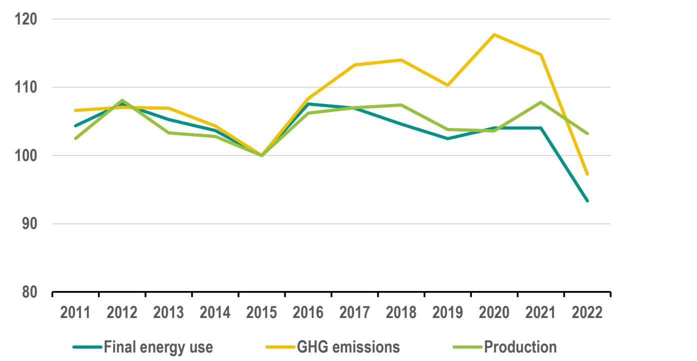
in PJ



Source: CBS, ABN AMRO Group Economics

Sector trend emissions GHG, energy use and output

index (2015=100)



Source: CBS, ABN AMRO Group Economics

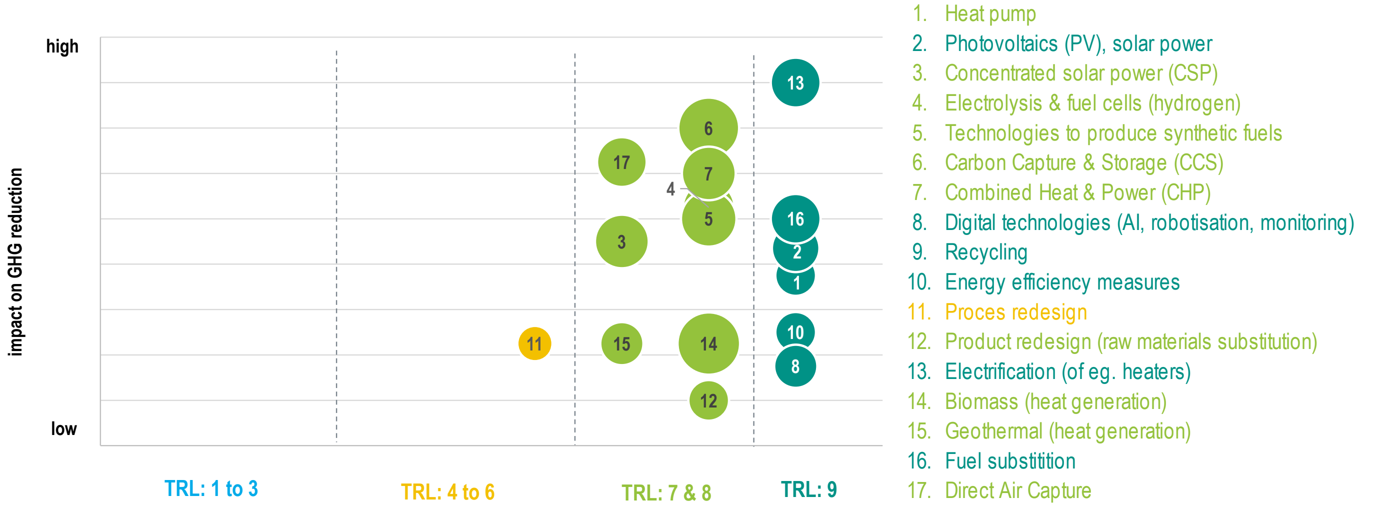
In basic organic chemicals, petroleum products are by far the most important energy carrier, followed by heat. In the other chemical subsectors, the main energy carriers are mainly natural gas and electricity. The trends in greenhouse gas emissions, final energy consumption and production follow each other closely (see right-hand figure above). Despite the chemical industry's increased investments and innovative capacity in relation to sustainability, GHG emissions and final energy consumption are at a stable level over the past 10 years.

Reduction strategy for the sector with current and future available low-carbon technologies

The chemical production process is one of the most polluting and energy- and resource-intensive processes. Many of the chemical industry's finished or semi-finished products find their way into other sectors and processes. In recent years, the chemical industry has invested a lot in cleaner production facilities, but the transition to carbon neutral still requires a lot of investment and effort from companies. In the matrix, the decarbonisation technologies are plotted broadly by *Technical Readiness Level* (TRL) and CO2 reduction potential.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

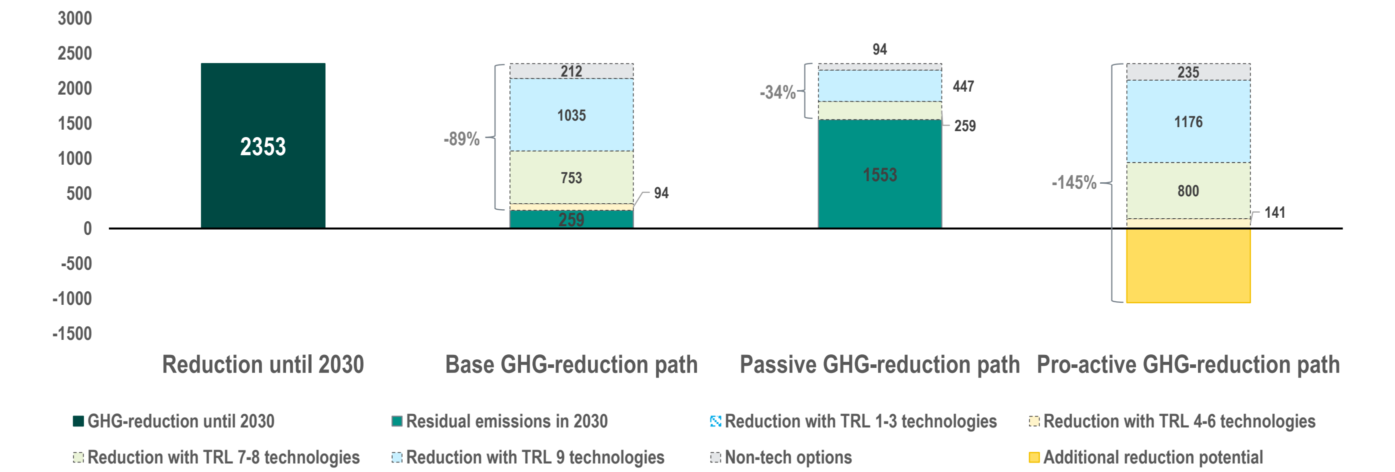
The most relevant decarbonisation options for the chemical industry involve carbon storage, electrification and fuel substitution. On balance, these deliver the most in terms of emission reduction. The CCS pathway involves relatively few modifications in many chemical production processes. However, CCS requires investment in new infrastructure for CO2 transport and storage. Investing in new and cleaner industrial processes and technologies not only reduces pollutant emissions, but also has the potential to be more cost-efficient. Electric crackers based on renewable energy, combined with other electrification measures, can largely eliminate GHG emissions. This process is under development and could be commercially available by 2026. Again, sufficient renewable electricity will be available by then. Because of the chemical industry's high energy intensity, the sector is closely linked to the energy sector. This involves both the supply of energy and raw materials as input for end products. Improving efficiency in energy and material flows therefore remains relevant. The use of bio-based materials, product innovations and circular working will also receive more attention in the coming years.

Emission reduction potential up to 2030

Our baseline scenario shows that the sustainability measures of companies collectively in the sector can have a lot of impact. About 89% of the 2,353 million kg CO2-eq. can be reduced by available low-carbon technologies in this scenario. In the passive scenario, emissions decrease at a relatively low rate.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



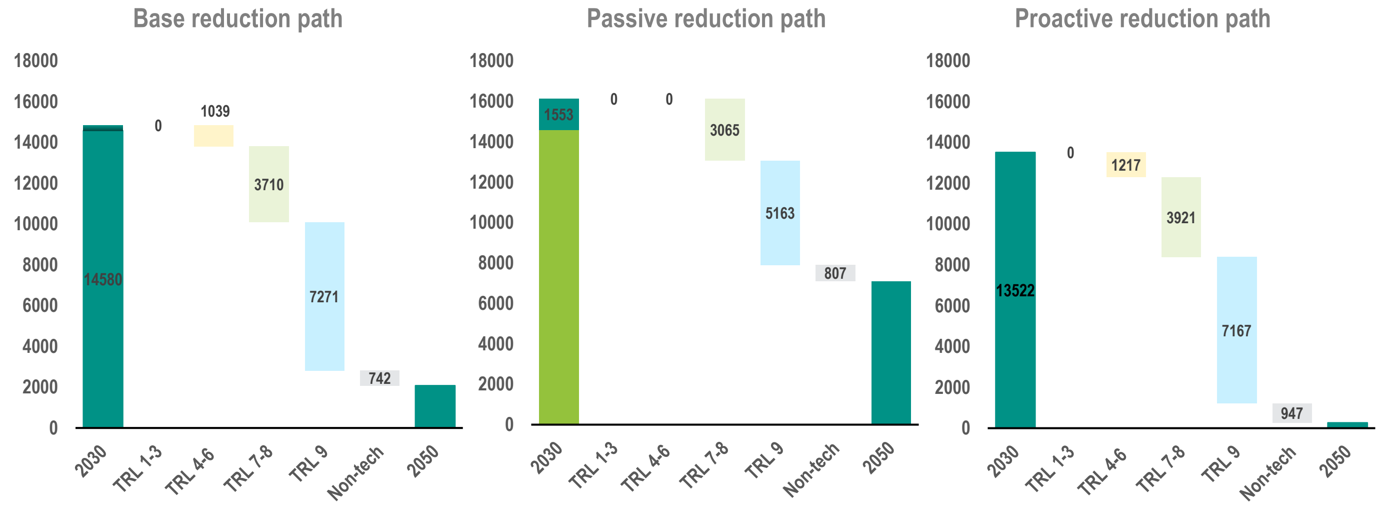
Source: CBS, ABN AMRO Group Economics

On balance, only 34% will be reduced in the passive scenario. Here, we assume that companies are much less willing to invest in the low-carbon technologies and policy pressure is somewhat lower. Finally, in the proactive scenario, the 2030 target is eventually met. In this scenario, there is a high probability of achieving more than the required emission reductions than initially agreed on.

Emission reduction potential 2030-2050

A low-carbon chemical industry in the Netherlands is certainly possible. What is important here is that a majority of chemical companies actually actively engage in the transition. The path between 2030 and 2050 is driven in particular by carbon storage, by increasing energy efficiency, fuel substitution, electrification and more efficient use of raw and auxiliary materials. This requires investment in less energy-intensive machinery and removal of obsolete machinery, as well as modernisation of buildings and use of renewable energy sources (biogas generation, solar and wind power). These are all ways to keep the 2050 climate target in sight.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)

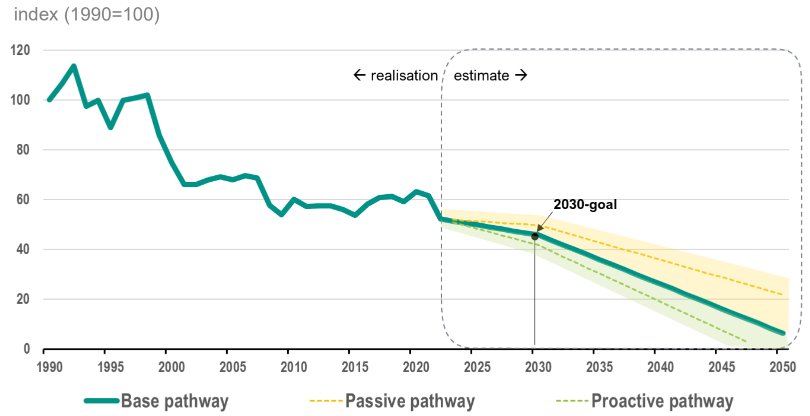


Source: CBS, ABN AMRO Group Economics

In the proactive path, breakthrough technologies are available and the target is more than met. In the passive path, we assume that chemical companies have little incentive to engage with existing low-carbon technologies. In this case, the carbon-neutral 2050 target is far from being achieved.

Finally, if we assume our base scenario towards 2050 in terms of emission reductions and available net-zero technologies in the chemical industry, our calculations show that the sector misses the set targets for 2030 and 2050 moderately. Sustainability measures are widely available and, with them at least, much emission reduction can be achieved. However, this path is still separate from the breakthrough technologies that might be introduced after 2030.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the chemical industry reaches carbon neutrality after 2050. However, this could be the case as early as around 2051. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emission projection. What could also start to help in the strategy towards 2050 is the sharp reduction in the cost of all decarbonisation technologies.

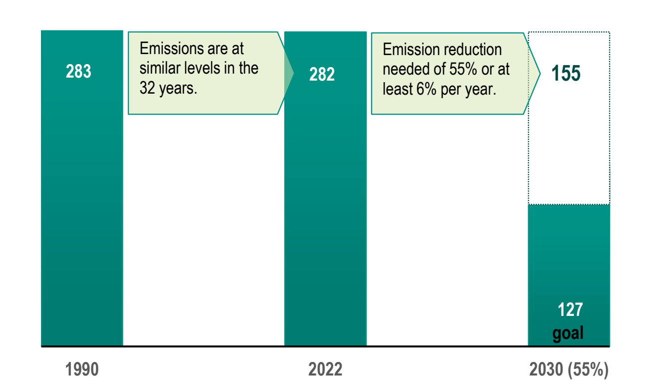
6. Rubber- & plastics products industry

The industry's 2030 climate challenge

The production of plastic products is one of the largest contributors to GHG emissions globally due to its energy-intensive processes and reliance on fossil fuels. Total GHG emissions in the rubber & plastic product industry in the Netherlands hover around 250 million kg CO2 equivalents annually from 1990 to 2014. After that, emissions increase more sharply. This is partly due to an increase in production and the growth of the number of companies operating in the sector. Emissions peaked in 2018 and are at a lower level in the following two years, but still above the average emission level from 1990-2014. It shows that the sector has done relatively little to reduce emissions and still has a considerable emission reduction mission ahead of it.

Sector greenhouse gas emissions and 2030 impact

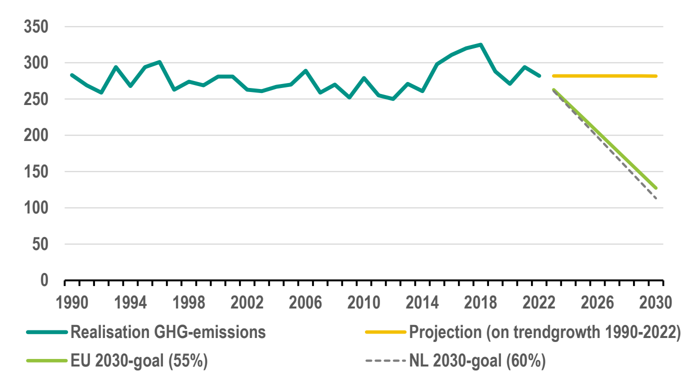
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

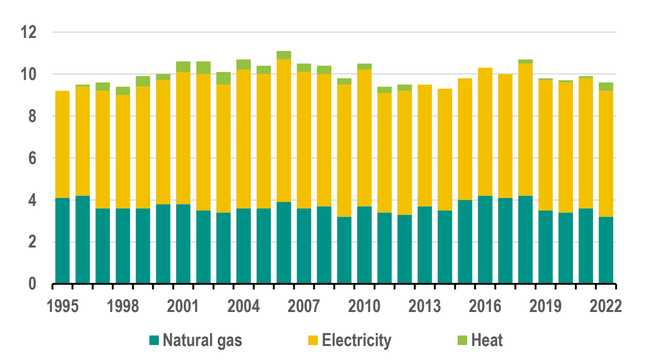
Based on the comparable GHG emissions of 1990 versus 2022, it seems a complex task for the sector to still reduce 155 million kg CO2 (eq.) over the next seven years. As such, we estimate the feasibility of the 2030 reduction target to be low. To do achieve this 2030 target, the sector will have to reduce at least 6% of its 2022 emission level per year.

Source of emissions

Today, petrochemical companies worldwide produce more than 350 million tonnes of plastics a year. Asia produces the most plastics (about half of total global primary production), while Europe and the US each account for 15%. The plastics supply chain for the plastic products industry is thus complex in nature, covering a wide range of products involving many producers from different sectors.

Final energy use in the sector

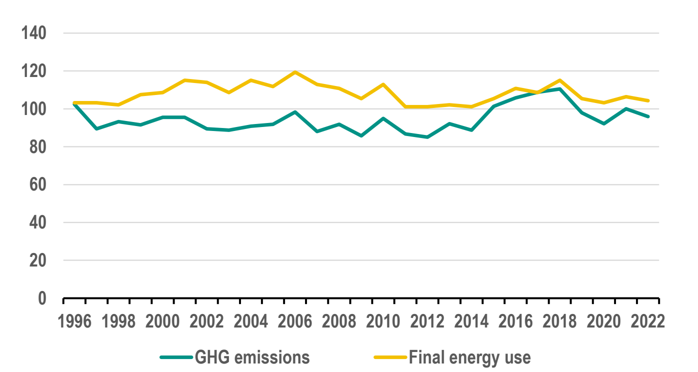
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend in emissions BKG and energy use

index (1995=100)



Source: CBS, ABN AMRO Group Economics

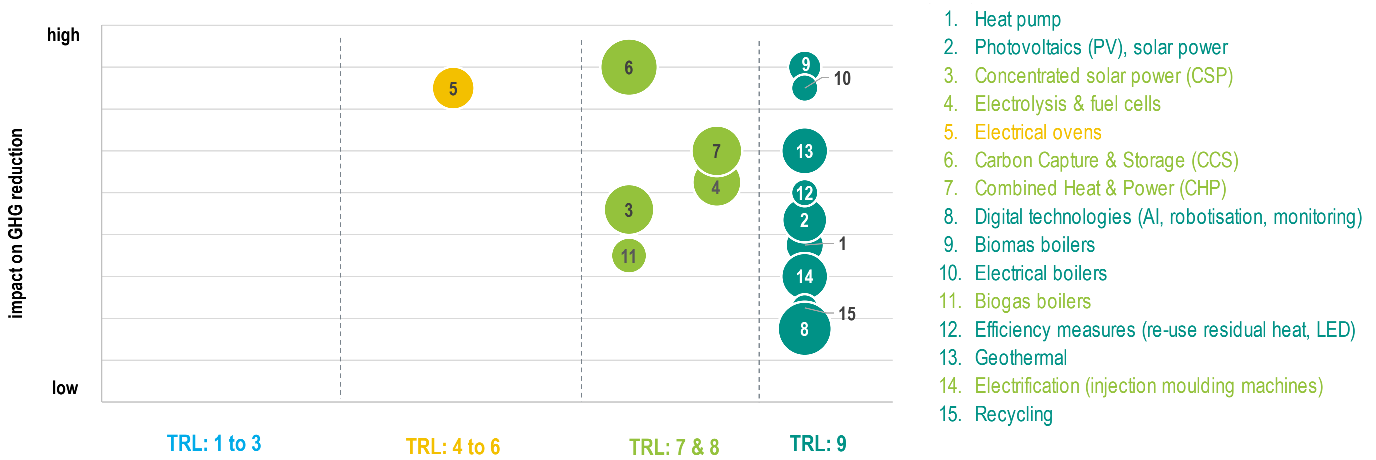
The sector is looking for opportunities to reduce GHG emissions at a faster pace across all industrial subsectors. Energy consumption is a major source of GHG emissions. Therefore, a good first step could be to replace fossil fuels, which power production processes. Final energy consumption consists mostly of electricity. The sector uses almost all energy carriers as inputs for heat generation. However, natural gas is used most for that heat. The electrical energy consumption of injection moulding machines in particular has a large share in the final energy consumption of the production process of plastic products.

Reduction strategy for the sector with current and future available low-carbon technologies

To get the carbon footprint of plastics to zero altogether, GHG emissions need to be addressed throughout the plastic life cycle. This is a complex issue. Switching from fossil fuels to, for example, hydrogen and renewable energy sources (biomass, geothermal, solar power) at least help significantly to further reduce carbon emissions. The sector can also reduce its GHG emissions by using energy-efficient technologies, such as high-efficiency machinery and LED lighting, as well as by insulating commercial buildings, for example.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

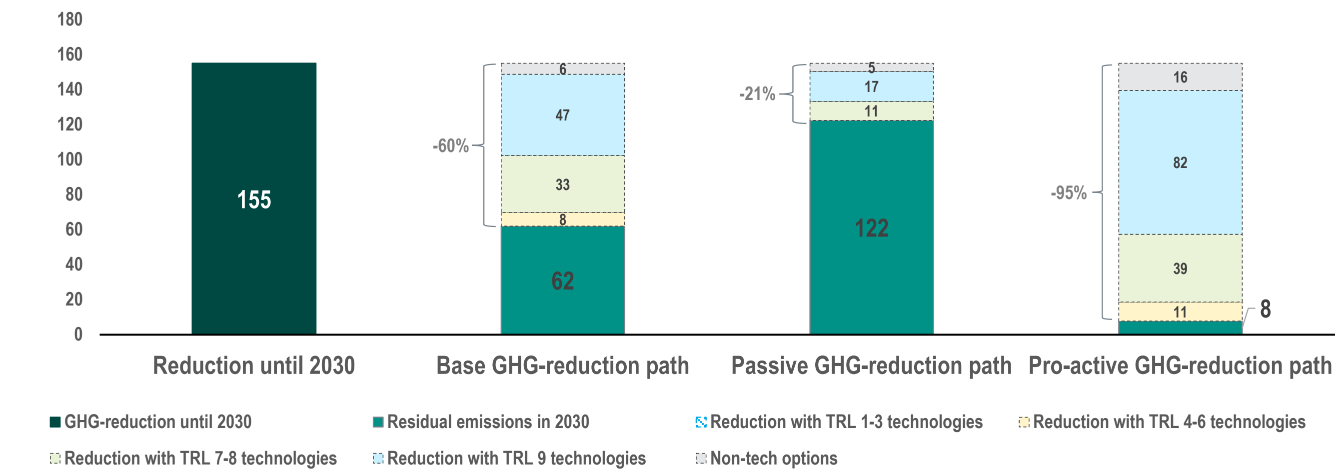
Furthermore, the efficiency of injection moulding machines, for example, can be improved by using variable-frequency speed controls and/or electromagnetic heating. Electric boilers are now more widely implemented, especially among SMEs. This is mainly due to the relatively low investment and operational costs. The reduction potential is also high, provided renewable energy sources are used here. CCS is a proven method for capturing large amounts of CO2 from natural gas combustion. Moreover, the sector can also opt for a more circular approach, where waste is recycled and reused as raw material. It reduces dependence on fossil fuels.

Emission reduction potential up to 2030

Sustainability in government policy will only increase in the coming years. With this, the sector will have to meet higher sustainability requirements. From 2027, for instance, a blending standard will be introduced, requiring the use of a minimum share of recyclate or bio-based plastics. The standard will start with a low percentage, which will be gradually increased until 2030. It is then about achieving the intended targets for 2030 and beyond to 2050. This trajectory will also look at current plastic consumption patterns, especially single-use. This segment will have to meet increasingly stringent sustainability requirements in the coming years, which will then demand a lot from the sector's innovative capacity. Our baseline scenario shows that the sustainability measures of companies collectively in the sector until 2030 are largely insufficient. Only 58% of the 155 million kg CO2-eq. is reduced by available low-carbon technologies in this scenario. In the passive scenario, the reduction is 21%. In the proactive scenario, more GHG is ultimately reduced than the base case, but low-carbon initiatives still fall short of meeting the 2030 target. This assumes greater end-user demand for sustainable alternatives.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents

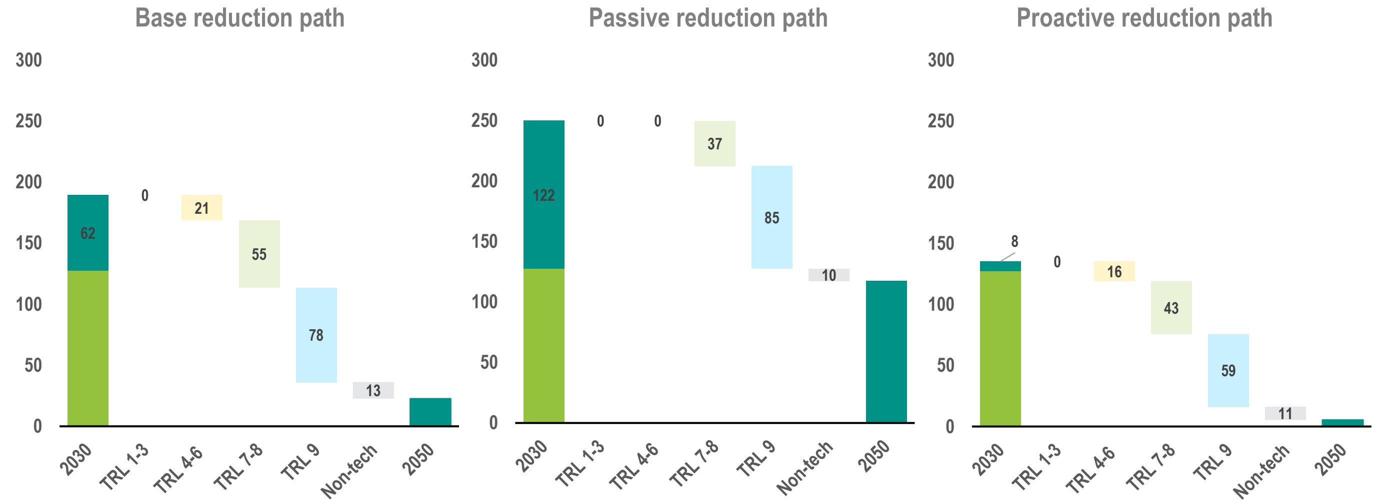


Source: CBS, ABN AMRO Group Economics

Emission reduction potential 2030-2050

Even in the long term, it remains important for the sector to have a more efficient production process high on the agenda. But also important is the deployment of more environmentally friendly materials, energy-saving technologies and green energy (wind energy, solar energy application). Above all, however, the path to 2050 will continue to require new breakthrough technologies. Without these breakthrough technologies, achieving carbon neutrality in 2050 is (too) far away. Moreover, it remains very important that companies in the sector commit to making production processes more sustainable in the coming years. Once that commitment is not there, net-zero in 2050 will not be achieved, as our passive scenario also shows. With enough commitment from companies, the 2050 target is more within reach.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)

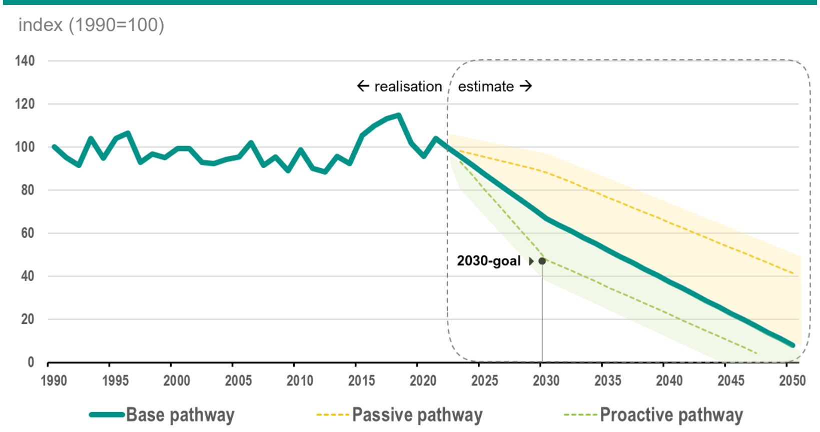


Source: CBS, ABN AMRO Group Economics

In the base path of GHG emission reductions between 2030 and 2050, we assume that the 2050 target will not be achieved. Here, we assume that available sustainability measures fall short and that an insufficient number of companies in the sector have a high level of ambition to reduce CO2 emissions more actively.

The emission reduction path between 1990 and 2050 is shown in the figure below, showing the possible three scenarios. The light green shaded area represents the uncertainty margin around the scenarios. As also shown in the figures above, we have not considered breakthrough technologies, which are in TRL stages 1 to 3, in this sector. We have not been able to identify these at the time of writing. This means that all scenarios outlined here do not take into account the introduction of potential breakthrough technologies that will see the light in the coming years. With this, upcoming innovative net-zero technologies could greatly improve our emission reduction projection.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

In any case, with today's net-zero knowledge, there is a significant chance that the rubber & plastic products industry will not achieve its targeted carbon neutrality until after 2050. This may be the case around 2052. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection. What could also start to help in the strategy towards 2050 is the sharp reduction in the cost of all decarbonisation technologies.

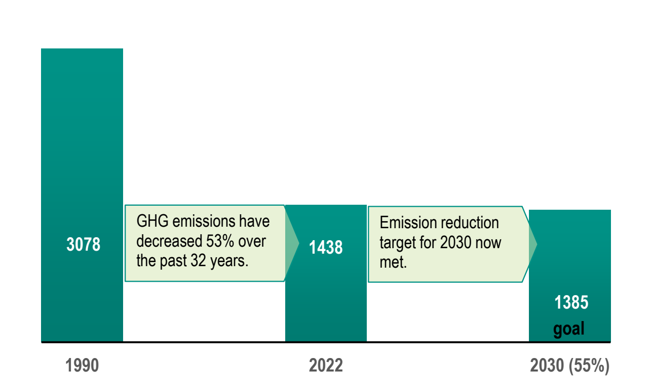
7. Building materials industry

The industry's 2030 climate challenge

Some building materials are natural, such as clay, sand and wood. These types of materials require relatively little additional processing. It is the synthetic building materials (artificially made by humans) that are associated with a lot of greenhouse gas emissions. These include glass, plaster, cement, bricks, insulation materials, plastics and ceramics. The demand for these building materials is high and will remain high in the Netherlands in the coming years, at least that is expected. Bio-based alternatives currently lack scale. The continuing high demand for building materials is due to the fact that the Netherlands is now well behind in housing construction, while the demand for new houses remains high. Renovation projects are also putting great pressure on demand. The soaring demand has the side effect of releasing a persistent flow of GHG into the atmosphere. To reduce that flow, companies in the sector need to decarbonise their processes.

Sector greenhouse gas emissions and 2030 impact

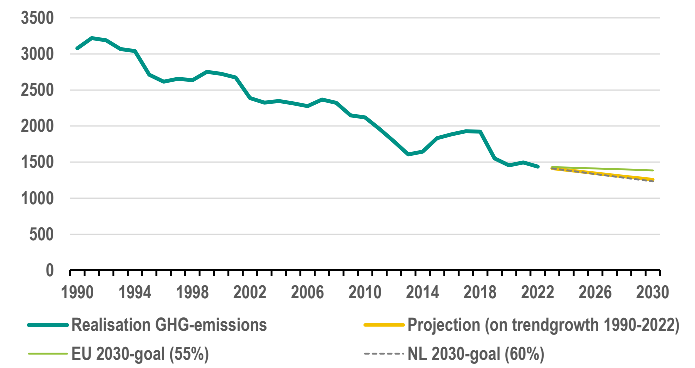
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

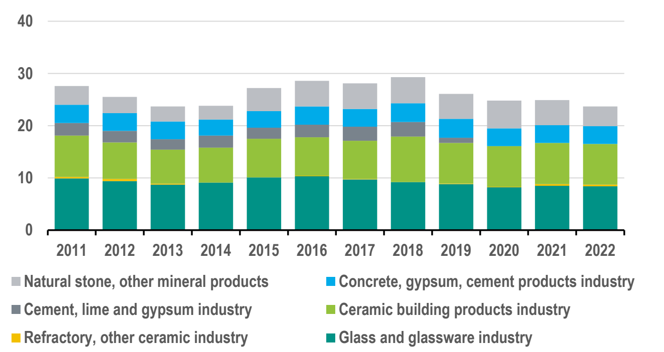
GHG emissions decreased 53% over the period from 1990 to 2022, or an average of almost 2% emission reduction per year. Not many sectors in the Dutch economy have managed this. This means that the 2030 target - which is 55% of the 1990 level of CO2 emissions - has already been met. The path to carbon neutral in 2050 thus seems to be within reach.

Source of emissions

In the Dutch building materials industry, most energy is consumed in the glass industry, the ceramic industry, the concrete, plaster and cement industry and the natural stone industry. In many of the subsectors, natural gas is the main energy carrier for the production process. On average, natural gas represents over three-quarters of total energy consumption. Especially in the glass and ceramics industry, this consumption is high (80-90%), while in the other subsectors natural gas accounts for about 63% of the energy mix on average, which is also relatively high. In addition, a lot of electricity is consumed within the sector.

Final energy use by subsector

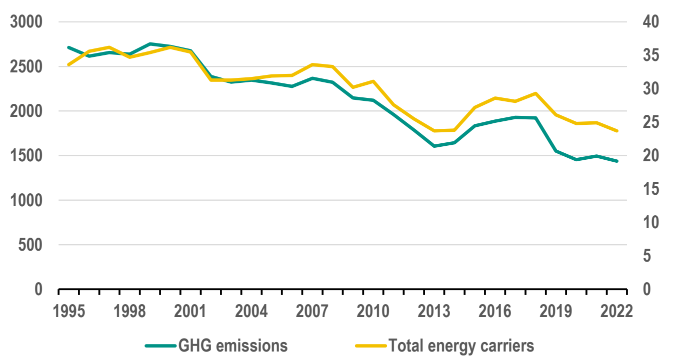
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend in emissions GHG and energy use

index (1995=100)



Source: CBS, ABN AMRO Group Economics

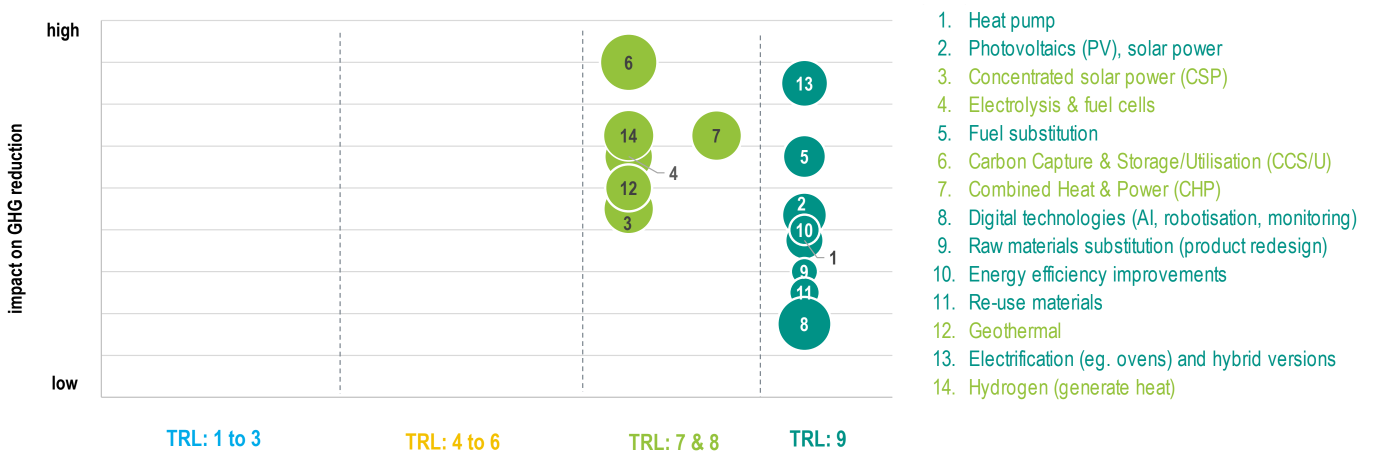
GHG emissions are mainly caused by final energy consumption (i.e. gas in particular). From 1995 to 2014, the two quantities run almost in parallel. After 2014, energy consumption increases again and GHG emissions follow, but at a slower pace. This may be as a direct consequence of increased efficiency and the introduction of decarbonisation techniques.

Reduction strategy for the sector with current and future available low-carbon technologies

The Dutch building materials industry is an energy-intensive sector, as high temperatures must often be reached (e.g. in ovens and in drying processes) to make the products. Process improvements can further reduce energy consumption for reaching high temperatures. Electrification is a common decarbonisation technique that can be applied across the industry. It has great potential to reduce GHG emissions from processes. And once electricity is produced using renewable energy sources, the industrial process becomes much more sustainable.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

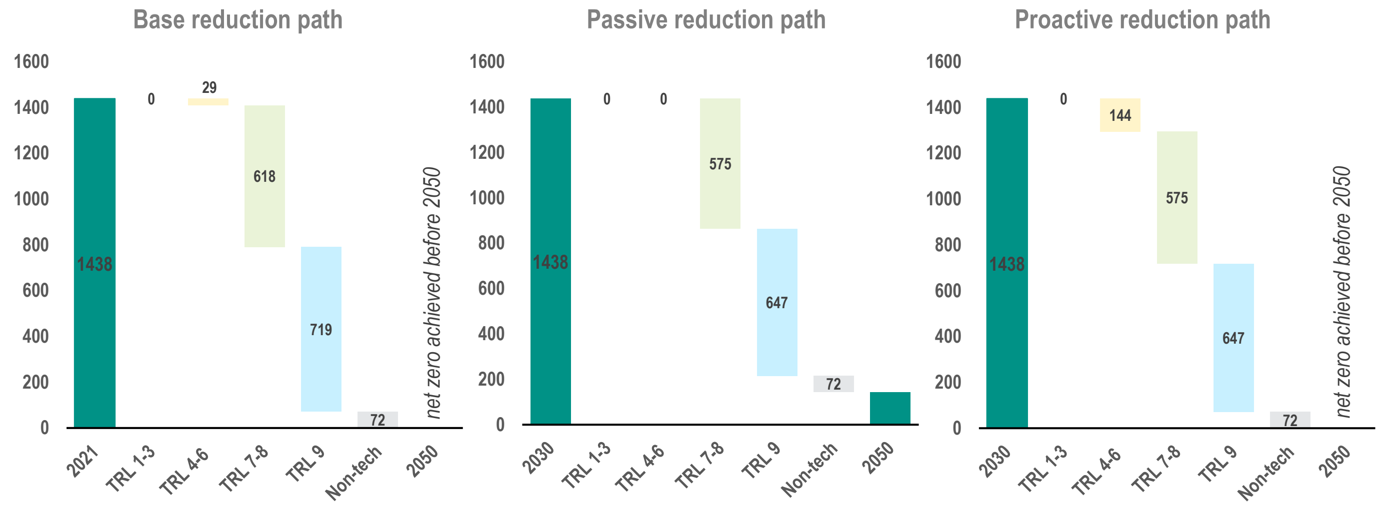
Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

With the replacement of gas for a low-emission alternative - such as increased use of heat pumps, hydrogen, biogas, waste heat or solar power as fuel - the sector can make good progress towards lower emissions. Carbon Capture Storage and Usage is at different stages of maturity for different subsectors. Whereas in one subsector it remains at TRL 5, in another the technology has TRL 9. In theory, the carbon storage ratio could reach 100% in all subsectors. However, often the scale is too small and the economic feasibility of this option is relatively low. Location of the production facility and high transport costs are often a barrier.

Emission reduction potential 2030-2050

Despite having already reached the 2030 target for the building materials industry, the sector will have to meet higher sustainability requirements. Government policy will become stricter in the coming years. This will also partly keep the target towards 2050 in sight.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)

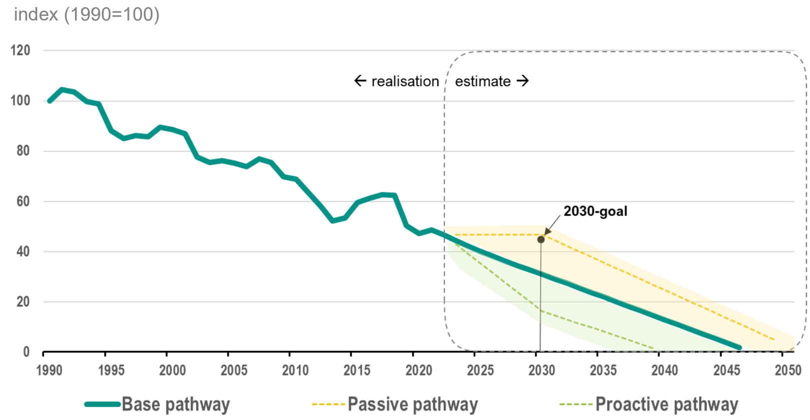


Source: CBS, ABN AMRO Group Economics

In both the base path and the proactive path, the 2050 net-zero target can be easily achieved. Despite climate neutrality being less remote than for other sectors, the steps to net zero will remain complex in practice. Many construction materials – among which concrete - will still be needed for a long time, while production techniques for making these materials are not yet emission-free. However, the sector does have sufficient sustainability measures at its disposal. In both scenarios, the technologies known so far from TRL stages 4 to 6 become available. In the most passive pathway, this is not the case and existing low-carbon technologies are not sufficient to achieve carbon neutrality by 2050.

The emission reduction path between 1990 and 2050 is shown in the figure below, showing the possible three scenarios. The light green shaded area shows the uncertainty margin around the scenarios. In this sector, we have not considered breakthrough technologies. We have not been able to identify these at the time of writing.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

In summary, with today's net-zero knowledge, the building materials industry is capable of achieving carbon neutrality before 2050. This could be the case by around 2047. But again, nothing is cast in stone. For one thing, innovative net-zero technologies may well be successfully introduced in the coming years. This is going to greatly improve our emissions projection. But on the other hand, at the point when the sustainable ambition level of companies in the sector decreases, the net-zero moment is around 2050.

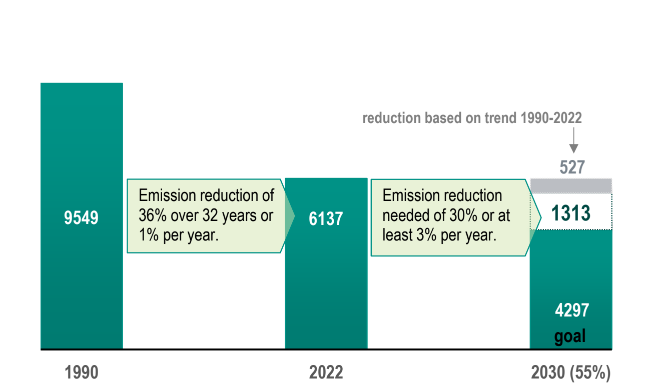
8. Base metal industry

The industry's 2030 climate challenge

The base metal industry has shown a declining trend in total GHG emissions since 1990. However, the decline in this has been at a relatively slow pace. From 1990 to 2022, GHG emissions decreased by only 36%, or 1% per year. This rate is still far from sufficient to meet the set 2030 target. The sector still needs to reduce some 1,313 million kg of CO2 equivalents until 2030, or 5% per year. It makes the challenge big. For this, the sector has several emission reduction options at its disposal.

Sector greenhouse gas emissions and 2030 impact

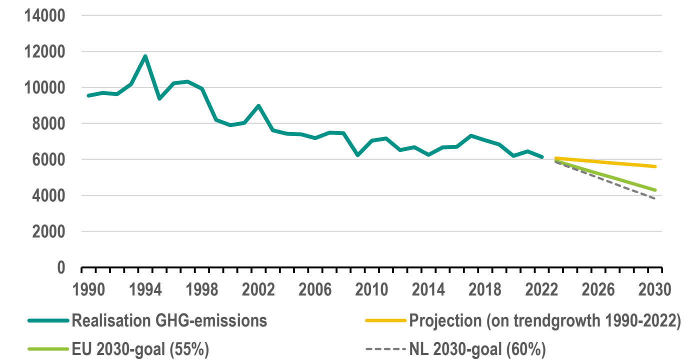
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

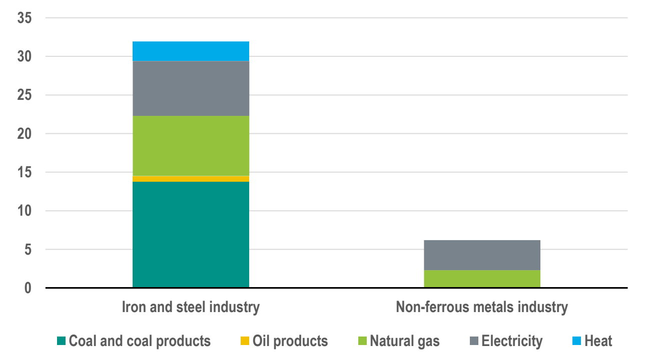
The base metal industry has a tough task ahead to drastically reduce its GHG emissions to meet EU climate targets. This requires substantial investments in the production process, while the sector has a fairly long investment cycle. At the same time, the sector must remain competitive in an international playing field.

Source of emissions

In the Dutch base metal industry, metals are delivered in their primary form, i.e. from the raw material (metal ore) to semi-finished products (such as hot- or cold-rolled steel). Within the base metal industry, two subsectors are distinguished: the ferrous metal industry (iron and steel products) and the non-ferrous metal industry (metal products not made of iron or steel). In terms of energy consumption, there is a significant difference between the two subsectors. For instance, the ferrous metal industry consumes 5x more energy than the non-ferrous metal industry, with a big difference in the quantities of the corresponding energy carriers. But this has not always been the case. The right-hand figure below shows the trend in final energy consumption since 1995. It shows that the difference in energy consumption of the two subsectors was not even that big between 1995 and 2011. After 2011, a sharp decrease in energy consumption is visible in the non-ferrous industry. As the decrease is not related to the trend in production or the number of companies in the sector, it is plausible that efficiency measures could be the cause of this.

Final energy use subsectors (2022)

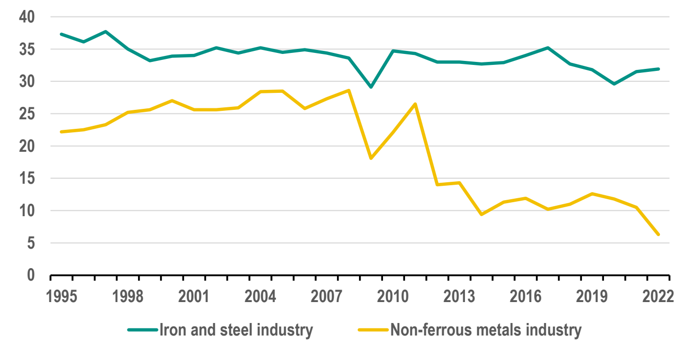
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend in energy use by subsector

PJ



Source: CBS, ABN AMRO Group Economics

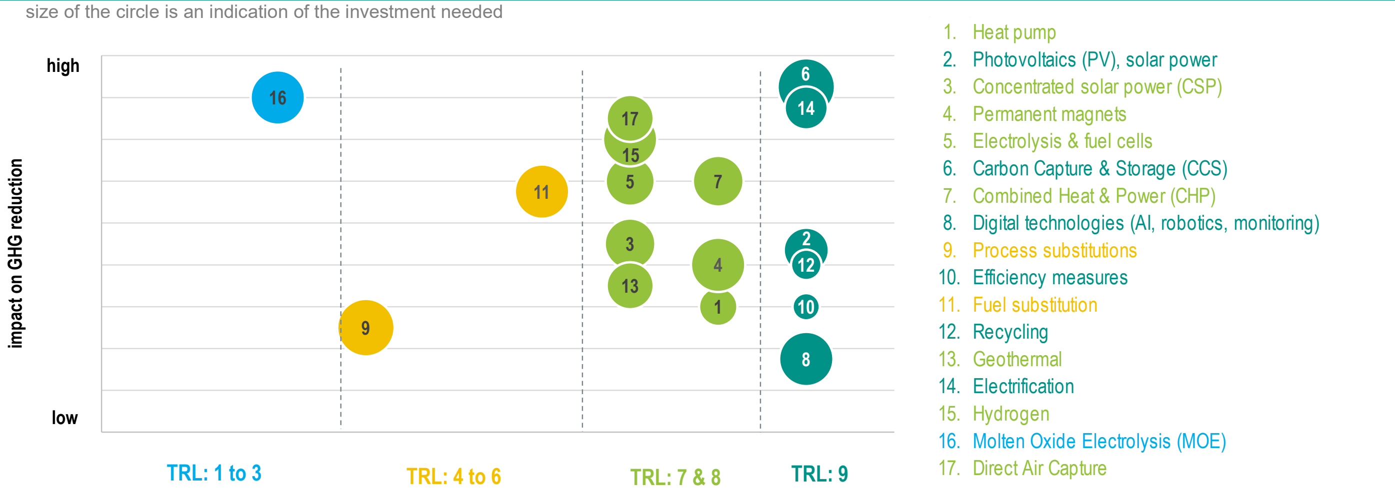
Final energy consumption across the base metal industry broadly follows the trend in greenhouse gas emissions. In addition to the difference in the trend in energy consumption, we also see that in the non-ferrous metals industry more natural gas and electricity (for the electrolysis process) are consumed, while the ferrous metals industry also processes a large proportion of coal in the production process.

Reduction strategy for the sector with current and future available low-carbon technologies

The main options with high greenhouse gas reduction potential are electrification, carbon storage and replacing fossil fuels in the production process for the carbon-free variants (such as hydrogen, renewable energy). In the aluminium industry, for example, the use of inert anodes is an interesting technique. Anodes are high-quality blocks of carbon used in the electrolysis process, and the inert variant of these is carbon-free. In addition, the base metal industry - like many other industries - has the opportunity to improve energy efficiency and optimise the production process. These are usually quite simple techniques to implement, but tend to have a low reduction potential.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

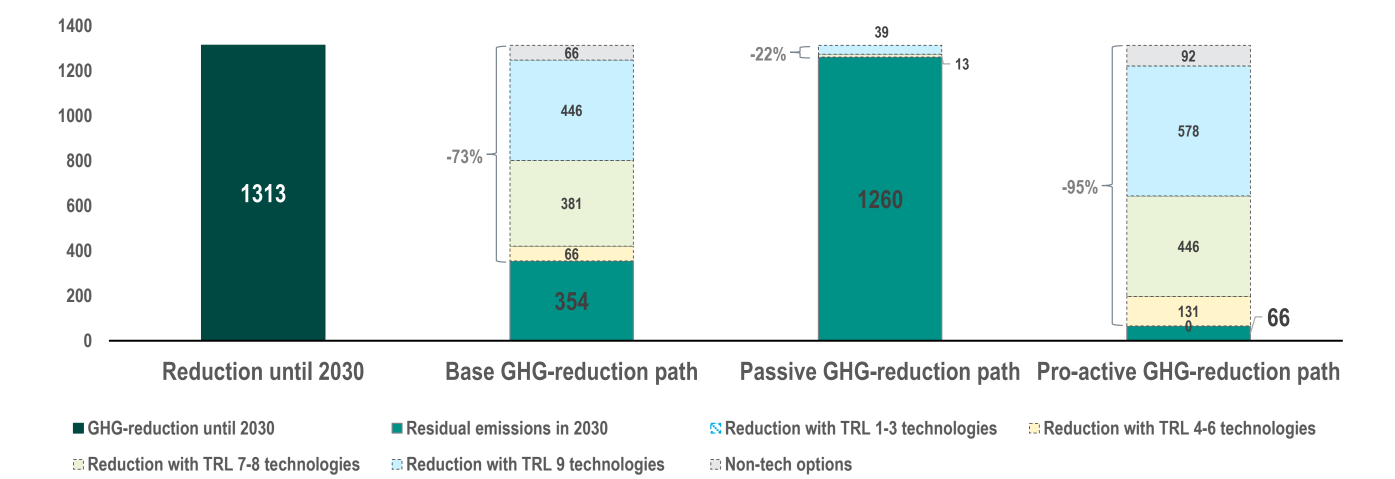
The adoption of decarbonisation technologies is in many cases tailor-made for each company and often depends on different operating conditions. This makes it complex to estimate which combination of low-carbon technologies will be used by the sector in the future. For instance, not only the regional conditions in which the company operates are important, but also aspects such as the availability of energy and its infrastructure, local legislation and its restrictions, and the technological level of business processes. Such aspects determine to what extent some breakthrough technologies can actually be deployed.

Emission reduction potential up to 2030

Our baseline scenario shows that the sustainability measures of companies collectively in the sector are not sufficient. About 73% of the 1,313 million kg CO2-eq. is reduced by available low-carbon technologies in this scenario. It therefore remains important in this sector as well to make companies aware of their responsibilities and the technical possibilities to reduce emissions. This includes the necessary technical and financial support for investment. After all, the base metal industry is not only an energy-intensive but also a capital-intensive sector. This makes the transition to climate-neutral a lot more complex. In the proactive scenario, we assume that the necessary investments will be made and that GHG reductions will gain momentum. In this case, the 2030 target is more within reach. This assumes that there is also much greater end-user demand for sustainable alternatives. Next to that, the sector has also some large companies which are mandatory to participate in the EU-ETS (emission trading system in Europe). In order to meet the requirements of the EU-ETS, emission reduction in this sector will increase relatively more.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



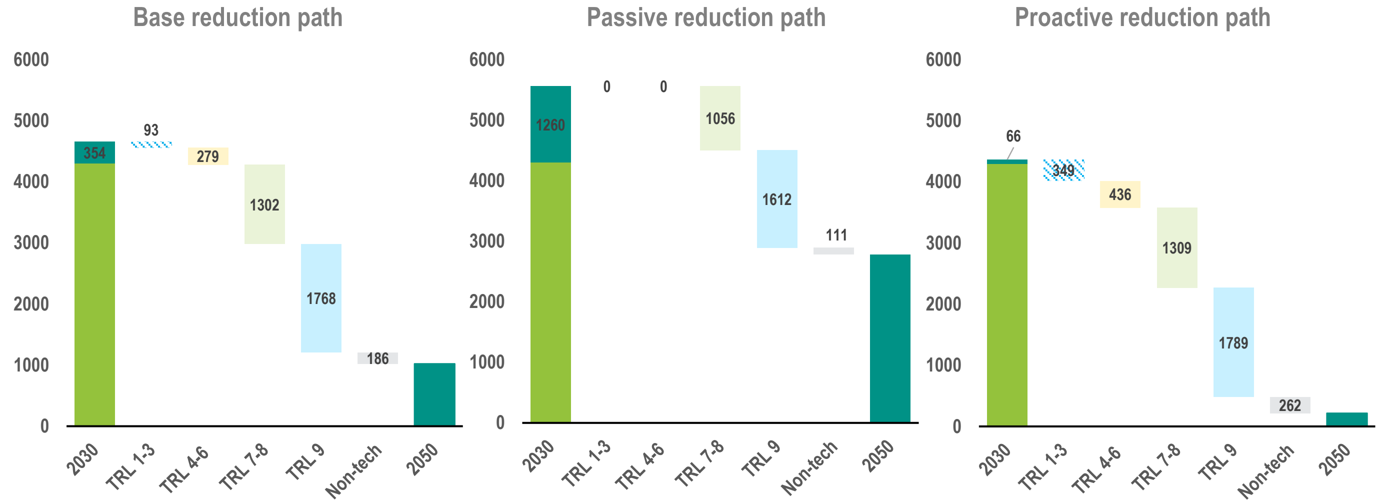
Source: CBS, ABN AMRO Group Economics

In the passive scenario, the 2030 target is not reached and only 22% reduction is achieved. Here we assume that companies are much less willing to invest in the low-carbon technologies and there is much less willingness from the government for financial support.

Emissions reduction potential 2030-2050

A low-carbon base metal industry in the Netherlands is among the possibilities within the set timeframes. However, the path towards it will be relatively slow. Given the high capital intensity of the sector, implementing low-carbon technologies (including engineering, licensing, construction) is a time-intensive process. In this sector, investment decisions cannot be made overnight. And in addition, it is quite possible that once the investment decisions have been made, the realisation is only in 10 years or more.

Emission reduction potential 2030-2050 (in mln kg CO2-equivalents)

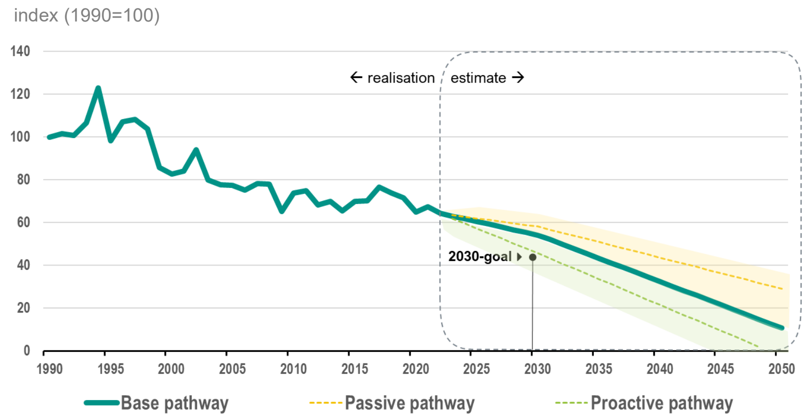


Source: CBS, ABN AMRO Group Economics

In any case, it is clear that a lot of investment is needed to achieve far-reaching decarbonisation. It is also important in this sector that a majority of companies actually actively engage in the transition. For the base metal industry, the emission reduction path between 2030 and 2050 is mainly driven by carbon capture and storage (CCS), fuel substitution, electrification, increased energy efficiency and more efficient use of raw and auxiliary materials. CCS will be particularly important in this sector, partly because of its longer investment cycle. But what also comes into play is the available capacity of CCS in Europe and its infrastructure.

In our base path of GHG emission reductions between 2030 and 2050, the 2050 target will not be achieved. The timeframe is too tight for that. In the proactive path, we assume that breakthrough technologies are widely available and the target is met by a fraction. In the passive path, existing low-carbon technologies are nowhere near sufficient to achieve carbon neutrality by 2050.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the base metal industry reaches carbon neutrality after 2050. This could be the case around 2055. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

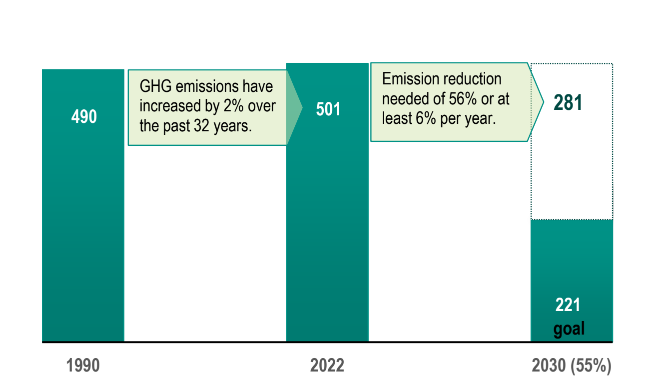
9. Metal products industry

The industry's 2030 climate challenge

In the Dutch metal products industry, GHG emissions increased by 2% between 1990 and 2022. This is in contrast to many other industrial subsectors, where GHG emissions have actually decreased over the past 25-30 years. There is thus still a considerable emission reduction task ahead for the sector in the coming years. For instance, the sector still needs to reduce 56% of the 2022 emission level to reach the 2030 target. This means a greenhouse gas reduction of at least 6% per year until 2030. This promises to be a tough task for the sector.

Sector greenhouse gas emissions and 2030 impact

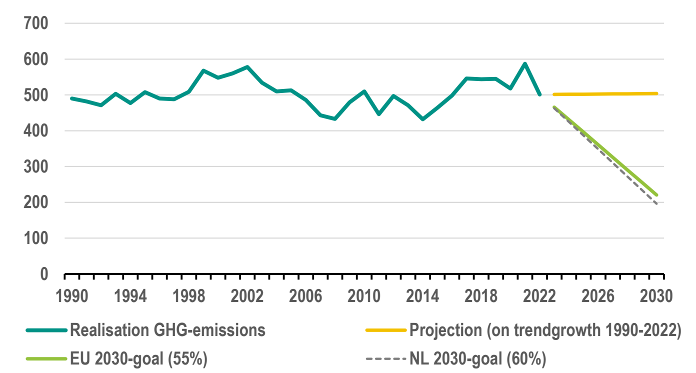
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

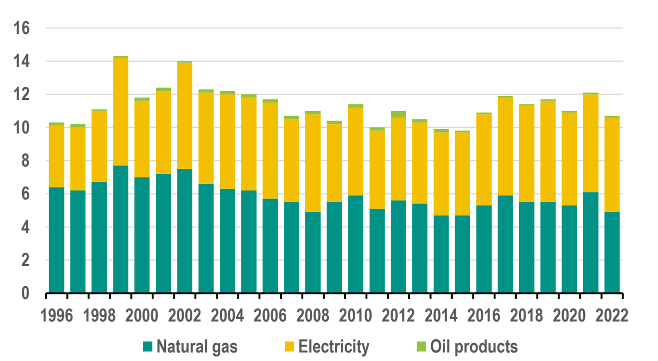
To achieve further GHG emission reductions by 2030, fossil fuel use needs to be reduced. Investment in low-carbon technologies has lagged behind in recent years because it is a capital-intensive process. Many of the companies operating in this sector are SMEs. For these companies, getting sufficient financial support for the transition to climate neutral is sometimes an obstacle. But low-hanging fruit can also play a major role in the transition. For instance, implementing efficiency measures is a proven technique to reduce energy consumption and thus emissions.

Source of emissions

The metal products industry is closely linked to the base metal industry. Primary metals from the base metal industry are further processed in the metal products industry. This includes a wide range of products such as structural work, tanks, boilers, scissors, cutlery, tools and hardware as well as bolts, screws and nuts. The sector is an important supplier to other industrial sectors, including the machinery industry. The processes in the metal products industry involve forging, pressing, stamping and profile rolling of metal and the surface treatment of metal. These operations require energy, mainly natural gas and electricity. The consumption of these energy carriers in the production process is the main source of these GHG emissions for the sector.

Final energy use

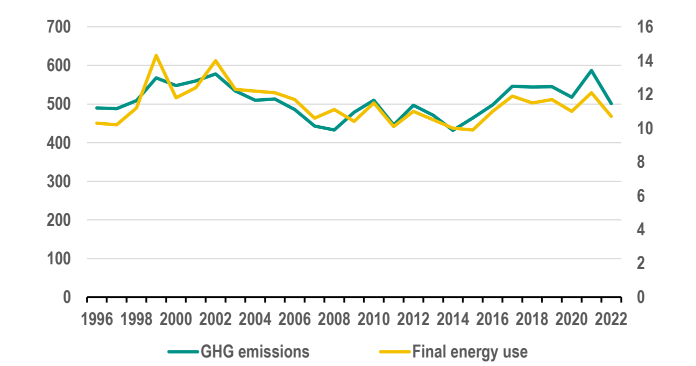
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use

mln kg CO2-eq PJ



Source: CBS, ABN AMRO Group Economics

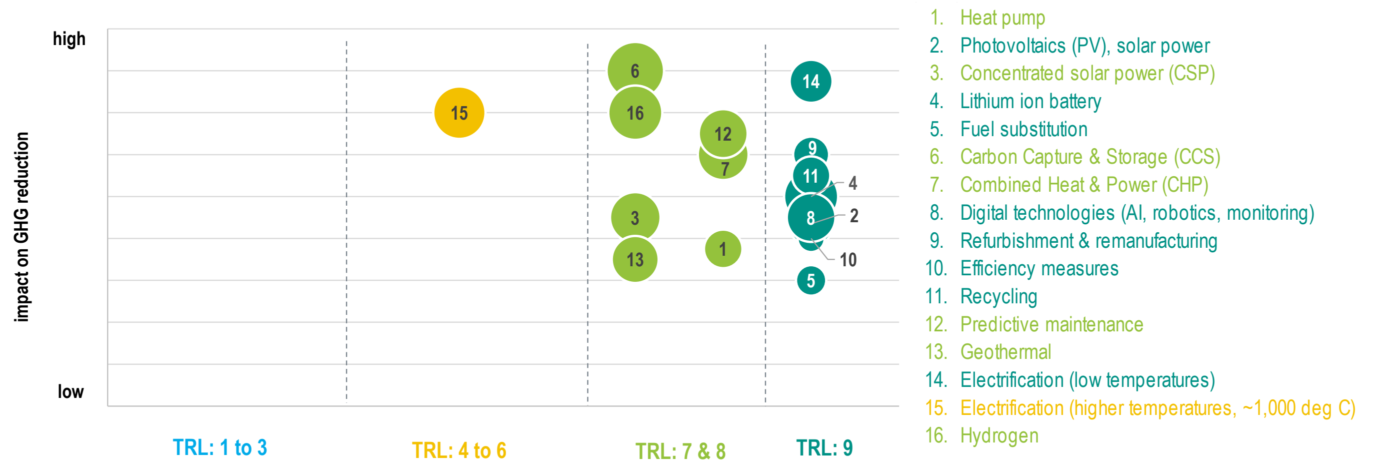
At 0.3%, the metal products industry has a low share in the Netherlands' total emissions. This makes the metal products industry very much less emission-intensive and also energy-intensive than the related base metal industry. But that does not mean that companies in the sector are immune from taking decarbonisation initiatives.

Reduction strategy for the sector with current and future available low-carbon technologies

Electrification of heat is the low-hanging fruit for many smaller and low-temperature plants in particular. The biggest challenge here is the relatively high electricity prices. For plants that need to reach higher temperatures (>1,000 degrees Celsius), electrification is still in development.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

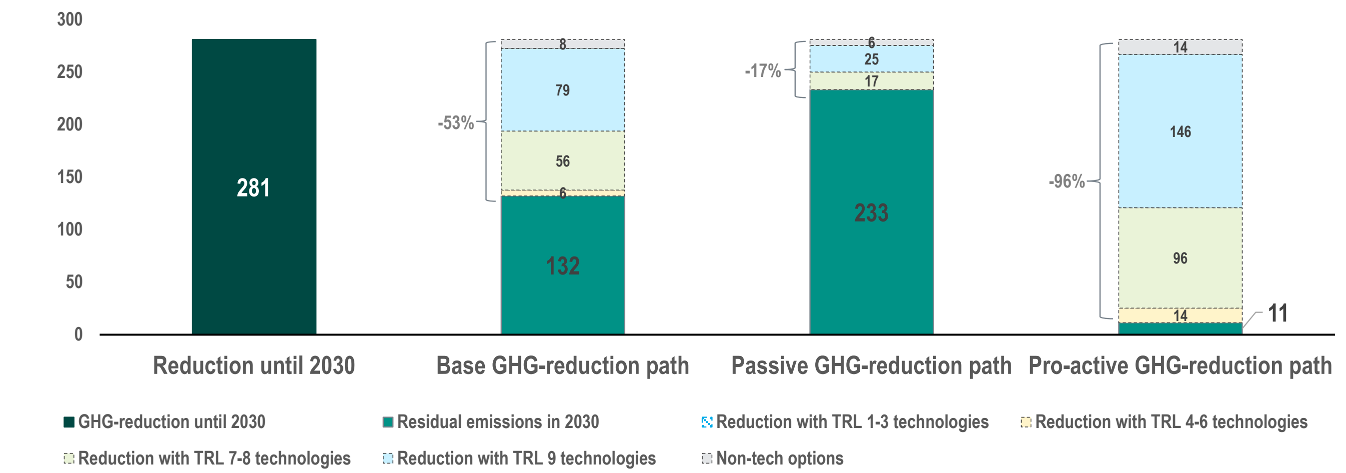
Recycling and circularity is a way to make metal use more sustainable. A TNO study showed that innovations across the manufacturing industry made a major contribution to reducing environmental impact (Manufacturing Industry Roadmap, 2022). The study showed that greenhouse gas emission reductions of 25-70% can be achieved through 1) smart maintenance: the use of ICT to achieve predictive maintenance, 2) smart materials: the use of new materials and new production technology (think Metal Injection Moulding and 3D metal printing), 3) refurbishment & remanufacturing and 4) introduction of as-a-service business models. Other ways of working can also bring many sustainability gains. For instance, welding requires a lot of energy. Instead of welding, gluing can be used, for example.

Emission reduction potential up to 2030

Despite the industry having plenty of low-carbon technologies at its disposal, meeting the set 2030 climate targets (and also towards 2050) remains a major challenge. The metal products industry is rich in SMEs, which often lack access to key infrastructure, such as for using hydrogen or CO2 capture. In addition, SMEs often do not have the immediate financial resources to invest in the transition, nor do they have access to R&D facilities to enable new technologies. It ensures that the implementation of low-carbon technologies and thus GHG reduction is relatively slow. This ensures that in our baseline scenario, GHG reduction is slow and only 53% of the 281 million kg CO2-eq. is reduced. It therefore remains important to support companies in this sector with the necessary technical and also financial support for investments. In the passive scenario, emissions decrease much more slowly. On balance, 17% will be reduced. In this passive path, we assume that companies will not be able to sufficiently join the transition, despite the fact that the low-carbon ambition level may be high. The preconditions fall short here. In the proactive scenario, much more GHG is ultimately reduced than initially needed to meet the 2030 target.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



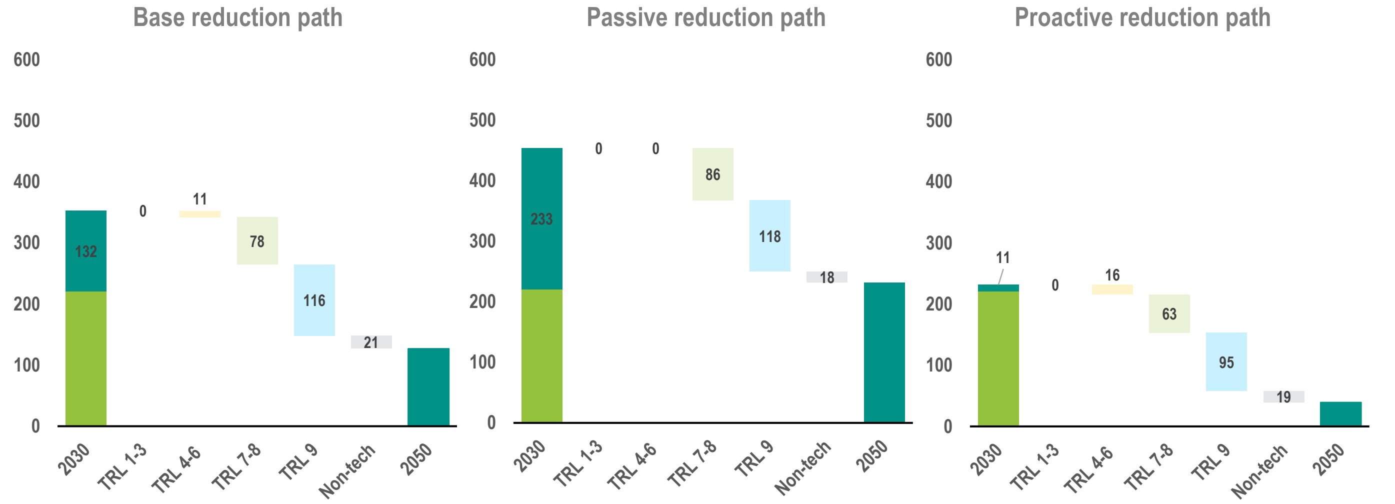
Source: CBS, ABN AMRO Group Economics

This assumes that companies are adequately supported to work on the energy transition. We also assume in this scenario that low-carbon technologies in Stages 4 to 8 are ready for commercial use much earlier and make a meaningful contribution.

Emission reduction potential 2030-2050

Estimating an emissions reduction pathway between 2030 and 2050 is complex, as many different circumstances have an impact here. For instance, low-carbon technologies that are currently not considered viable may offer more emission reduction potential at a later stage. This could be due to innovation, lower commodity prices or government policy incentives, for example. Ultimately, the most economically viable and technically appropriate technologies will shape the emissions reduction pathway between 2030 and 2050.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



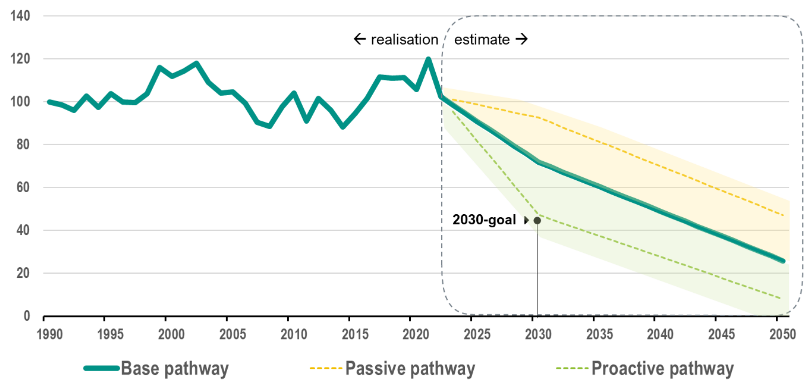
Source: CBS, ABN AMRO Group Economics

In the Dutch metal products industry, many investments by companies are still needed to reduce GHG emissions more significantly between 2030 and 2050. It is also important in this sector that a majority of companies actually actively engage in the transition. For the metal products industry, the emission reduction path between 2030 and 2050 is mainly driven by electrification, by using used products or components in industrial processes, recycling, increased energy efficiency and more efficient use of raw and auxiliary materials.

In our base path of GHG emission reductions between 2030 and 2050, the 2050 target is not achieved. For that, the timeframe is too tight and the GHG emission reduction task too large. In the proactive path, we assume that technologies from TRL stages 4 to 8 are widely available. In this case, the climate-neutral target will be met by a fraction. In the passive path, existing low-carbon technologies are nowhere near sufficient to achieve carbon neutrality in 2050.

Emission reduction pathways towards 2050

index (1990=100)



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the metal products industry reaches carbon neutrality after 2050. This may not be the case until around 2054. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

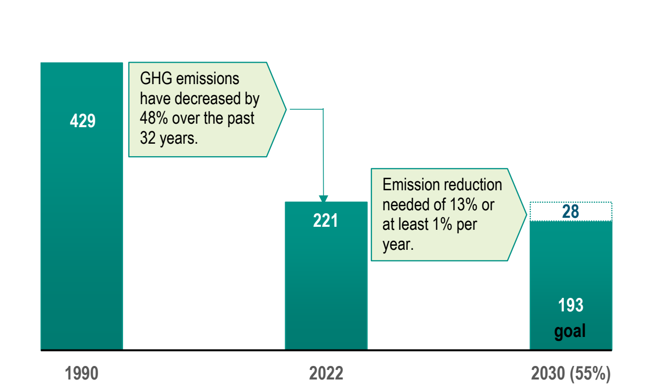
10. Electrical and electronics industry

The industry's 2030 climate challenge2030

This sector includes companies active in making equipment that operate based on electricity (such as sewing machines, radiant heaters, etc.) and equipment that contains circuits (transistors, chips), such as computers and optical equipment. The energy and emission intensity of the sector is relatively low. Companies in the sector have managed to reduce GHG emissions at a rapid pace since 1990. This is not only due to the introduction of various efficiency measures over time, but also the reduction in the number of companies due to economic conditions have reduced GHG emissions.

Sector greenhouse gas emissions and 2030 impact

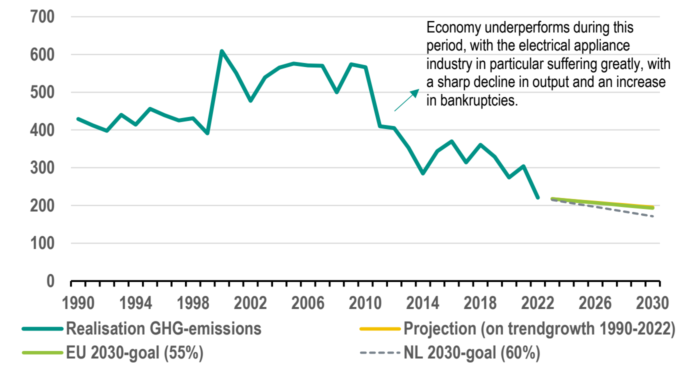
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

GHG emissions decreased by 48% over the period from 1990 to 2022, or an average 1.5% emission reduction per year. Not many sectors in the Dutch economy have managed this. This means that the 2030 target - which is 55% of the 1990 level of CO2 emissions - has already been met. This ensures that the 2050 carbon-neutral target is within reach.

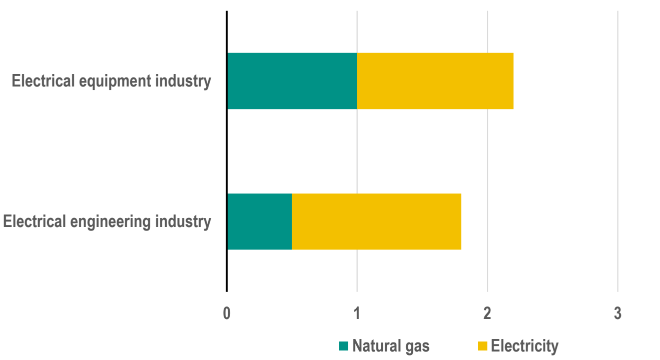
Electrification is taking place in many sectors. Electricity is likely to become the (secondary) energy carrier of the future. The electrical industry is promotes this development and is well positioned with its products. After all, end users benefit from sustainably produced energy-efficient equipment. It can bring companies a competitive advantage in the long run. However, it requires more investment in more low-carbon technologies, knowledge & skills and R&D.

Source of emissions

Final energy consumption decreased by 39% across the sector since 2011, with consumption decreasing by 51% in the electrical appliances industry and 14% in the electrical engineering industry over the same period. By 2022, there is very little difference in total energy consumption between the two subsectors. However, the composition of energy consumption does differ. More natural gas is consumed in the electrical appliance industry than in the electrical engineering industry. In terms of electricity consumption, there are few differences between the two subsectors.

Final energy use by subsector 2022

PJ

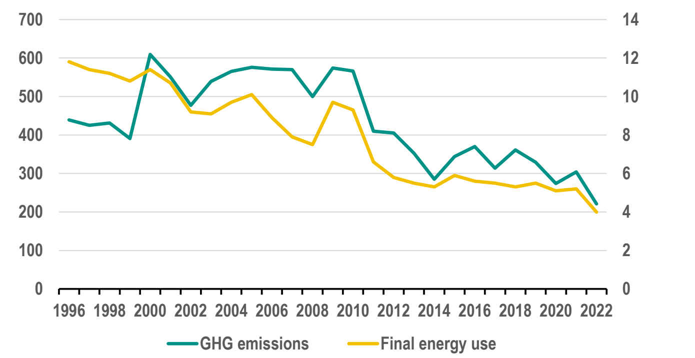


Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use

index (2015=100)

PJ



Source: CBS, ABN AMRO Group Economics

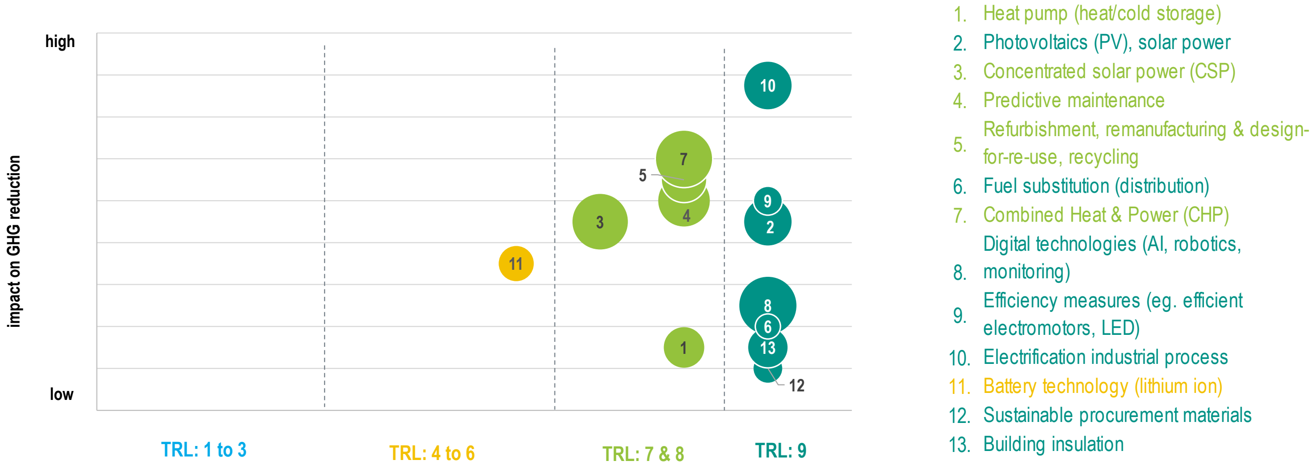
Final energy consumption has decreased by 60% since 2005 and greenhouse gas emissions have fallen by almost 85%. Over the same period, production continued to increase, by 59%. It indicates some improvement in energy efficiency in the sector in those years.

Reduction strategy for the sector with current and future available low-carbon technologies

The electrical and electronics industry has a wide range of low-carbon technologies available. These include electrification of processes and machinery, improvements in energy and material efficiency and acceleration in circular solutions. Improving energy efficiency involves, for example, automation (monitoring and metering), process optimisation, sustainable design and inbound and outbound logistics solutions. Renewable energy production (via e.g. solar power) can also mean a lot in the sector.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

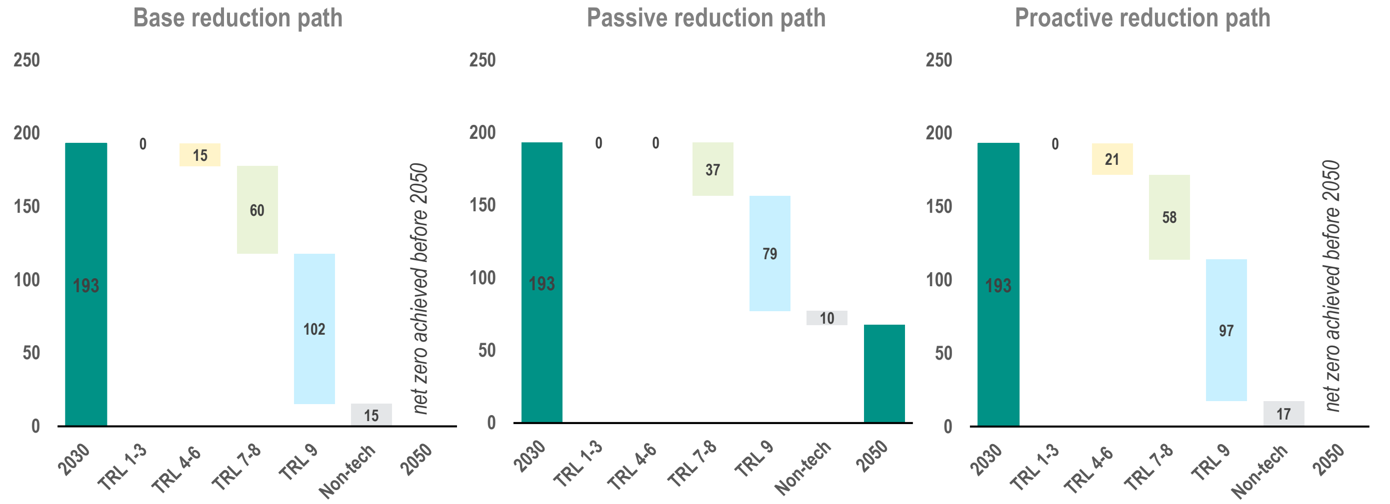
Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

Extending the average lifespan of an electrotechnical product from three to, say, five years can have a significant impact on the environmental footprint of the device, but also of the industry. The European Commission has updated its energy label requirement for electronic products and proposed minimum efficiency requirements for IT equipment. The *EU Waste Electrical and Electronic Equipment Directive* requires 75% of small IT equipment to be recovered by the manufacturer and 55% to be prepared for reuse and recycling.

Emission reduction potential 2030-2050

The 2030 climate target has already been reached for the sector. That leaves a small portion of GHG emissions to reduce in the coming years. This will not be a difficult task for the sector as a whole. We also see this in the three scenarios below, where in both the baseline scenario and the proactive scenario, the climate-neutral 2050 target is achieved with ease. In the passive path, we assume that companies in the sector have low-carbon ambitions to further reduce residual emissions. In this case, some residual greenhouse gas emissions are still emitted in 2050.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

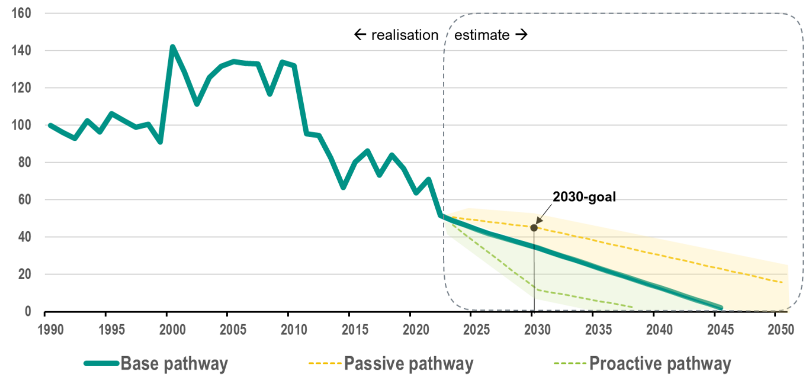
To still keep the level of ambition high in this sector, a favourable business and market environment remains a necessary condition. This means transparent and stable public policies and financial incentives and support to promote major forward-looking investments. The industry's low-carbon technological solutions have a major impact on end-user emission reduction. Hence, it is important that the industry continues to invest in low-carbon production processes and ways of working in the coming years.

If we assume the base scenario and the proactive scenario in terms of emission reductions and available net-zero technologies in the electrical and electronics industry, our calculations and estimates show that the sector will easily meet the set targets for 2050.

In the passive scenarios, there are slightly more potential obstacles. However, this path is still independent of the breakthrough technologies that might be introduced after 2030.

Emission reduction pathways towards 2050

index (1990=100)



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the electrical and electronics industry achieves carbon neutrality before 2050. This could be the case by 2046. Moreover, innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

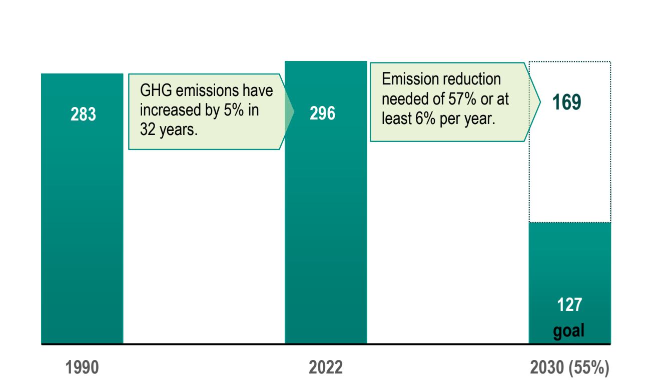
11. Machinery

The industry's 2030 climate challenge

The machinery industry in the Netherlands has a low GHG emission intensity. Since 1990, the sector has done little to reduce GHG emissions. The level of GHG emissions is at a higher level in 2022 than in 1990: it has increased by 5% in those 30 years. This means that companies in the sector still need to make many efforts to reduce GHG emissions up to 2030. To reach this 2030 target, the sector needs to reduce emissions by at least 6% annually. However, over the past 32 years, on average, the sector has added around 5% in GHG emissions, or 0.1% annually on average. This makes the 2030 target challenging for the sector.

Sector greenhouse gas emissions and 2030 impact

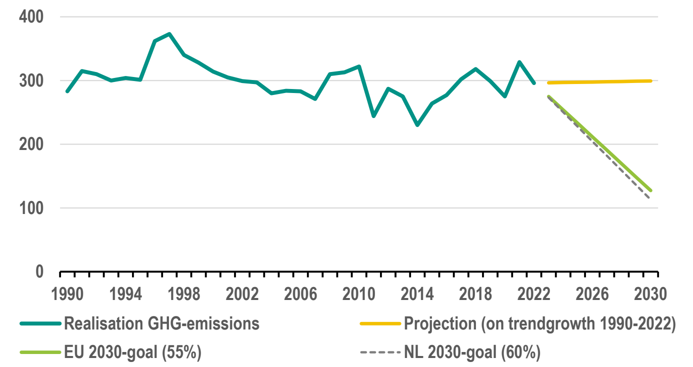
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

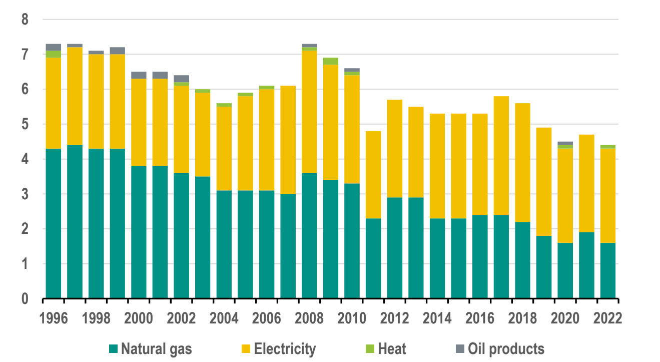
Almost every stage in the machinery manufacturing process has an impact on the environment. For making the larger industrial machines, this impact tends to be greater due to the higher energy-intensive production processes. Many production processes of companies in the machinery industry often still rely on fossil fuels. By increasing the energy efficiency of the production process and investing more in low-carbon technologies, sustainability efforts by the sector improve. In addition, companies can replace fossil fuels and switch to renewable energy sources, for example, and thus further reduce their GHG emissions.

Source of emissions

Over the past 30 years, the sector has made a switch from less and less natural gas to more use of electricity. And with this transition, total final energy consumption has also decreased. Between 1995 and 2022, energy consumption decreased by about 31%. With the decrease in energy consumption, GHG emissions also initially decreased. In the period 1995 to 2017, the correlation between energy consumption and GHG emissions was very high, with a correlation of 0.90. After that, the correlation coefficient drops back to around 0.4.

Final energy use

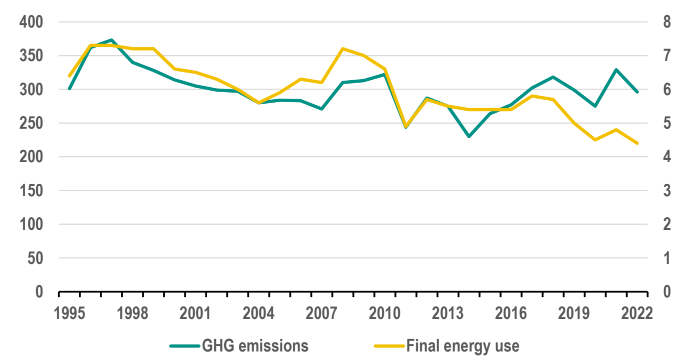
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use

PJ index (2015=100)



Source: CBS, ABN AMRO Group Economics

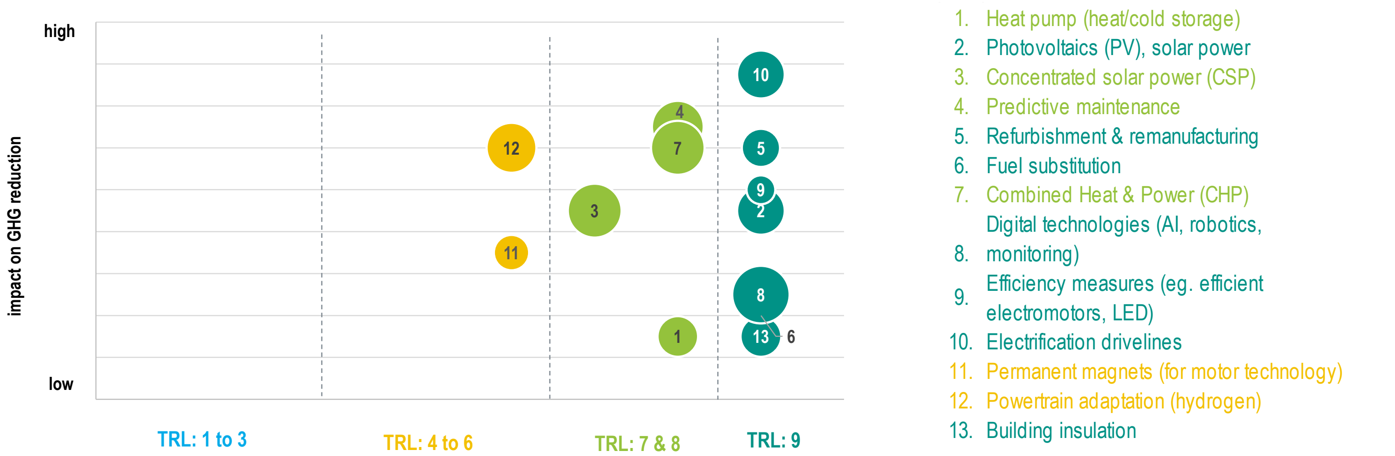
After 2017, production in the sector increases much more strongly and GHG emissions also rise again. During this period, growth in the Dutch machinery industry was highest of the whole industry, especially due to stronger demand for chip machines. Especially from 2020 to 2022, growth in production was strong.

Reduction strategy for the sector with current and future available low-carbon technologies

More progress on GHG abatement is clearly necessary. This can be achieved in several ways. For this, the industry has a wide variety of decarbonisation options. For instance, machine builders can reduce energy consumption during production, optimise transport logistics and implement efficient waste management systems. Some of the initiatives currently being taken by major players in the sector include using alternative fuels and renewable energy sources and reducing the energy intensity.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

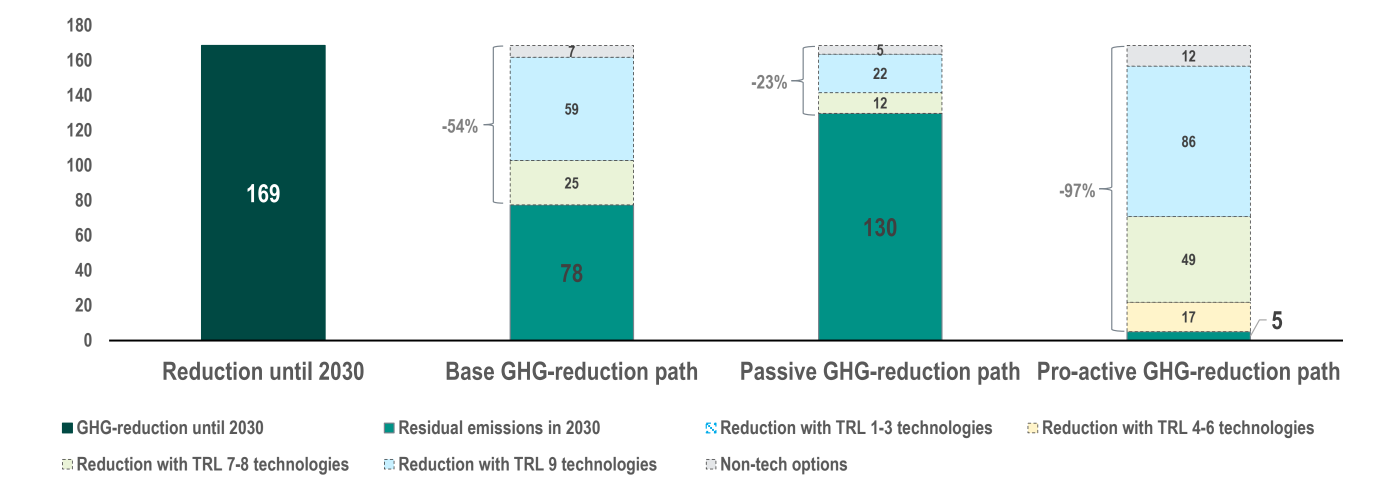
Electrification is the most impactful measure to reduce greenhouse gas emissions. Refurbishment & remanufacturing is also interesting from a sustainability and economic point of view, as reuse leads to significantly less consumption of raw materials and it can ultimately result in considerable cost savings for the end user. For the machine manufacturer itself, it can be an interesting (new) business model. Improving efficiency within the machinery industry involves optimising the primary production process. Further automation, precision applications and connectivity between machine further increases efficiency. Thanks to the use of advanced technologies such as GPS and smart sensors, machine builders are able to achieve ever higher accuracy in the work process.

Emission reduction potential up to 2030

The growing public interest in climate change has a lot of impact on the way companies operate. For machine builders, they are constantly connecting to innovative and more economically viable technologies to future-proof production processes. It cannot be otherwise because government policy will only become more stringent on sustainability in the coming years. But not only that. Financiers and investors are also keen on climate-friendly changes in production processes. The growing demand for machinery implies that GHG emissions will remain high as long as the industry does not work towards decarbonisation. Many machine builders are now committed to sustainability, but more ambition and, above all, more sustainable investments are needed to eventually reach the climate targets. Achieving the 2030 target will not be an easy task for many companies in the sector. In our baseline scenario up to 2030, we assume that further sustainability progress is relatively slow. Electrification remains the most impactful way to decarbonise in the coming years, but is difficult to implement in some cases. A few obstacles come into play here,

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



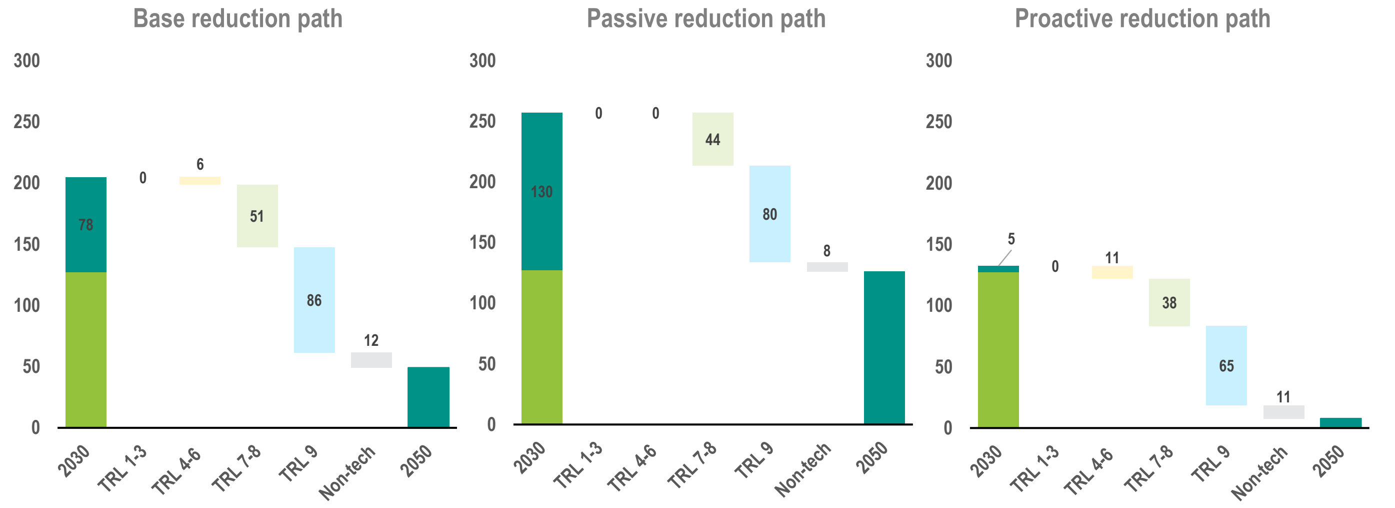
Source: CBS, ABN AMRO Group Economics

that companies in the sector cannot directly influence, such as limited grid capacity and staff availability. In the base case, we also assume that the decarbonisation options in TRL stages 4 to 6 are not going to make a meaningful contribution. In the passive path, we assume that companies will not be able to sufficiently join the transition, despite the fact that the low-carbon ambition level may be high. In the proactive scenario, much more GHG is ultimately reduced. Here, we assume that the electrification of production processes gains momentum. We also assume in this scenario that the low-carbon technologies in Stages 4 to 8 are ready for commercial use much earlier and can thus also start making a meaningful contribution.

Emission reduction potential 2030-2050

In order to stick to the climate-neutral target until 2050, every machine builder in the sector should invest more in low-carbon technologies in order to proactively further address sustainability. This cannot be started early enough. Our proactive scenario shows the path in GHG emissions at the time when actual companies in the sector have a high level of ambition. Here, we assume that the technologies in TRL 4 to 8 will also make a meaningful contribution to the emission reduction path between 2030 and 2050. The 2050 climate target is almost achieved in this case. In our passive scenario, this is not the case. The necessary ambition is lacking among companies in the sector and low-carbon investment remains hopelessly behind.

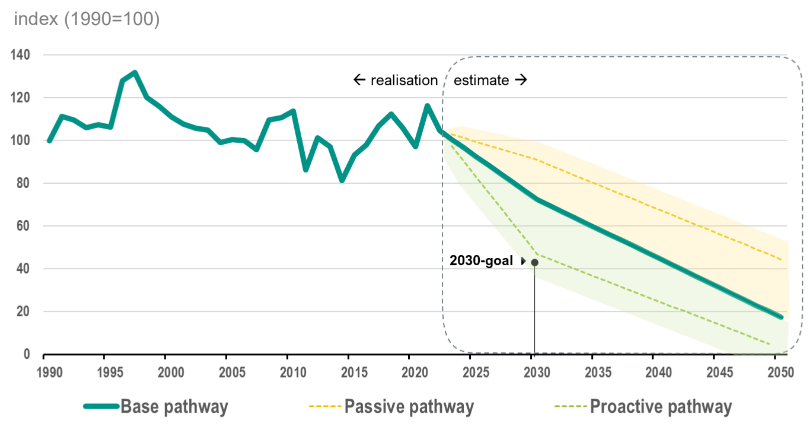
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

If we start from our baseline scenario in terms of emission reduction and available net-zero technologies in the machinery industry, our estimates show that the sector is also not going to meet the set target for 2050. This path is still independent of breakthrough technologies that might be introduced after 2030.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the machinery industry does not reach carbon neutrality until after 2050. This may be the case around 2055. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emission projection.

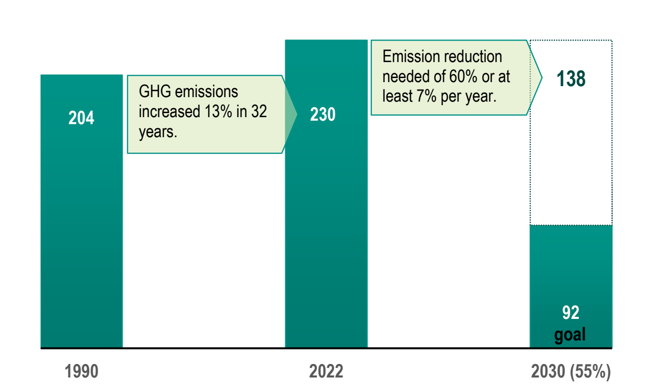
12. Transport goods industry

The industry's 2030 climate challenge

The variety of subsectors in the transport equipment industry is wide. Among other things, cars, trailers, semi-trailers, ships, aircraft, bicycles, mopeds and motorbikes are made in this part of the industry. The Netherlands has relatively many shipbuilding companies (especially recreational shipbuilding), accounting for 44% of the total number of companies in the transport equipment industry. This is followed by car body builders (such as for trucks) and producers of trailers and semi-trailers, with a combined share of 22%.

Sector greenhouse gas emissions and 2030 impact

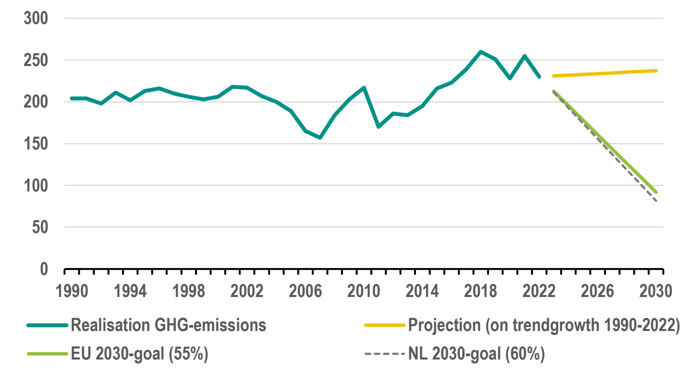
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

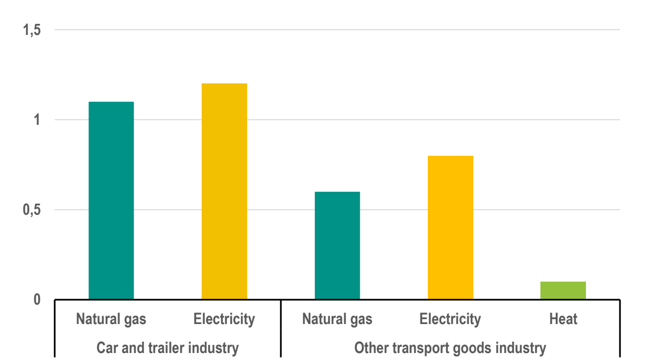
The transport equipment industry as a whole shows a increasing trend in GHG emissions. Indeed, over the period between 1990 and 2022, GHG emissions rose by 13%. This is in contrast to many other industry subsectors, where GHG emissions have actually decreased over the past 32 years. There is thus still a considerable emission reduction task ahead for the sector in the coming years. For instance, the sector still needs to reduce 60% of the 2022 emission level to reach the 2030 target. This means a greenhouse gas reduction of at least 7% per year until 2030.

Source of emissions

The most common production processes within the transport equipment industry consume a lot of energy, metals and plastics. Developing strategies in the transport equipment industry to reduce emissions therefore remains of great importance, especially achieving emission reductions on a larger scale.

Final energy use by subsectors 2022

PJ

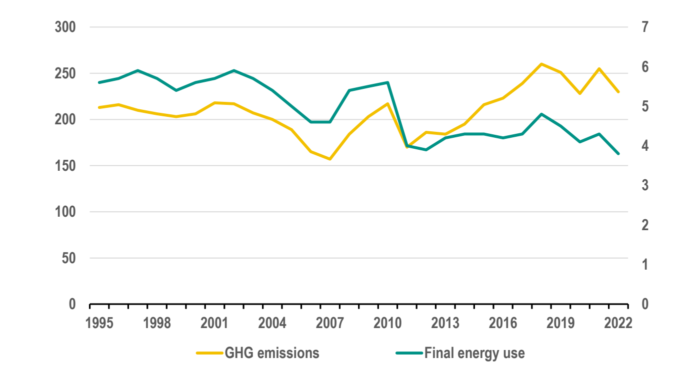


Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use

index (2015=100)

mln kg CO2-eq.



Source: CBS, ABN AMRO Group Economics

The transport equipment industry has two major subsectors: the car and trailer industry and other transport equipment (such as ships, bicycles, mopeds, etc.). The car and trailer industry consumes more energy than the other transport equipment industry, although the differences are small. In both subsectors, more electricity is consumed in production processes than natural gas. In the car and trailer industry, this electricity consumption has increased by 9% since 1995. This is the only exception. Indeed, consumption of the other energy carriers in both subsectors has declined solidly since 1995, by an average of about 40%. Production in the sector has a close relationship with GHG emissions, as does the trend in final energy consumption.

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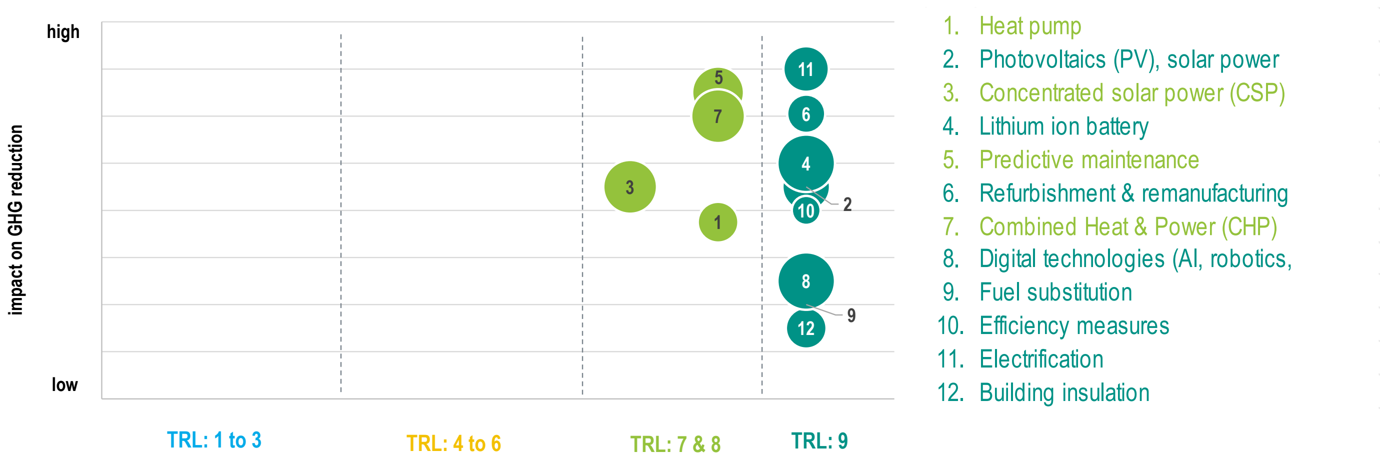
Reduction strategy for the sector with current and future available low-carbon technologies

Reducing greenhouse gases will require a lot of effort from companies in the coming years. Above all, it requires companies to use new low-carbon technologies and scale up further. Manufacturers of transport equipment can harness sustainable procurement and processing methods to avoid non-renewable raw materials and reduce material wastage on production floors. This fits under the heading of efficiency as well as reuse and sustainable procurement. Integrating renewable energy into existing power grids and then into production processes is also essential to make the production of transport equipment more low-carbon.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

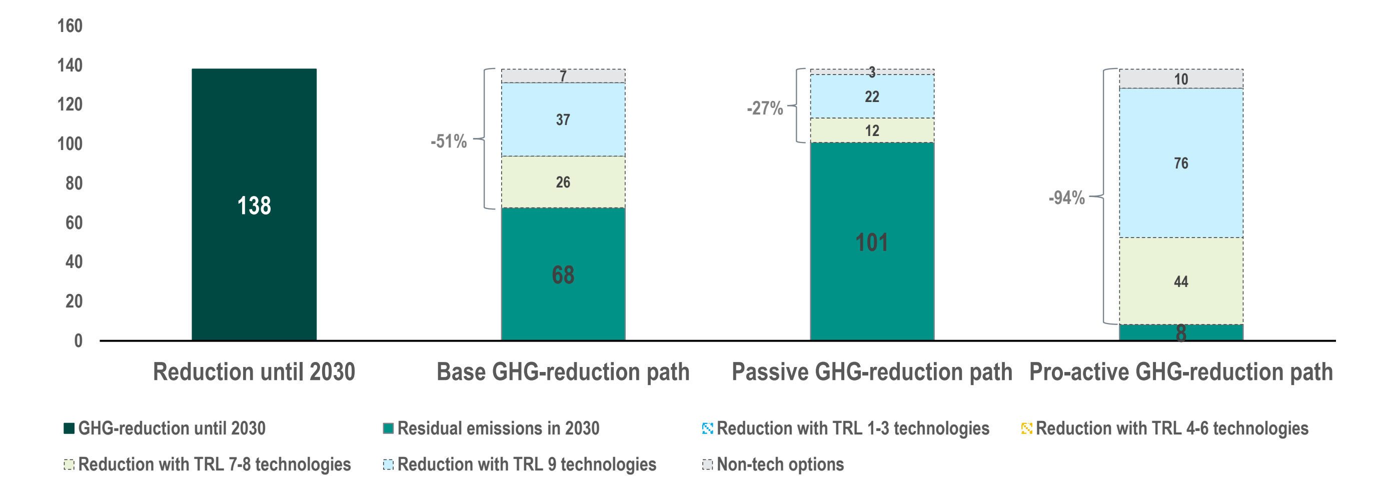
Although companies in the transport equipment industry are generally relatively efficient, there are still significant opportunities to reduce energy demand. Due to the complexity of different processes and technological variation, there is a wide range of potential options for energy efficiency. Energy management plans can also play a role in improving energy efficiency. The sector is rich in waste prevention and management measures. This is because the sector has traditionally always had a strong focus on lean production methods, quality controls and cost reduction.

Emission reduction potential up to 2030

Implementing low-carbon technologies in the production process - such as electrification, energy efficiency, digital technologies - can further reduce GHG emissions in the short term. In the longer term, this can be the basis of an effective environmental management system that continuously monitors environmental performance and key climate indicators. Our baseline scenario shows that the available sustainability measures of companies collectively in the sector are not sufficient. About 51% of the 138 million kg CO2-eq. is reduced by available low-carbon technologie4s until 2030 in this scenario. In the passive scenario, emissions decrease at a relatively low rate. On balance, only 27% will be reduced. In the proactive scenario, much more GHG is ultimately reduced than initially needed to meet the 2030 target. This assumes that there are relatively few obstacles to accelerating electrification.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents

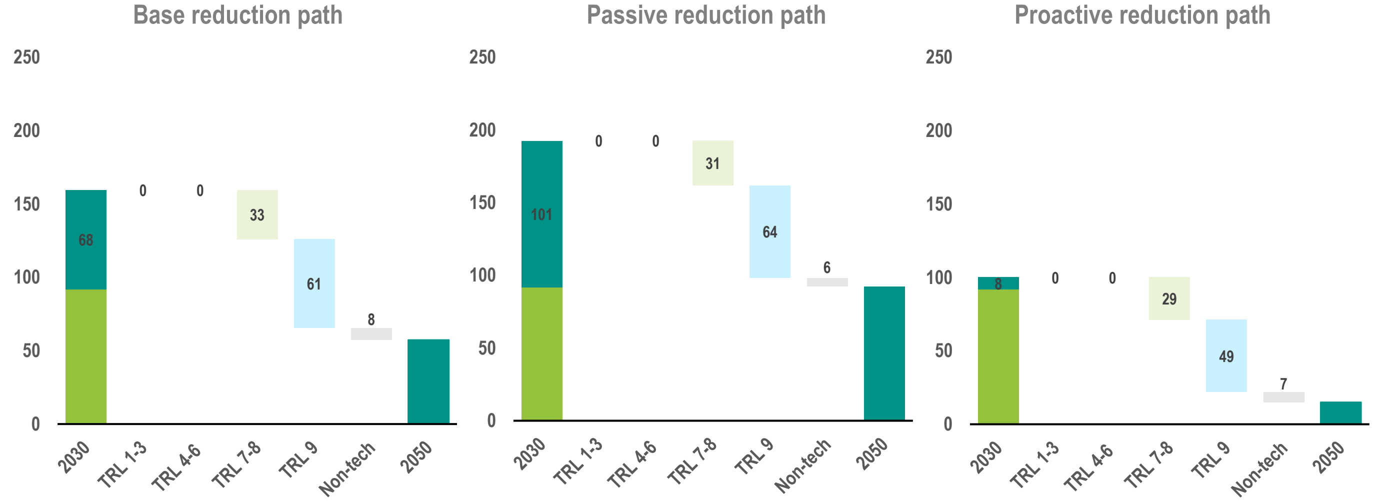


Source: CBS, ABN AMRO Group Economics

Emission reduction potential 2030-2050

To stick to the climate-neutral target until 2050, every producer of transport equipment should have a high level of ambition to reach the climate targets. Specifically, it means that companies should invest more in low-carbon technologies. Only in this way will companies stay on the necessary sustainability path. This cannot be started early enough, as the emissions reduction task for the sector is substantial. Our proactive scenario shows the path in GHG emissions at the time when actual companies invest and become much more sustainable. Here, we assume that the technologies in TRL 7 and 8 will also make a meaningful contribution to the emission reduction path between 2030 and 2050. The 2050 climate target is almost reached in this scenario. In our passive scenario, this is far from the case. The necessary ambition is lacking among transport equipment manufacturers and low-carbon investment is hopelessly lagging behind.

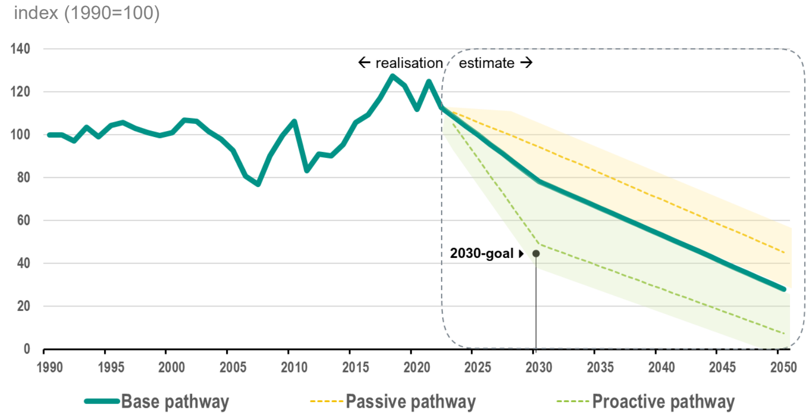
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

In our baseline scenario, the sector does not reach the 2050 target. Specifically, it means that breakthrough technologies and further development of existing low-carbon technologies will be indispensable in this sector. To still keep traction in the emission reduction path, companies should prioritise the energy-intensive production processes and those processes with the highest environmental impact. A strong focus on such processes can have a greater impact on climate indicators.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the transport equipment industry reaches carbon neutrality after 2050. This could be the case by around 2054. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

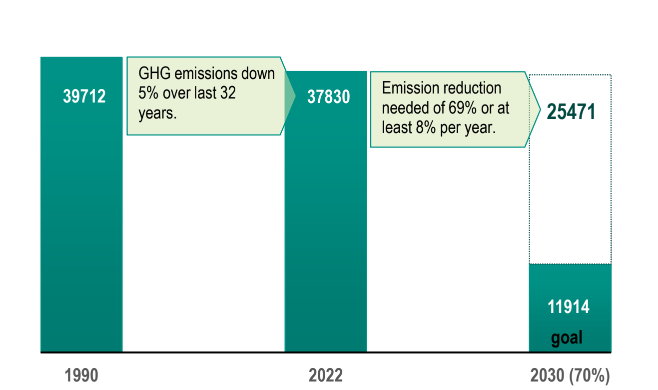
13. Energy supply

The industry's 2030 climate challenge

Climate policy aims to reduce fossil fuel combustion, thereby reducing GHG emissions and controlling temperature rise. The high fossil dependence of our energy system makes it clear that a rapid transition is necessary to limit the global temperature rise to 1.5°C. Decarbonising the energy sector is important because many other sectors (buildings, industry, transport) depend on it.

Sector greenhouse gas emissions and 2030 impact

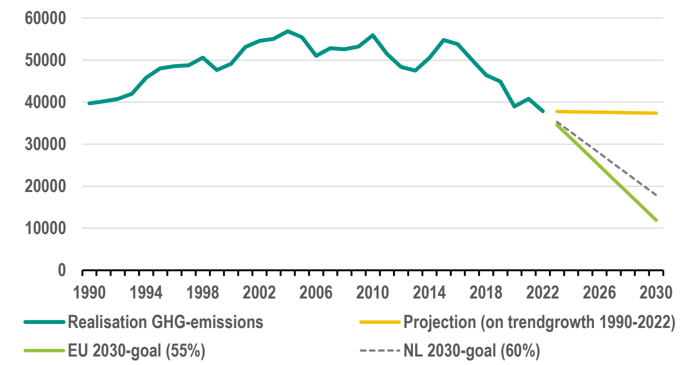
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

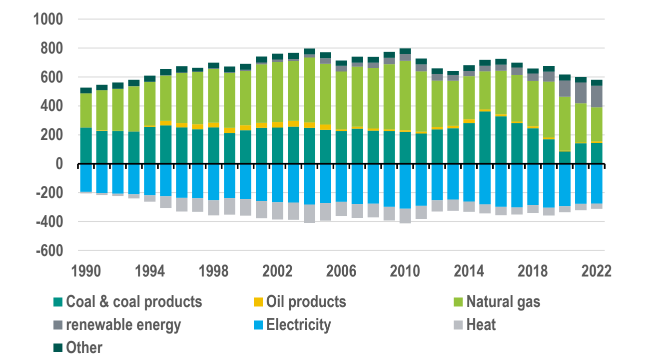
The level of GHG emissions in 2022 in the Netherlands is not far below 1990 levels. It is only 5% lower. Specifically, this means that energy companies still need to make a lot of efforts to reduce GHG emissions until 2030. To reach the 2030 target - 70% of 1990 levels - the sector needs to reduce at least 8% in GHG emissions annually. This makes the 2030 target challenging, but not unachievable with sufficient investment and effort.

Source of emissions

The electricity sector is seen as a key link in the energy transition, as it is easier to decarbonise the electricity mix than to phase out all fossil fuels in other sectors. The transformation of the sector is now in full swing, with low-carbon energy technologies - such as solar and wind power - gaining a foothold, although the pace is slow. The power sector is receiving the necessary support from the government with subsidy schemes, infrastructure investment and support in the formation of low-carbon gas-fired power plants (i.e. including carbon capture and storage, CCS). Many companies are also covered by the EU ETS system. The Netherlands is expected to achieve a renewable energy share of around 30% by 2030 (range 27%-33%) based on established policy (KEV 2022).

Total energy use energy companies per year

PJ

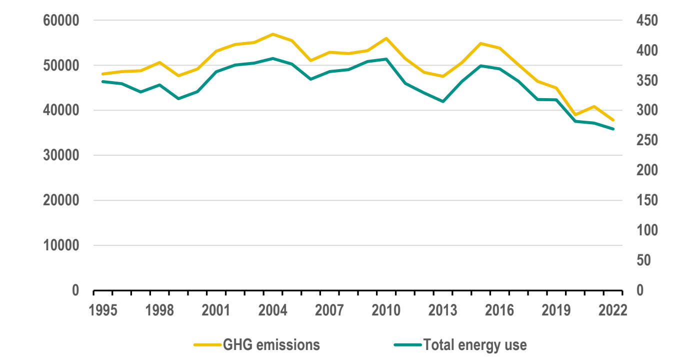


Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use

mln kg CO2-eq

PJ



Source: CBS, ABN AMRO Group Economics

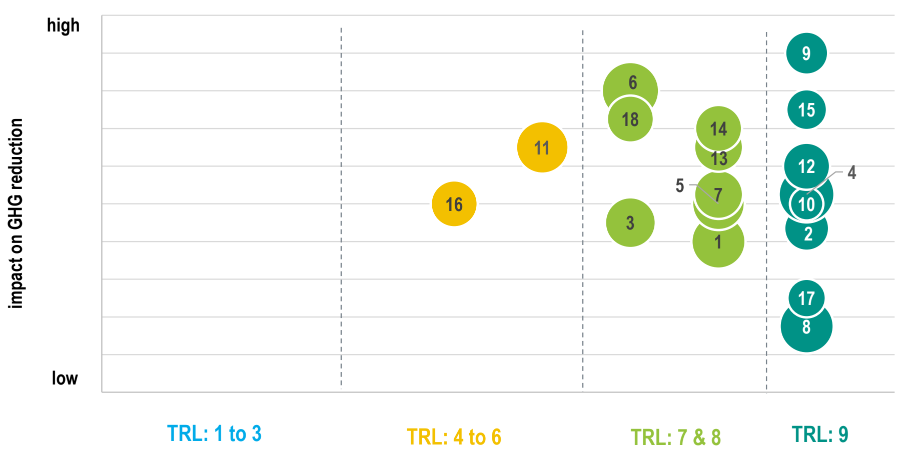
The largest share of total energy consumption by power companies is natural gas, followed by coal and renewables. These generate electricity and heat (below the x-axis). Coal has shown the biggest decline in recent years. From 2016 to 2018, coal consumption decreased due to closure of old coal-fired power plants. This was followed by a period of relatively low natural gas prices, making it difficult for coal plants to compete. Energy is also lost in the process through conversion, use in the power sector and distribution. GHG emissions parallel energy consumption. Petroleum continues to play a dominant role as a fuel in the transport sector and as a raw material for products in the chemical industry for the time being.

Reduction strategy for the sector with current and future available low-carbon technologies

The ultimate goal is to achieve an energy supply based on renewable energy. Then a reliable energy grid with sufficient capacity is an important prerequisite. This is at the basis of a successful energy transition. The grid is rapidly evolving due to both demand and supply factors. Rapidly growing demand due to the electrification of industry and data centres make rapid grid reinforcement a priority. But also the construction of private and public initiatives generating renewable energy on a larger scale are putting great pressure on grid capacity.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



1. Permanent magnets
2. Photovoltaics (PV), solar power
3. Concentrated solar power (CSP)
4. Wind energy using aerodynamic force
5. Technologies to produce synthetic fuels
6. Carbon storage/sequestration
7. Electrolysis & fuel cells
8. Digital technologies (AI, monitoring)
9. Power-to-gas-to-power (P2G2P)
10. Efficiency measures (process redesign)
11. Battery operated storage (seasonal)
12. Fuel substitution (hydrogen, biogas)
13. Predictive maintenance
14. Geo- and aqua-thermal heat sources
15. Electrification
16. Super Critical Water gasification, SCW
17. Building insulation
18. Direct Air Capture

Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

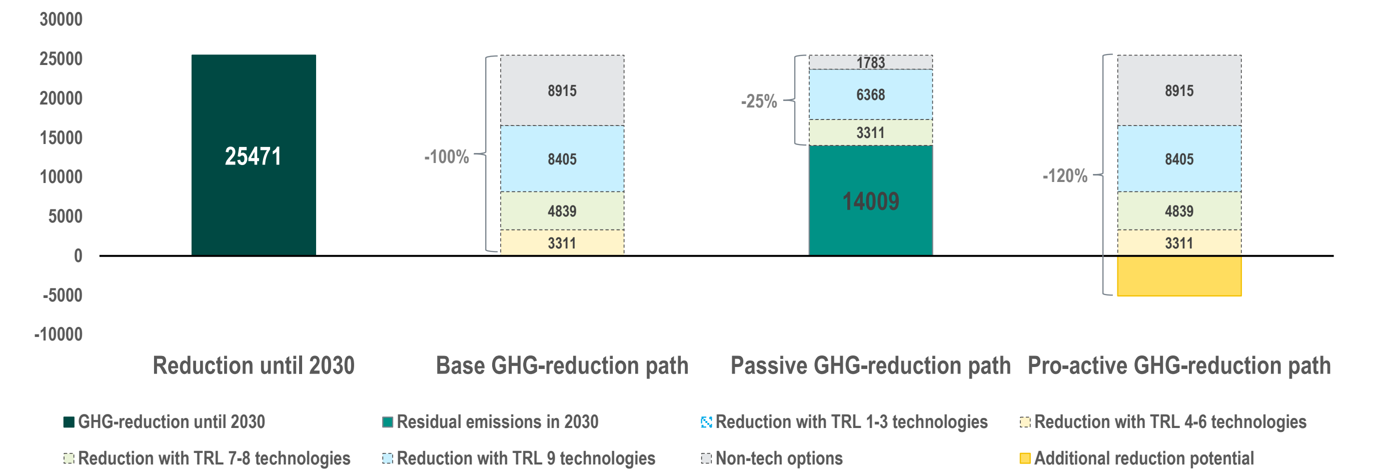
According to the IPCC, scaling up carbon-free energy technologies is going to help decarbonise the power sector. These include solar, wind, hydropower, biomass, nuclear and geothermal technologies. The growth of solar and wind power in particular has already surged. Besides building wind and solar capacity, improving grid infrastructure and efficiency is needed. Underlying a rapid transition to the deployment of more renewable energy is strong political commitment, supportive laws and regulations and favourable financial conditions for renewable energy. The government is committed to investing in hydrogen (and hydrogen production at sea), battery innovations and mandating batteries at larger solar farms. It encourages this, for instance, through subsidy schemes (SDE++) and projects (IPCEI).

Emission reduction potential up to 2030

For the electricity sector, the pace towards carbon neutral is relatively high. This is mainly because investments in solar and wind power for electricity generation have increased sharply in recent years. Moreover, this trend is expected to continue in the coming years, with investments in wind-to-sea in particular increasing strongly. The goal is to have an almost 100% carbon-neutral electricity sector by 2035 (draft Integral National Energy and Climate Plan, June 2022). This means that by 2030, GHG emissions will be about 70% below 1990 levels (instead of 55%). However, the challenge is that not only the construction of solar and wind farms is time-consuming, but also the necessary infrastructure expansions. This could potentially cause delays in the path towards 2030, with the possibility of some acceleration only after 2030. Besides stronger growth in energy from solar and wind power, much progress can be made in the short term by replacing fossil fuels for electricity generation with low-carbon fuels.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

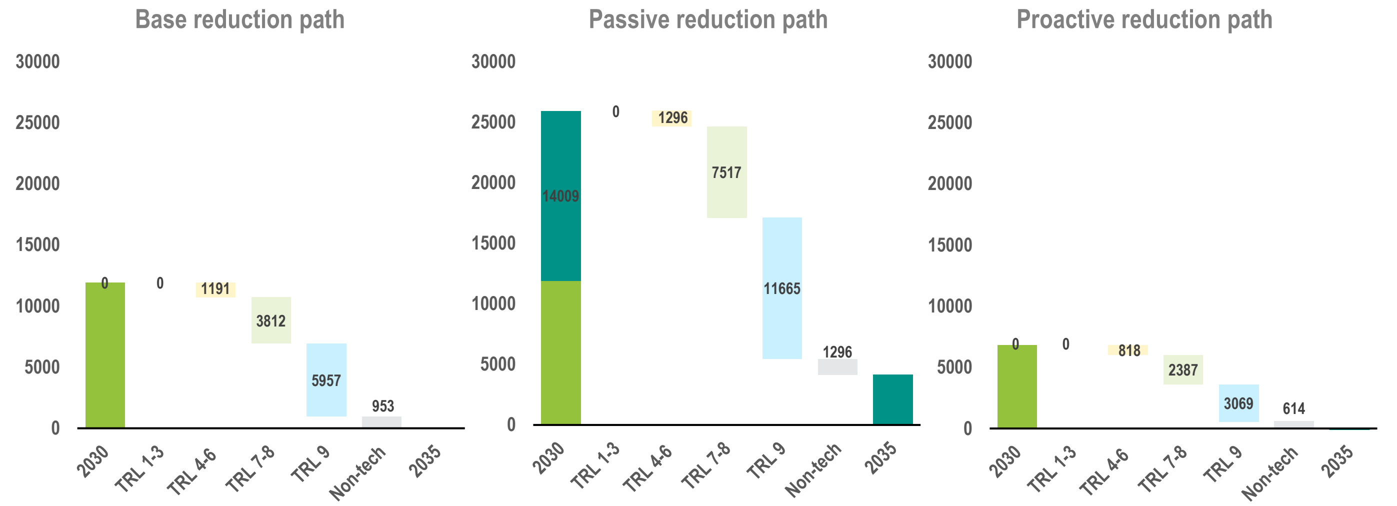
Carbon storage (Carbon Capture & Storage, CCS) can also play a role here, but again, scaling up is relatively slow. In any case, it is important that there is sufficient grid capacity. In our baseline scenario up to 2030, we assume that further sustainability gains momentum, helped by numerous subsidies and government policies. This achieves the 2030 target. In the base case, however, we assume that decarbonisation options in TRL stages 4 to 8 do not yet deliver a significant difference. In the proactive scenario, this is more the case. Here, we assume more government support and decarbonisation ambition. In the passive path, we assume that the sector is unable to sufficiently catch up with the transition. This is partly due to insufficient investments in infrastructure and other obstacles, such as persistent lack of manpower and lack of clarity in government policy.

Emission reduction potential 2030-2035

In the future energy system, electricity will be the main energy carrier, with variable sources of solar and wind power dominating. To accommodate the variability of these sources, the sector has several options (draft Integral National Plan Energy & Climate, June 2022): 1. flexible demand-side management, 2. controllable power (on-demand power to balance energy demand and supply), 3. electricity exchange with other countries (Germany, Belgium, UK, Denmark, Norway), 4. conversion (Power-2-Gas, Power-2-Heat, Power-2-Fuels & Feedstock) and 5. energy storage (battery technology).

Our proactive scenario assumes that the climate-neutral target is achieved by 2035. Here, all technologies in TRL 4 to 8 are going to make a strong contribution to the emission reduction path. In our passive scenario, the 2035 target is not reached. The preconditions (such as sufficient infrastructure investment) are not met. The necessary ambition is lower among energy companies in the sector, partly due to persistent obstacles and uncertainty in government policy.

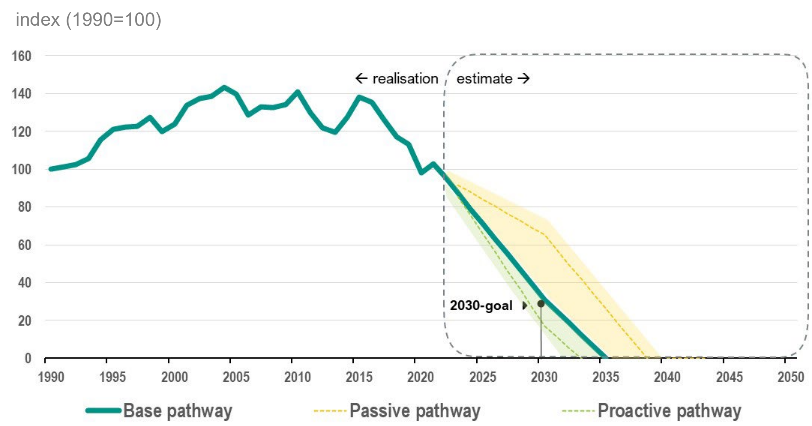
Emission reduction 2030-2035 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

If we start from our baseline scenario, our calculations show that the power sector will fall just short of the 2035 target. The guidance, ambition and contribution of decarbonisation options are ample. However, this path is still separate from the breakthrough technologies that may be introduced after 2030.

Emission reduction pathways towards 2035



Source: CBS, ABN AMRO Group Economics

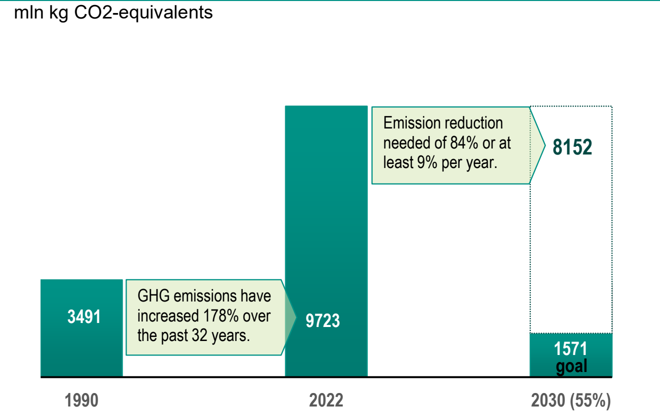
With today's net-zero knowledge, the power sector will achieve carbon neutrality between 2035 and 2040. But again, nothing is cast in stone. Innovative net-zero technologies may well be successfully introduced or new challenges overcome in the coming years. This could strongly influence our emissions projection.

14. Water companies & waste management

The industry's 2030 climate challenge

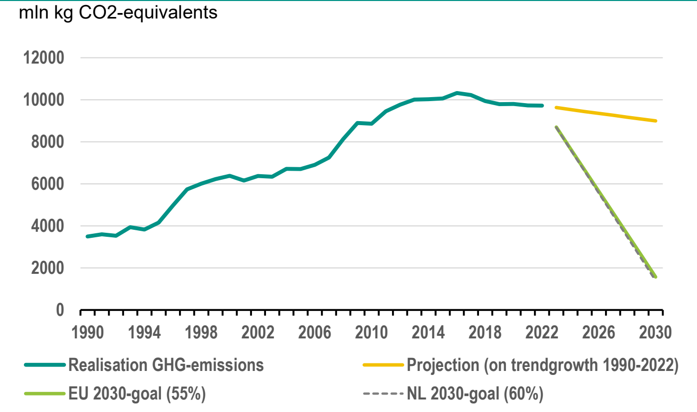
Water companies have a dual task in the transition to low-carbon processes. On the one hand, it is necessary for the sector to reduce GHG emissions, but it must also continue to ensure clean drinking water. Because one of the consequences of climate change could be an increase in water-borne diseases and this must be effectively prevented. The challenges for waste management companies are also set to increase in the coming years. After all, consumption levels are higher than ever and only increasing. The waste mountain continues to grow. This increases the urgency for better waste management, more circularity and also having a decarbonisation strategy to manage the adverse effects of growth in waste.

Sector greenhouse gas emissions and 2030 impact



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector



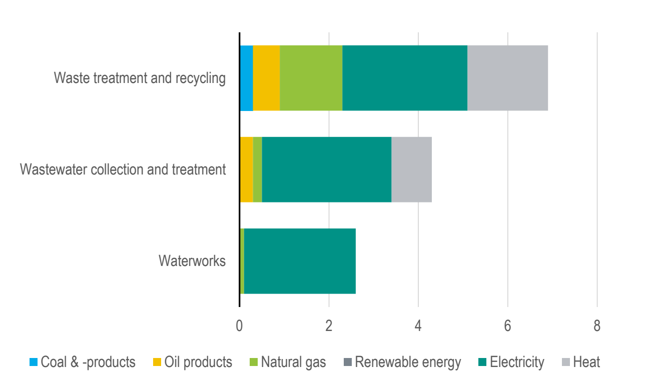
Source: CBS, ABN AMRO Group Economics

The water utilities & waste management sector in the Netherlands has a high GHG emission intensity. Since 1990, the sector has done little to reduce GHG emissions. Indeed, the level of GHG emissions is at a much higher level in 2022 than in 1990. One reason for the increased GHG emissions could possibly be due to the outdated plants, the relatively high use of fossil fuels in the production and transportation of water, the additional energy required today to purify the drinking water used and the growth of the amount of waste. An unprecedented 178% growth in 32 years. So companies in the sector still have a lot of efforts to make to reduce GHG emissions up to 2030. To reach this 2030 target, the sector needs to reduce at least 9% in emissions annually. This makes the 2030 target a big challenge for the sector.

Source of emissions

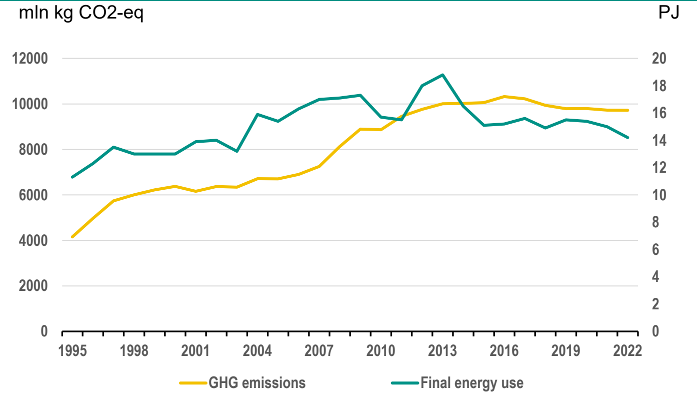
Energy consumption in the water and waste sector relies heavily on fossil sources. As a result, GHG emissions continue to increase. In particular, the subsectors consume a lot of electricity. Their total consumption has increased by 42% since 1995. Water utilities in particular consume a lot of electricity in their processes. The energy mix in wastewater collection and treatment is more diverse. The waste treatment and recycling subsector also consumes a lot of natural gas. However, this consumption has decreased by about 30% over the past decade. The processes in waste treatment and water collection are very energy-intensive.

Final energy use by subsector



Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use



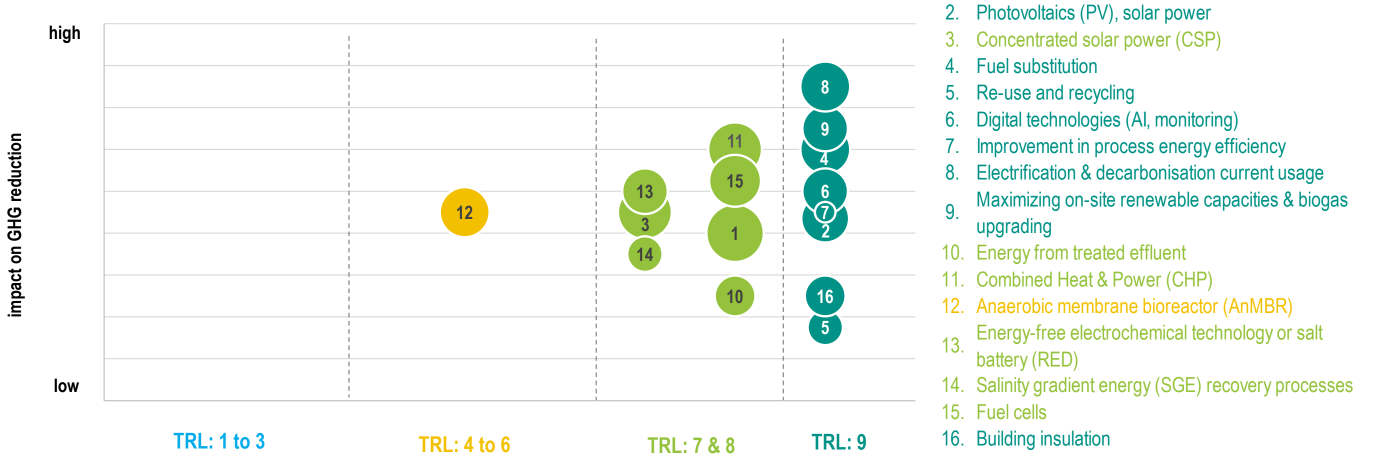
Source: CBS, ABN AMRO Group Economics

Wastewater volumes are also expected to increase more sharply in the coming years. Worldwide, almost 400 billion m3 of wastewater is produced annually and this is expected to increase by 25 and 50% in 2030 and 2050, respectively. Wastewater treatment processes in particular are very GHG-intensive.

Reduction strategy for the sector with current and future available low-carbon technologies
In recent years, some (waste) water companies have been able to curb or reduce the growth of their energy consumption and GHG emissions by improving the energy efficiency of their processes. Electrification of processes and deployment of renewable energy production have also contributed to the tilt in the trend of GHG emissions.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

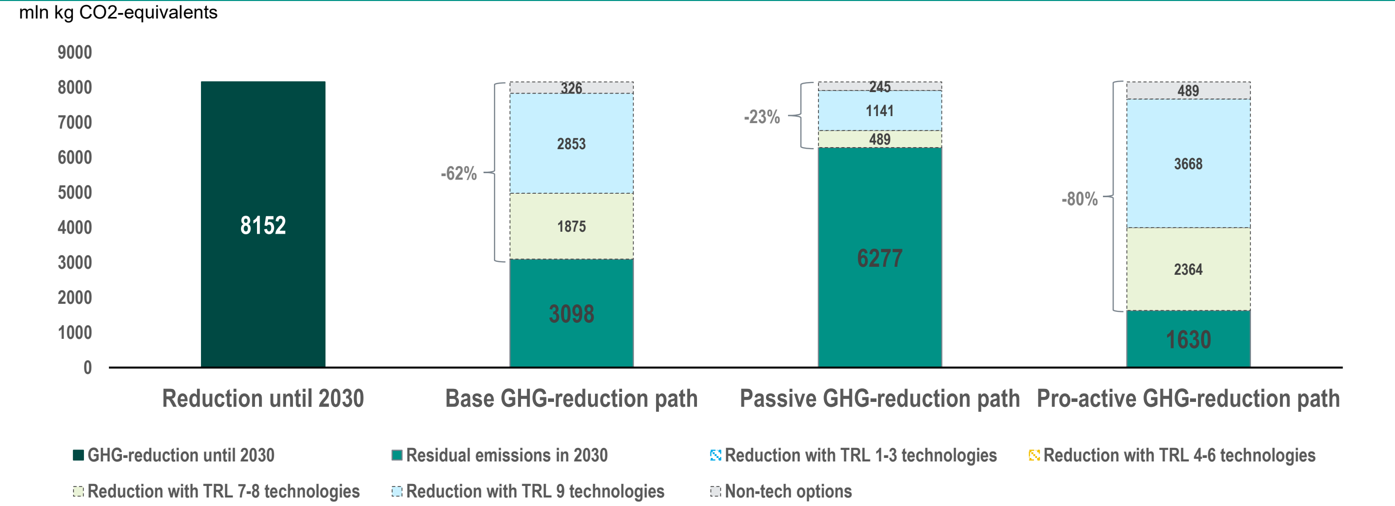
It is clear from the matrix that many low-carbon technologies are in the commercially deployable phase (TRL 9) and a good number are soon to follow (TRL 7 and 8). There are still relatively few new technologies in the pilot and concept phase (TRL 1 to 6), to our knowledge. Importantly, innovation is not standing still here, because it is precisely low-carbon innovations that remain essential for the path towards making the water and waste sector sustainable for the emission reduction path between 2030 and 2050. There remains a need to improve the energy efficiency of processes while reducing energy consumption. Apart from efficiency gains from new low-carbon technical capabilities, it also remains important to understand the economic feasibility of the technology. This is going to help determine the success of the decarbonisation strategy.

Emission reduction potential up to 2030
The path to a low-carbon water sector requires a lot of investment. Financing the low-carbon pathway will remain a challenge for the water and waste sector, partly because it involves public utilities. To still get financing off the ground means concretely sufficient financial support from the government and/or an increase in water and waste tariffs in order to keep sustainability economically viable that way. Price increases are always sensitive, but it can help end users in raising awareness of the true value of our public services. However, it is a powerful tool. Through pricing, consumer behaviour can be highly influenced.

In our baseline scenario up to 2030, we assume that further sustainability is relatively slow. After all, the sector is only at the beginning of the sustainability and emission reduction path. Electrification remains the most impactful way to decarbonise in the coming years. In the base case, we also assume that the decarbonisation options in TRL stages 4 to 6 will not make a meaningful contribution.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



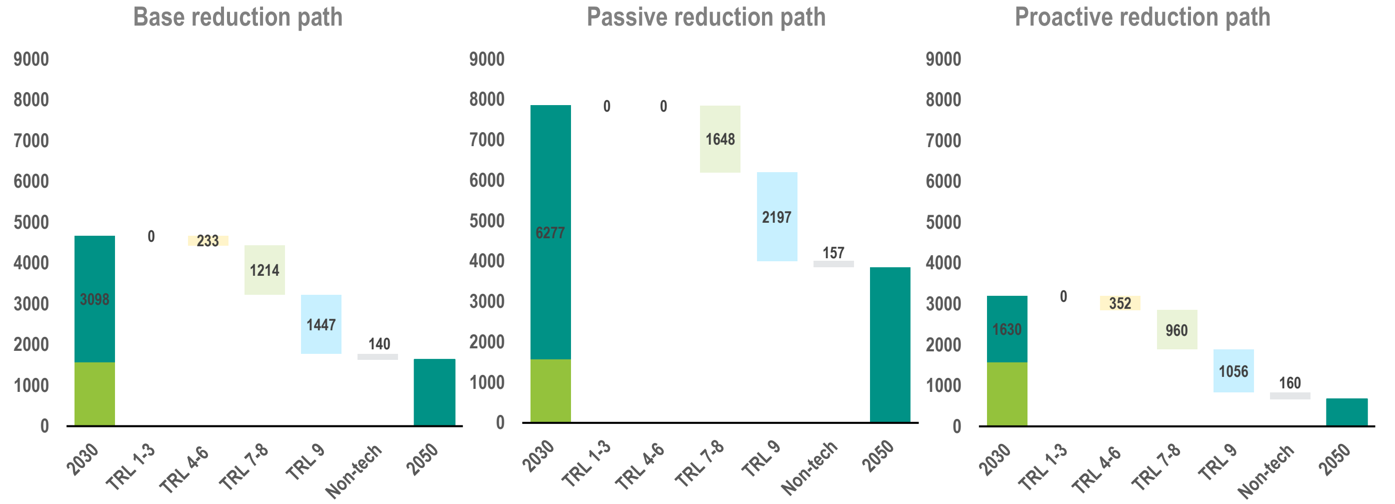
Source: CBS, ABN AMRO Group Economics

In the passive path, we do not think companies are able to sufficiently join the transition. This is partly due to too little financial support from the government and willingness among companies in the water and waste sector to make sustainability further and faster. In the proactive scenario, that support and ambition is there and more GHG is ultimately reduced. Here, we assume that electrification of production processes will gain momentum. We also assume in this scenario that the low-carbon technologies in phases 4 to 8 are ready for commercial use much earlier and can thus also start making a meaningful contribution.

Emission reduction potential 2030-2050

Towards the carbon-neutral goal in 2050, regulations are likely to become increasingly stringent. Companies in the water and waste sector will thus be more-and-more encouraged to have a low-carbon strategy. To stick to the climate-neutral target until 2050, every company in the water and waste sector would have to invest much more in low-carbon technologies. As the decarbonisation pathway for the sector is challenging, it cannot be started early enough. Our proactive scenario shows the path in GHG emissions if companies in the sector actually maintain a high level of ambition beyond 2030. Here, we assume that the technologies in TRL 4 to 8 will also make a meaningful contribution to the emission reduction path between 2030 and 2050. However, the 2050 climate target is not achieved in this case. In our passive scenario, the 2050 target is not reached either. In this scenario, companies in the sector lack the necessary ambition and financial support is limited. As a result, low-carbon investments lag hopelessly behind.

Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)

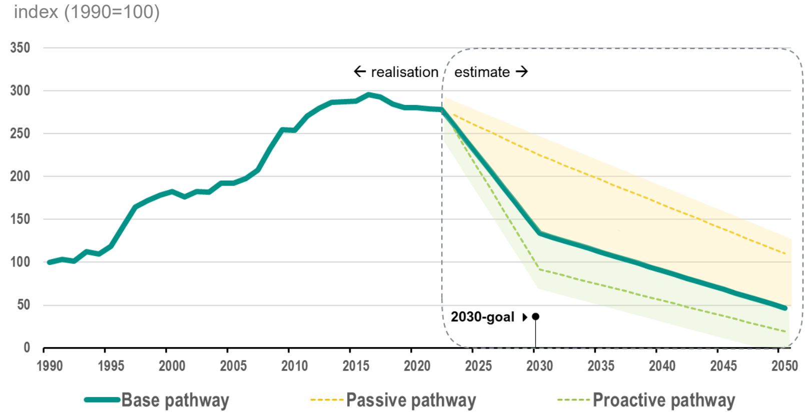


Source: CBS, ABN AMRO Group Economics

If we start from our baseline scenario in terms of emission reduction and available net-zero technologies in the water and waste sector, our calculations show that the sector is not going to meet the set target for 2050 either. For that, existing technologies fall short. This path is even apart from breakthrough technologies that might be introduced after 2030.

Emission reduction pathways towards 2050

index (1990=100)



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the water and waste sector reaches carbon neutrality after 2050. This could be the case by around 2058. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emission projection.

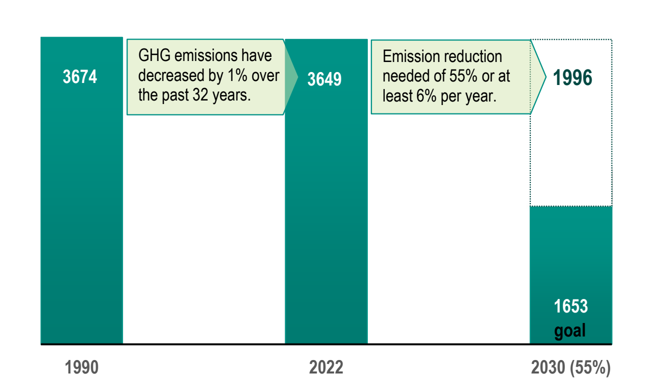
15. Construction

The industry's 2030 climate challenge

The construction sector in the Netherlands is very fragmented and the entire construction process has many different steps. A multitude of parties are involved in that whole construction cycle. This makes reducing greenhouse gases in this sector a lot more complex. Despite this complexity, in recent years the construction sector has increasingly focused on sustainable construction throughout the construction cycle, especially in the areas of energy consumption, circularity, resource efficiency and waste management. However, this has not led directly to an acceleration in GHG reductions. Compared to 1990 levels, GHG emissions decreased by only 1%. It was only from the year 2000 onwards that GHG emissions went into a downward trend. A positive tilt, in which only the pace in emission reduction disappoints. From 2015 onwards, GHG emissions are again increasing slightly.

Sector greenhouse gas emissions and 2030 impact

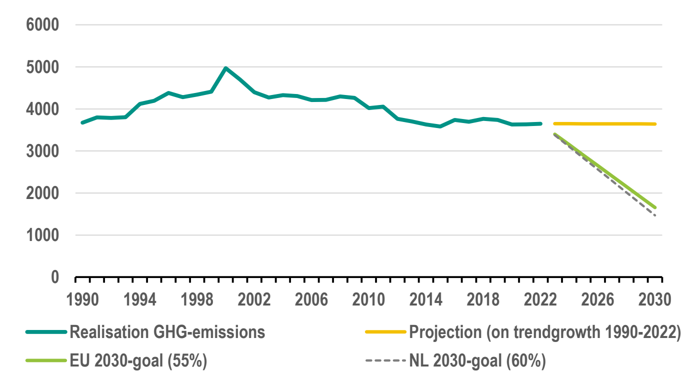
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

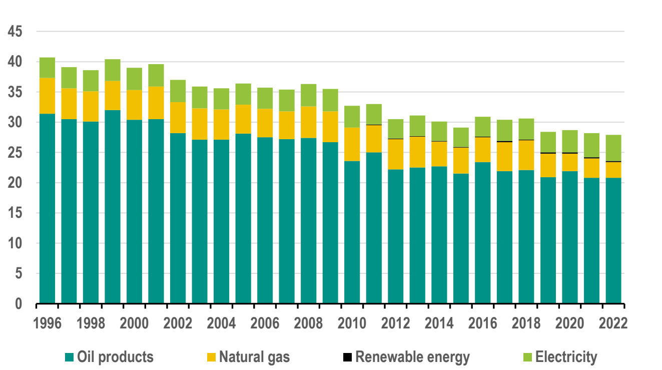
To achieve the stated 2030 target - that is 55% of the 1990 GHG emission level - the sector still has a tough task ahead of it, especially given the sector's history in emission reduction. Specifically, it means a 55% GHG emission reduction from the 2022 GHG emission level to 2030, or at least 6% per year.

Source of emissions

Many fossil fuels are still consumed in the construction sector. Oil and gas consumption during the on-site construction process, as well as electricity consumption (the non-renewable variety) all contribute to GHG emissions from the construction sector. Petroleum products (especially diesel) are the main energy carrier. Its consumption has decreased by more than 30% since 1995. However, gas consumption decreased even faster by 45% over the period 1995-2022. Electricity consumption, however, has seen a marked growth of 30% over the same period.

Final energy use

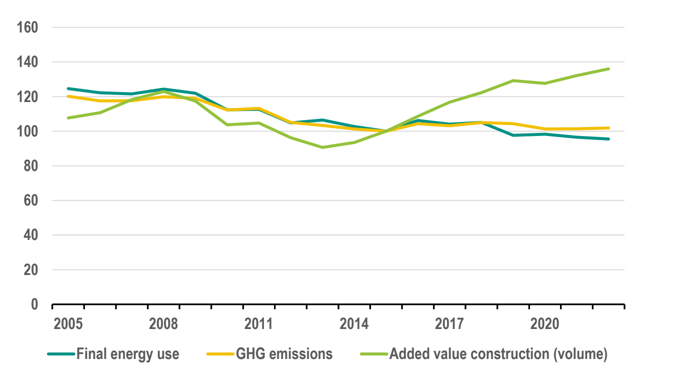
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend GHG-emissions, energy use and output

index (2015=100)



Source: CBS, ABN AMRO Group Economics

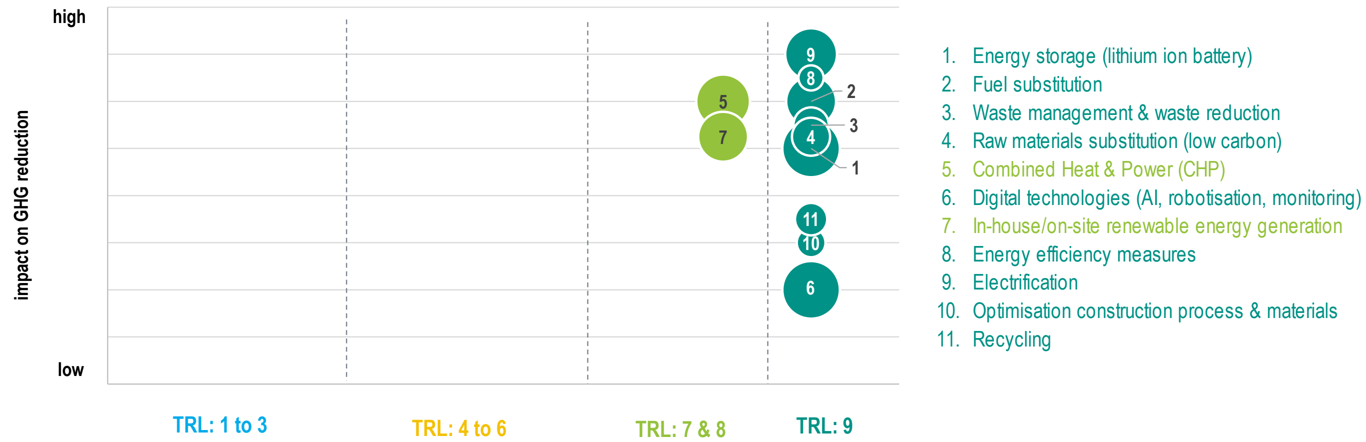
In the construction process, there are several activities that affect GHG emissions, such as use of machinery, equipment (cranes, excavators, etc.), material use (primary or secondary), construction activity and office space on site, and transport movements. GHG emissions are closely related to the trend in final energy consumption. The contrarian trend in value added (in terms of volume) compared to energy consumption from 2016 shows that efficiency has increased in the construction sector. However, this has not led to greenhouse gas reductions at the same rate.

Reduction strategy for the sector with current and future available low-carbon technologies

In a construction project, two streams of CO2 emissions can be distinguished. The construction has to deal with *direct* emissions (this is the operational CO2 from the construction activity) and *indirect* emissions, or so-called 'embodied' CO2. The latter are the carbon emissions caused by the (raw) materials. The construction sector - compared to other sectors in the Dutch economy - has relatively few low-carbon technologies at its disposal. Therefore, to further reduce carbon emissions and energy consumption and achieve carbon-neutral construction, low-carbon innovation in products, services and construction processes remains crucial. Moreover, the sector has a relatively long value chain. Thus a more holistic approach to GHG emission reduction is a more effective approach. Cooperation and coordination with partners in the chain then becomes much more relevant. Providing enough government support - e.g. through subsidies or transparent regulation - to all parties in the value chain is going to help determine the achievement of climate targets. In addition, the initial building design is decisive in the final amount of GHG emissions during the lifetime of the new building. This is because the design lays down many decisions that have a lot of impact on GHG emissions.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

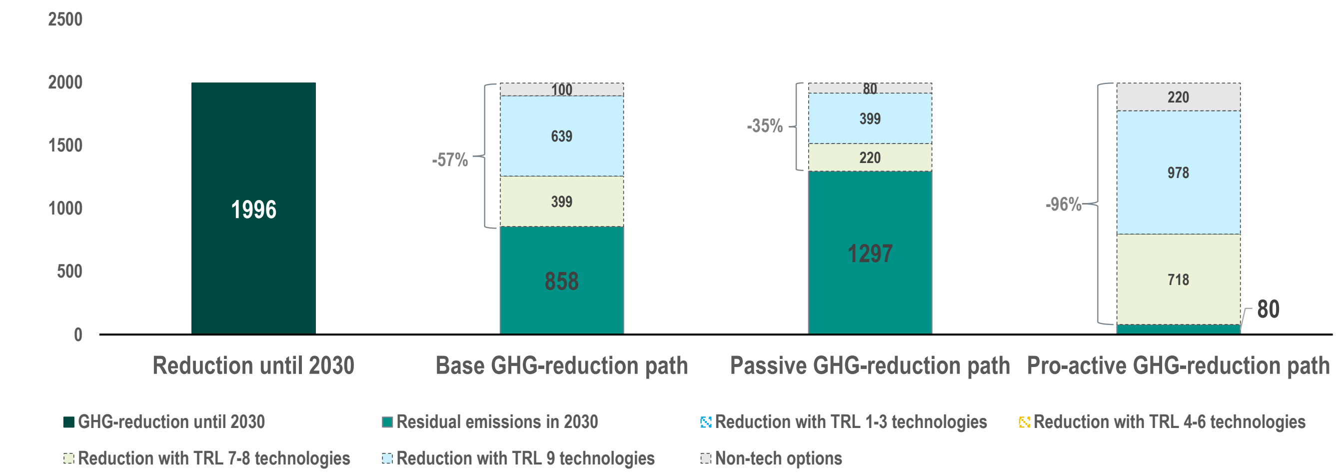
Even more impact on GHG emissions reduction can be achieved through new technology and/or materials or by switching to renewable energy, green hydrogen and biofuels - or a combination thereof. Natural products, such as wood, have also benefited from low-carbon technologies and more efficient equipment in their production processes, such as carbon-free mills and energy-efficient kilns. Improving energy efficiency and optimising the use of construction machinery and equipment can reduce direct carbon emissions in construction. This can be done, for example, by electrifying commonly used machinery and equipment that uses diesel (HVO diesel made from waste vegetable oils and residual waste). Decarbonisation of raw materials can be achieved by not opting for primary materials, but rather, for example, recycling/circularity/effective waste management and/or substitutes such as biomaterials that even store CO2 (wood).

Emission reduction potential up to 2030

Demand for new housing and infrastructure works will remain high in the coming years. Regulatory pressures will also push further abatement progress. The construction sector therefore faces multiple challenges.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



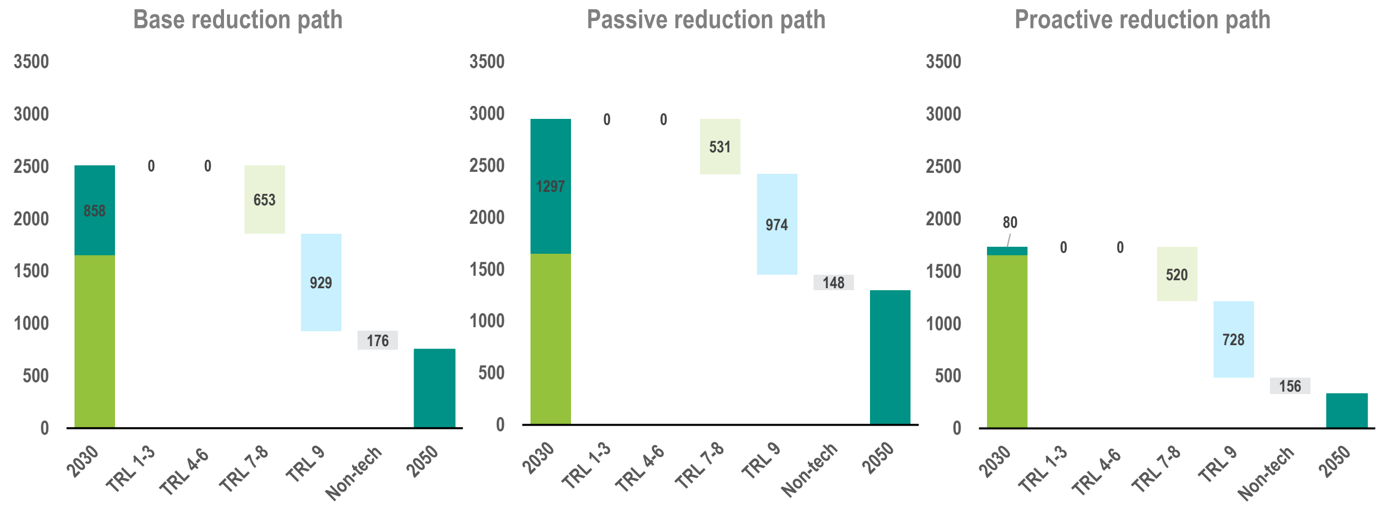
Source: CBS, ABN AMRO Group Economics

Growing public interest in climate change and tighter regulations are going to increasingly impact the way construction companies work. As a result, innovative and more economically viable technologies are important for the construction industry to make construction processes more future-proof. However, in our baseline scenario up to 2030, we assume that further sustainability is relatively slow. Electrification helps to decarbonise, provided the electricity used is green and energy efficiency increases. But in a majority of building projects, this is relatively difficult to achieve. In the passive path, we assume that companies are unable to sufficiently engage in the transition. In this case, commitment is too low and the government offers little support. In the proactive scenario, much more GHG is ultimately reduced. Here, we assume that low-carbon technologies in TRL phases 7 and 8 are ready for commercial use much earlier.

Emission reduction potential 2030-2050

None of the decarbonisation techniques mentioned is a panacea. Because the construction sector is highly fragmented, deals with many parties in the value chain and consumes a wide range of materials, a combination of low-carbon techniques is always necessary for the path beyond 2030. According to the IEA, achieving net-zero emissions by 2050 is possible for the sector, but this requires encouraging, transparent and ambitious public policies to give low-carbon initiatives an opportunity and impetus. Here, the EU Taxonomy/Corporate Sustainability Reporting Directive (CSRD) can help improve transparency and trigger an acceleration of GHG reductions. Indeed, the EU Taxonomy prescribes how to build sustainably for various construction activities. It requires large companies to report on sustainability in their annual reports. To do so, they need sustainability information from parties in the construction chain. Often, these (SME) companies are not yet CSRD-compliant, but are directed by large companies to reduce their GHG emissions.

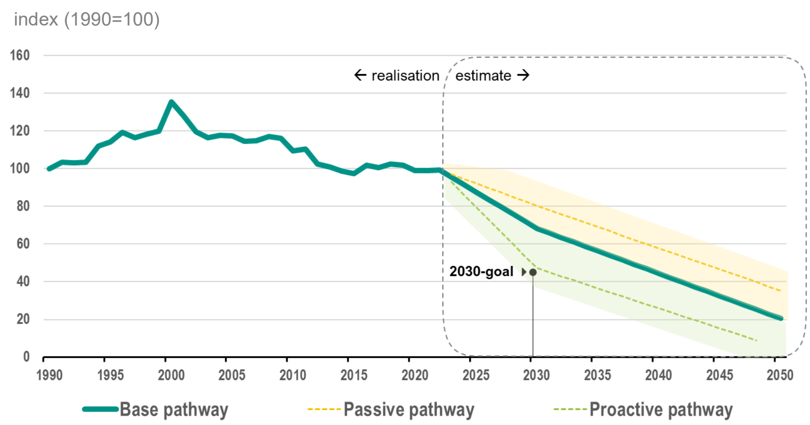
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

In the base path of GHG emission reductions between 2030 and 2050, the 2050 target is not achieved. For that, the available sustainability measures fall short. In both proactive path and passive path, the target is also not achieved. For that, existing low-carbon technologies are not sufficient to achieve carbon neutrality in 2050.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the construction sector will achieve carbon neutrality after 2050. This could be the case by around 2055. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

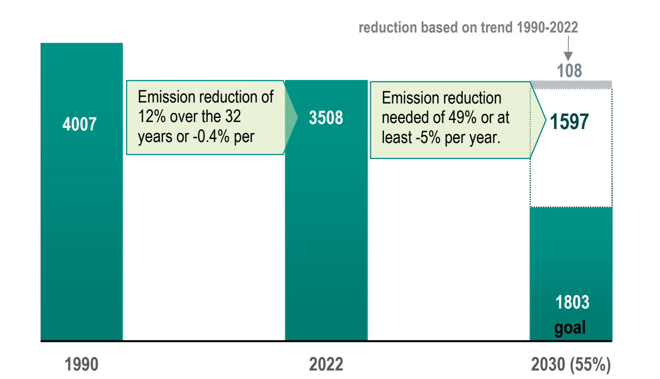
16. Retail & wholesale trade

The industry's 2030 climate challenge

The retail and wholesale sector consists of a multitude of (often small) companies, which contribute marginally to the total with scope 1 emissions of the economy but significantly more with scope 3 emissions. Still, the sector has much to gain from actively reducing its carbon footprint. Indeed, climate change brings systemic risk to both retailers and wholesale companies. For instance, acute physical risk factors - such as droughts, floods, forest fires or environmental disasters - can impact business activities. These extreme climate and environmental events can cause the loss of shop assets (not for online retail), severely disrupt (global) supply chains and distribution channels, and increase commodity prices.

Sector greenhouse gas emissions and 2030 impact

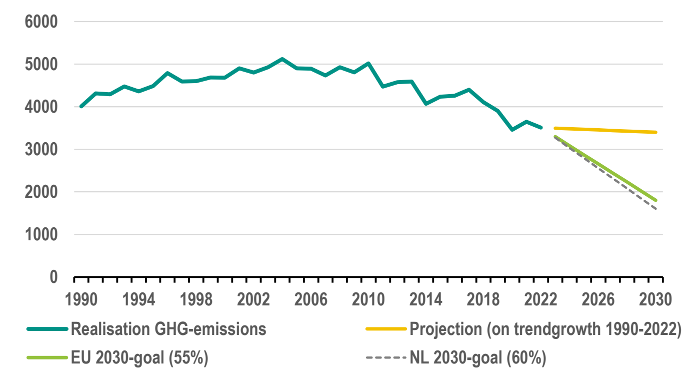
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

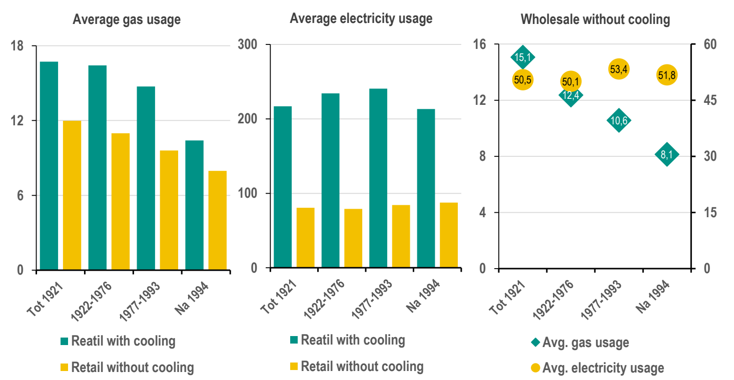
Retail and wholesale trade have only marginally reduced direct GHG emissions over the past 30 years. Until 2020, GHG emissions were still above 1990 GHG emission levels. From 1990 to 2022, GHG emissions decreased by 12%. At a minimum GHG emission reduction of 5% annually, the sector has a big job to do until 2030.

Source of emissions

The sum of GHG emissions from shops and their (main) offices - the 'primary retail process' - usually represents only a small part of the retailer's total emissions. A holistic approach is needed to get a good picture of the origin of GHG emissions. This applies to both retail and wholesale. This is because most GHG emissions take place 'upstream' in the value chain through the production of goods and transportation, and 'downstream' through the use of the products and their waste. To ultimately achieve climate neutrality, working with partners in the value chain is a sensible approach. This allows retail and wholesale businesses to have a much greater impact on GHG emission reductions from a much larger part of the economy.

Average energy use retail & wholesale trade

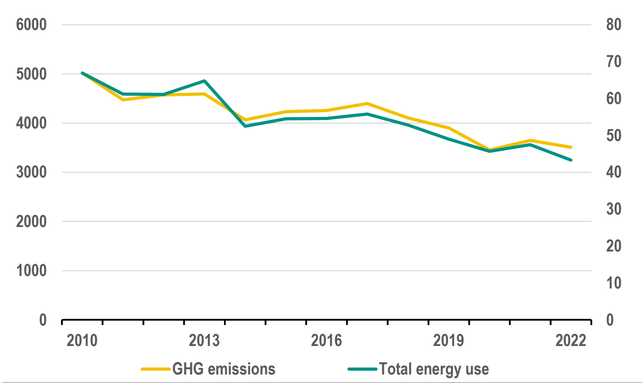
m3/m2 kWh/m2 m3/m2 kWh/m2



Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use

mln kg CO2-eq PJ



Source: CBS, ABN AMRO Group Economics

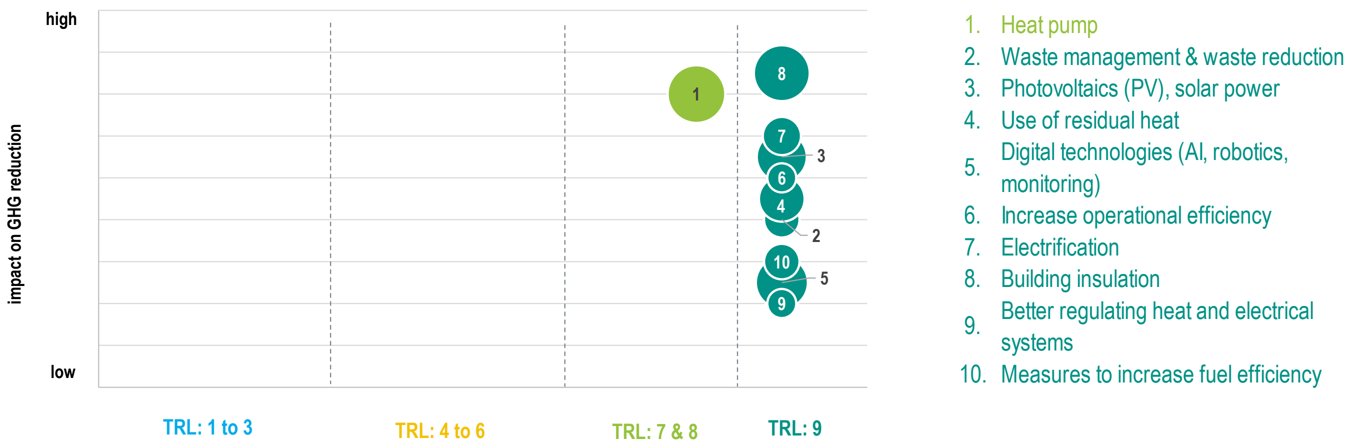
Retail and wholesale premises have a major impact on energy consumption and therefore on GHG emissions. CBS figures show that the older the retail or wholesale premises, the higher the gas consumption. There is very little difference in electricity consumption. To reduce GHG emissions faster in the coming years, building insulation is going to help make the difference. The problem is, however, that retail and wholesale buildings are often not owner-occupied.

Reduction strategy for the sector with current and future available low-carbon technologies

Retail or wholesale businesses that own premises can invest in building insulation. Not only does it provide many cost savings on energy bills, it also benefits the environment. In terms of energy consumption, it is especially important to be aware of energy use and to be alert to energy consumption when lighting, heating the shop and/or storage area and cooling products. But there are other efficiency measures. Examples include avoiding open refrigeration and freezer cabinets, reusing packaging, closed front doors in hot weather (air conditioning optimisation) and cold weather (heat hedges), combating food waste (cooperation with food banks, catering), more seasonal organic local produce, less meat products, LED lighting and sensoring. These are all relatively low-threshold ways to reduce GHG emissions. The same goes for electrification of vehicle fleets and innovations in sustainable packaging. Waste management can also play a big role in GHG emission reduction.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

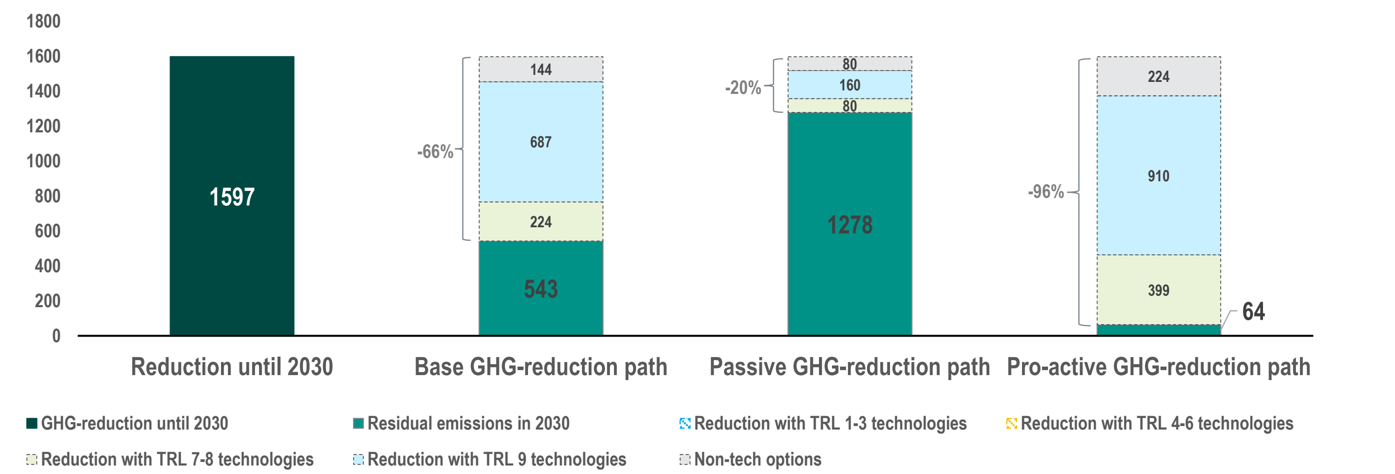
Retail and wholesale businesses are also switching to renewable energy production to reduce GHG emissions and be more cost-efficient. More and more companies in the sector with physically owned shops and business premises are switching to rooftop solar panels to meet their energy needs. Heat pumps can be installed in many small businesses - which are well insulated. In many wholesale businesses and large retailers, it is sometimes a more complex operation.

Emission reduction potential up to 2030

In the coming years, retail and wholesale businesses will also come under more pressure from transition risks. The impact is expected to be through, among others, changes in government policies, emerging technologies that may affect competitiveness and changing consumer preferences. Here, intensified collaboration in the chain - to make the transition to carbon neutrality - is going to move the sector forward. In our baseline scenario up to 2030, we assume that further abatement progress is relatively slow. After all, with the level of GHG emissions comparable to 1990, the sector is effectively only at the beginning of the sustainability and emission reduction pathway. In the baseline scenario, we assume that the heat pump will make a relatively limited contribution until 2030. In our proactive scenario, that contribution is much larger.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



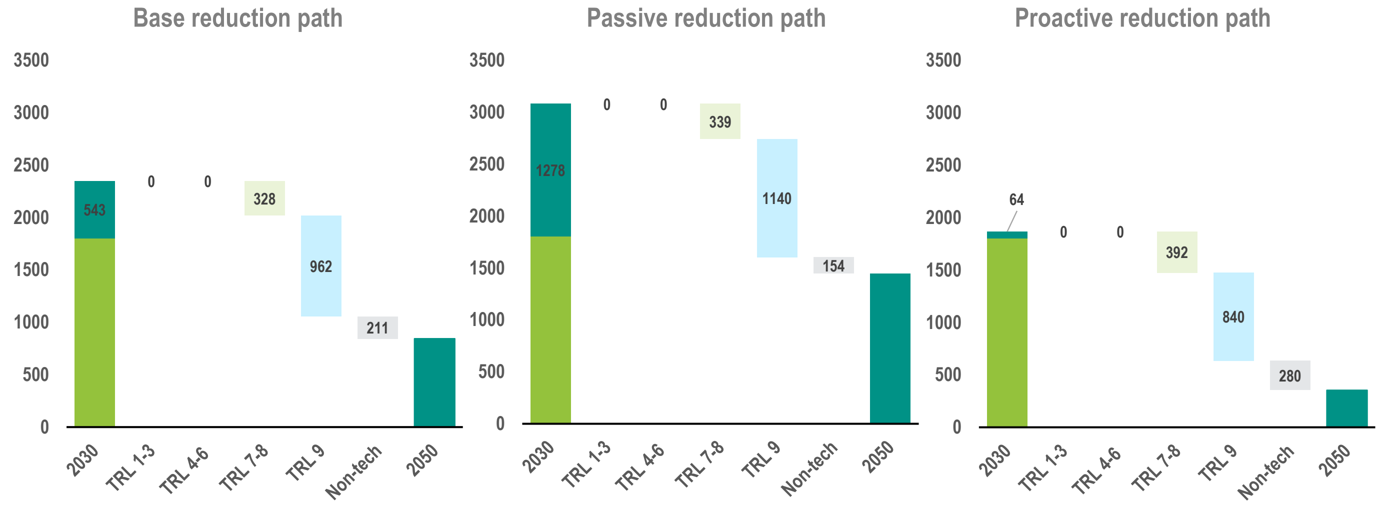
Source: CBS, ABN AMRO Group Economics

In the passive path, we think companies are unable to sufficiently catch up with the transition. This is partly because investments in sustainability are relatively high, in a sector with low margins and little room for large investments. In the proactive scenario, there is more financial support from the government, but also more ambition to become more sustainable. Here, we assume that the use of heat pumps will gain momentum, but also that much more is done in terms of building insulation.

Emission reduction potential 2030-2050

Retail and wholesale companies can play an important role in influencing consumers and their buying behaviour. Helping customers in making the low-carbon choices and making the assortment more sustainable can start a movement that is going to have a sustainable effect in a long value chain. Working towards this early on will have a major long-term impact on many parts of the economic system. Towards the carbon-neutral goal in 2050, regulations are likely to become increasingly stringent. Companies in the sector will thus be more-and-more encouraged to have a low-carbon strategy. To stick to the climate-neutral target until 2050, more retail and wholesale companies will need to invest in low-carbon technologies and ways of working. Our proactive scenario shows the path in GHG emissions at the time when actual companies in the sector maintain a high level of ambition after 2030. But even in this scenario, the 2050 climate target is not reached in this case. In our passive scenario, gap between the outcome and the 2050 target is even higher. The necessary ambition and public financial support are missing in this case. This leaves low-carbon investment and sustainability in the sector hopelessly behind.

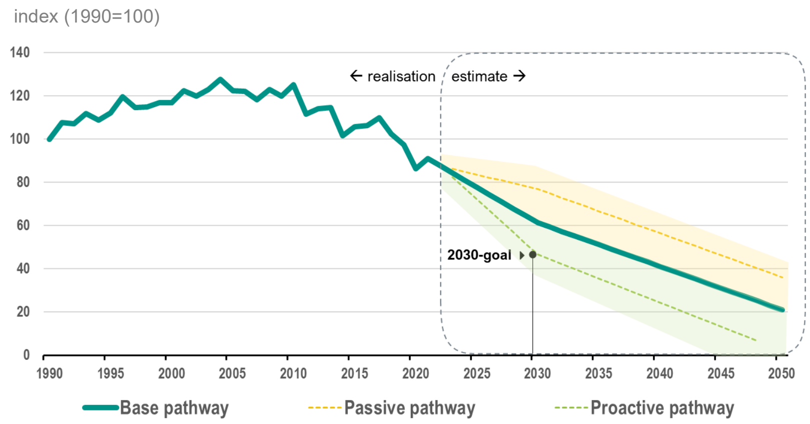
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

If we assume our baseline scenario in terms of emission reduction and the net-zero technologies available in the sector, our calculations and estimations show that the sector is also not going to meet the set target for 2050. For that, existing technologies fall short. This path is without the breakthrough technologies that might be introduced after 2030.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, retail and wholesale will achieve carbon neutrality after 2050. This could be the case around 2053. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

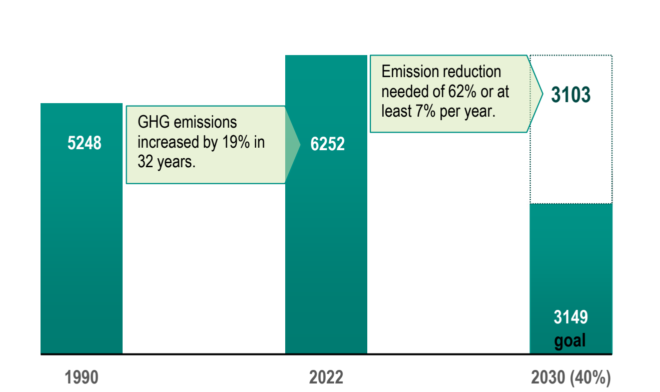
17. Transport by land

The industry's 2030 climate challenge

The transport sector as a whole accounts for about 13% of total GHG emissions. Land transport - passenger and freight transport - accounts for about 3% in the Netherlands. This gives this subsector an important role in the trajectory towards 2030 and beyond to achieve climate targets. But to decarbonise land transport is a challenging task. The investment cycle in this subsector is relatively long. For instance, the average age of a truck in the Netherlands is 9.8 years. A longer lifespan of many vehicles creates an additional complication in the transition.

Sector greenhouse gas emissions and 2030 impact

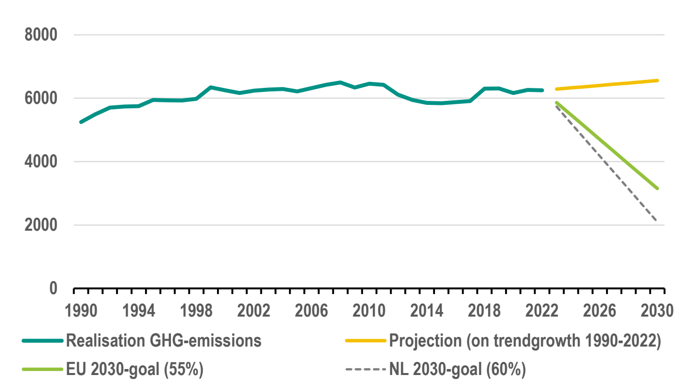
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

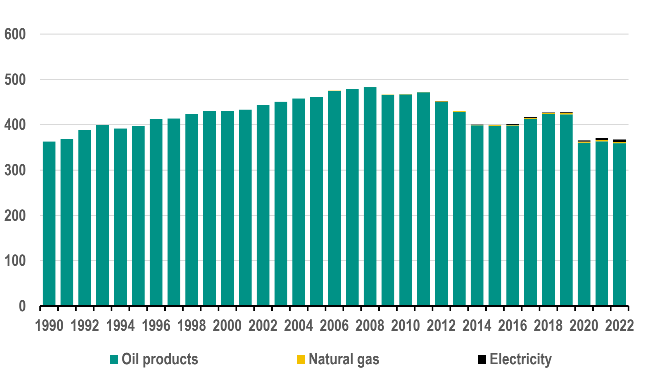
From 1990 to 2022, greenhouse gas emissions increased by 19%. With this, the sector still has a long way to go towards 2030 to meet the set targets. The difference between emissions in 2022 and the desired level in 2030 is still 62%. This means that at least 7% of emissions need to be reduced annually from this point. As in other transport sectors - by water and by air - climate ambitions are high, but goal feasibility remains tricky.

Source of emissions

Consumption of petroleum products predominates in the sector and parallels GHG emissions over time. In decarbonising the sector, electrification plays a major role in the short term. However, public and private initiatives so far are far from ambitious enough, partly due to still high investments. Biofuels (such as Hydrotreated Vegetable Oil, HVO) are also alternatives.

Energy-delivery road transport

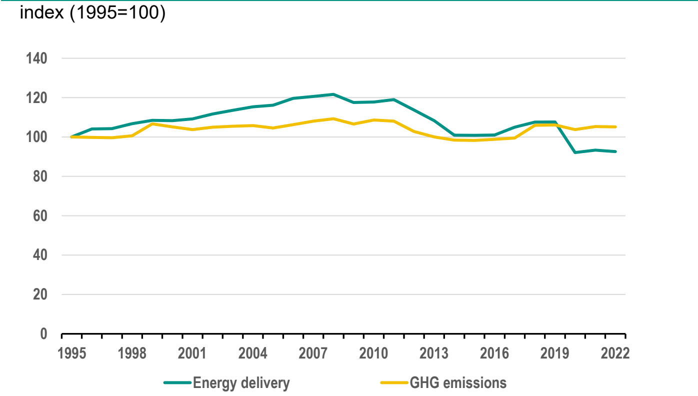
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend in emissions GHG and energy-delivery

index (1995=100)



Source: CBS, ABN AMRO Group Economics

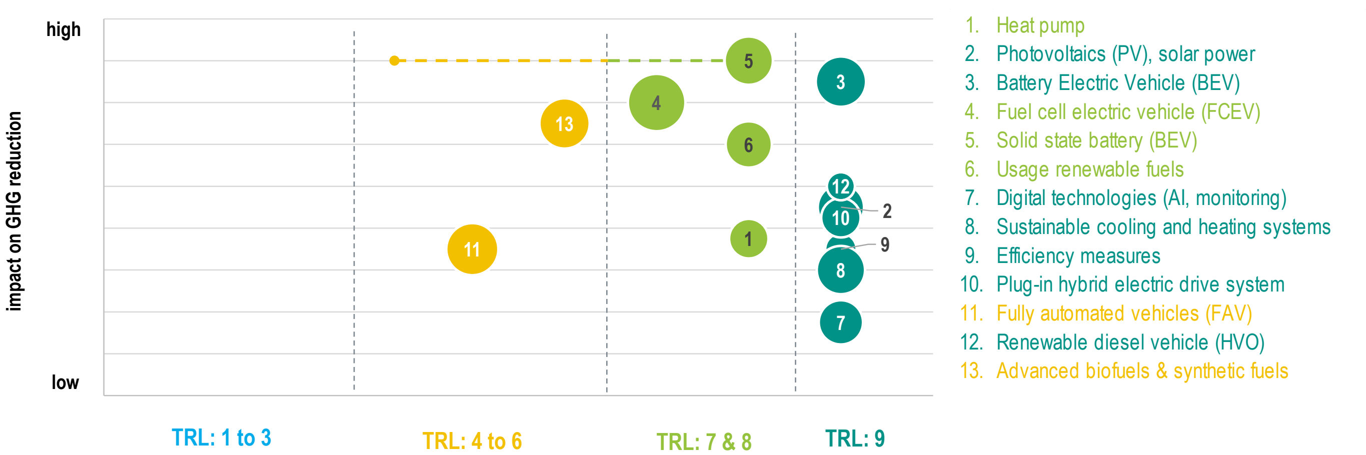
It is clear that electrification in this subsector of transport is the main way to reduce the demand for fossil fuels for passenger cars, vans and buses. Only government policies can start to make a difference in this in the coming years, but they are often not strict enough yet. An increasing number of countries are therefore formulating standards for more vehicle efficiency and many are even setting requirements for the sale of zero-emission vehicles. According to the International Energy Agency (IEA), all passenger cars and vans must be emission-free by 2035 to be climate-neutral by 2050. The European Union is also pursuing this goal. From 2035, only emission-free cars may be sold in the EU. The Netherlands is more ambitious and wants to ban new sales of vehicles based on fossil fuels as early as 2030.

Reduction strategy for the sector with current and future available low-carbon technologies

The transport sector as a whole lags considerably behind in decarbonising its operations. However, there is a host of (new) technologies available for decarbonising processes. These range from the processing and use of lower-emission fuels and/or materials (biofuels) to the further development of electric vehicles. Year-on-year, the affordability, reliability and hence accessibility of these continues to increase. To accelerate the reduction of GHG emissions in the sector, the industry can also increase its energy efficiency and accelerate the development of new low-carbon technologies. More 'soft' decarbonisation options can also help reduce GHG emissions, such as sustainable logistics planning and more sustainable customer demand.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

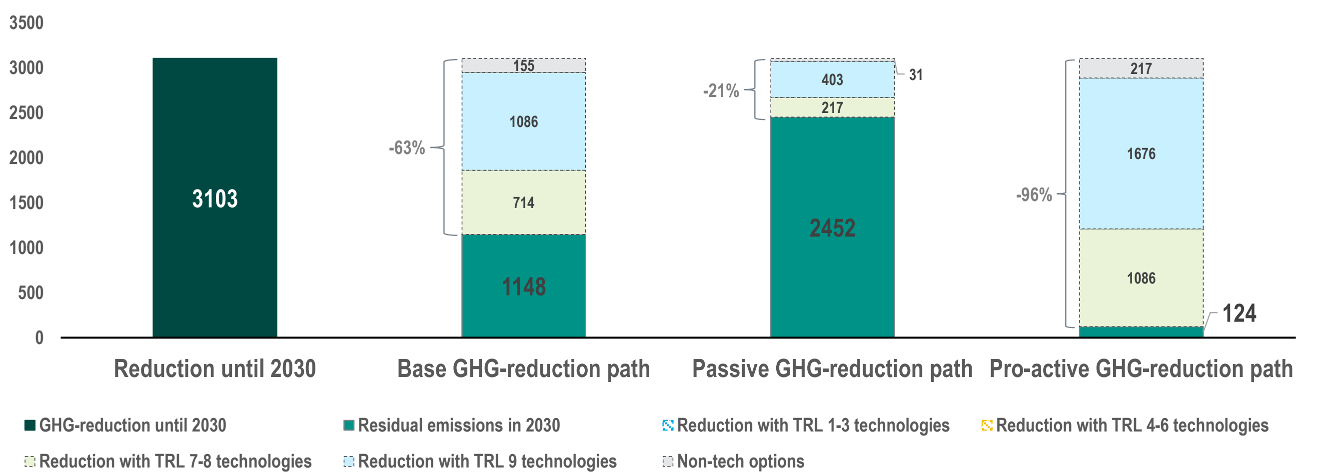
Rapid introduction of zero-emission vehicles combined with a fossil-free electricity grid is essential for stronger GHG emission reductions. Land transport is one of the largest markets for electrification. As battery costs continue to fall, so will the initial costs of electric vehicles, making them more competitive with conventional variants. In addition, electric vehicles have lower maintenance, higher energy efficiency and lower user costs. It is assumed that with the increase in energy efficiency - partly due to further electrification and the lower ownership cost of electric vehicles (Total Cost of Ownership) - low-carbon road transport will further accelerate. Road transport emissions are mainly driven by increasing road transport demand. A shift to more sustainable forms of transport, an increase in the number of passengers per vehicle or a higher load factor of trucks can help reduce GHG emissions.

Emission reduction potential up to 2030

To meet climate targets, the International Energy Agency (IEA) assumes that this sector will have to move from more than 90% fossil fuels to an energy mix dominated by low-carbon forms of electricity and biofuels. Many of the pathways to a low-carbon economy assume a non-fossil electricity grid. Once this is the case, then electrification has much impact on the reduction quantity of GHG emissions. Land-based carbon-free transport technologies have a lot of reduction potential. In this, the three most promising options are: switching from fossil fuels to carbon-free e-fuels (in the form of liquid or gaseous fuels made from renewable energy), using (renewable) electricity directly or in combination with batteries, or using biofuels.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



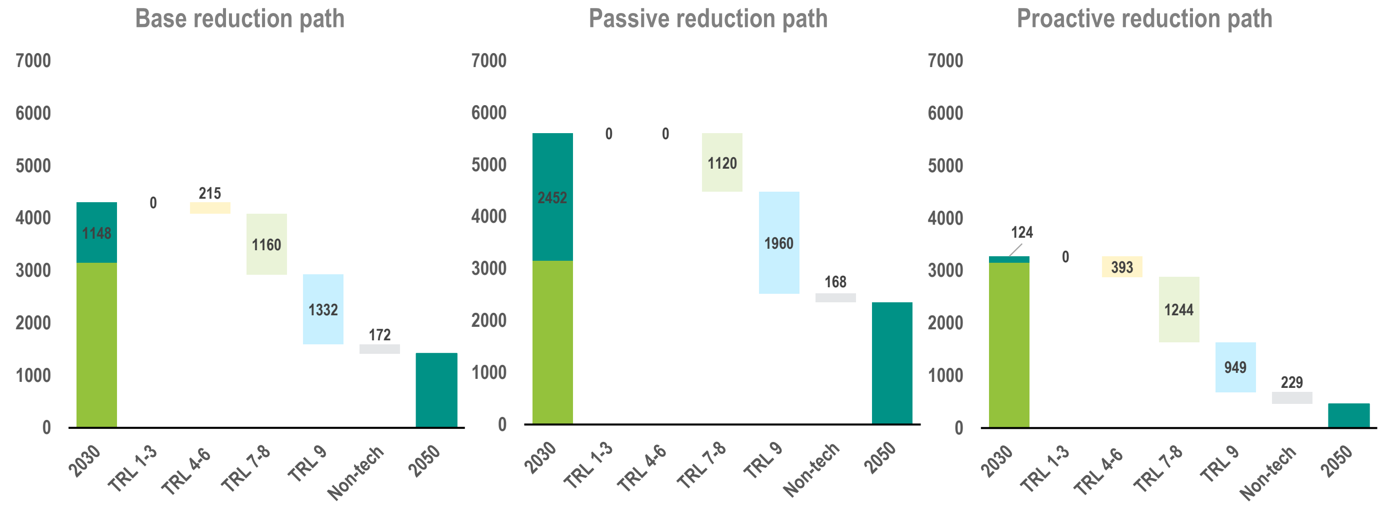
Source: CBS, ABN AMRO Group Economics

Important in this is the scale at which this takes place. This is reflected in our three scenarios. In our proactive scenario towards 2030, we assume that scaling up will take place more quickly. The biggest obstacles to this scale-up have been removed by supportive government policies. This is not the case in our passive scenario, creating a large backlog up to the 2030 target. Our baseline scenario shows that the 2030 target will not be reached. Electrification proceeds more slowly than expected because stimulating government policies lag behind. New technologies at TRL stage 7 and 8 are also unable to contribute much to the reduction.

Emission reduction potential 2030-2050

In the long term, it is in principle possible for the transport sector to reach the 2050 GHG emission target. This could be achieved, for example, by reducing transport kilometres through smarter planning, deployment of efficient vehicles on a larger scale and intensifying demand for the lower-carbon transport option and modes, among other things. However, much work is still needed to decarbonise land transport faster. In doing so, it is crucial to determine which mix of technologies can best support a sustainable transition. This is where future government policy and also public investment in charging infrastructure should be aligned. In any case, the government continues to play a crucial role throughout the sector's decarbonisation journey.

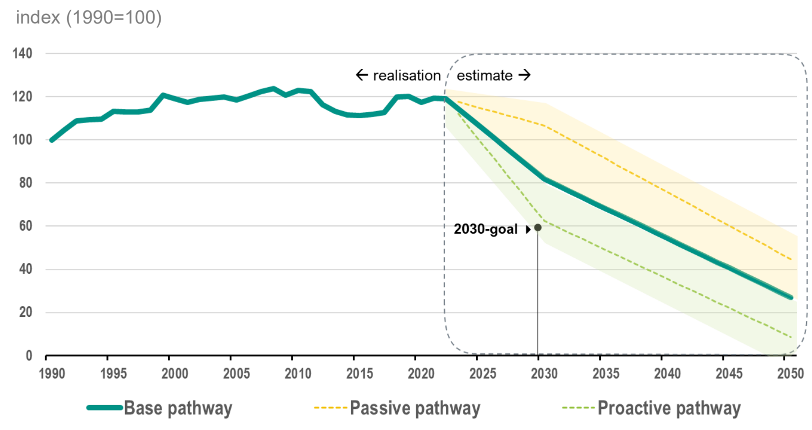
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

The EU is preparing stricter CO2 standards for new trucks on the European market, with a goal of zero emissions across the EU-27 by 2050. Such policies have an impact on the scenarios. Our proactive scenario shows the path in GHG emissions at the time when companies face much stricter and strict policies. The 2050 climate target is almost reached in this scenario. In our passive scenario, these policies are hopelessly delayed. Ambition is richly lacking among entrepreneurs and low-carbon investments lag behind. Even in our baseline scenario, the sector does not reach the 2050 target, partly because of policy uncertainty and the lack of sufficient government support to pace the transition.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, land transport reaches carbon neutrality after 2050. This could be the case by around 2055. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

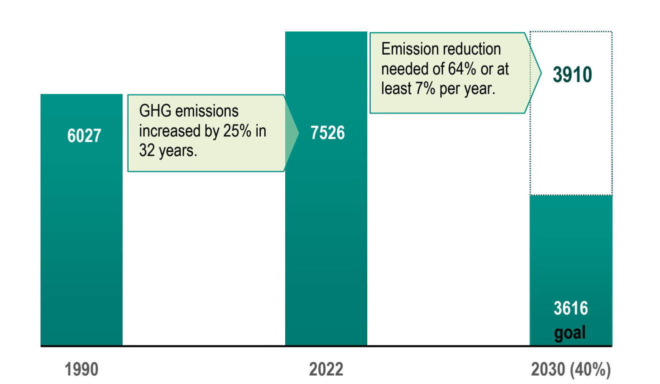
18. Transport by water

The industry's 2030 climate challenge

The sector includes Dutch companies active in inland as well as maritime and coastal shipping. Both may involve both passenger and freight transport. Over 60% of the companies in this sector are active in inland shipping (mainly dry cargo & tanker shipping). It is a capital-intensive sector, with a relatively long investment cycle. In this case, investment decisions take time, as transparency in (cross-border) government policy is often still lacking to minimise all risks. Regulations for inland, maritime and coastal shipping are often complex, national and international regulations apply and these regulations are subject to a lot of change. Often more so than in other sectors.

Sector greenhouse gas emissions and 2030 impact

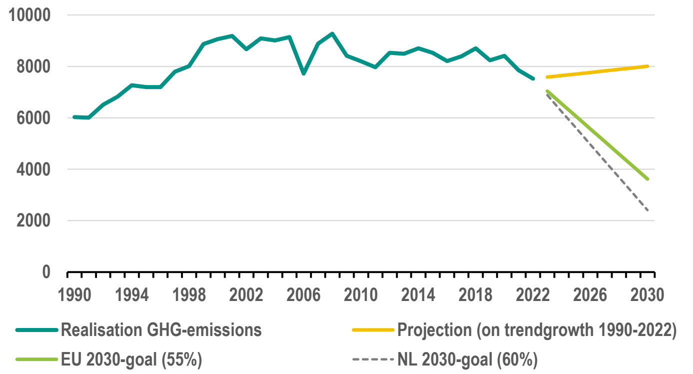
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

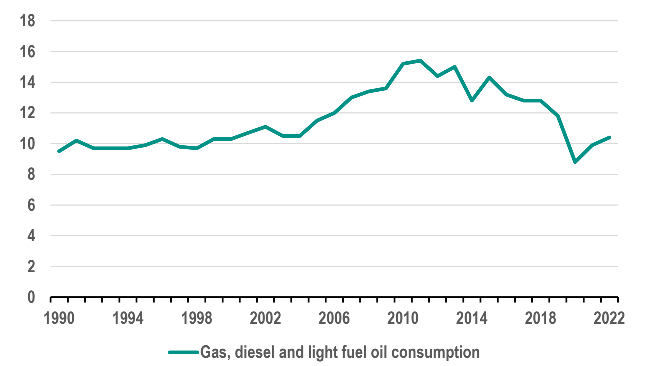
On average, inland navigation has much shorter trips compared to international or maritime and coastal navigation. As a result, inland navigation makes more stops to refuel or recharge. Due to the lower action radius and lower need for fuel storage, inland navigation has more opportunities to decarbonise than international sea and coastal navigation. GHG emissions have not been reduced in waterborne transport over the past three decades. Emissions increased by 25% over the period from 1990 to 2022. However, emissions show a volatile pattern over time. Until 2030, the sector still needs to reduce emissions by at least 7% annually to meet the 2030 target.

Source of emissions

Most ships have internal combustion engines that burn fossil fuels such as gasoil and diesel. Their combustion is the main cause of GHG emissions. Consumption of gas oil, diesel oil and light fuel oil is almost 10% higher than 1990 levels in 2021. To reduce fossil fuel consumption on a more structural basis, emission requirements on inland navigation engines have been tightened from 1 January 2022. From then on, only Stage V or Stage V certified diesel engines may be installed on new-build vessels. This has no direct CO2 impact but helps to reduce total GHG emissions. However, the pace of reduction will be slow due to the long investment cycle.

Use of gas-, diesel oil and light fuel oil

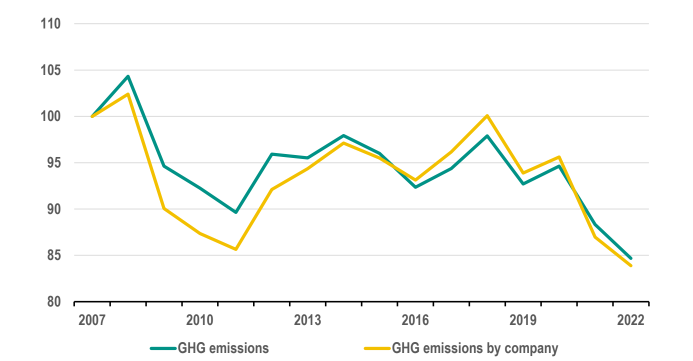
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend in GHG emissions and intensities

index (2007=100)



Source: CBS, ABN AMRO Group Economics

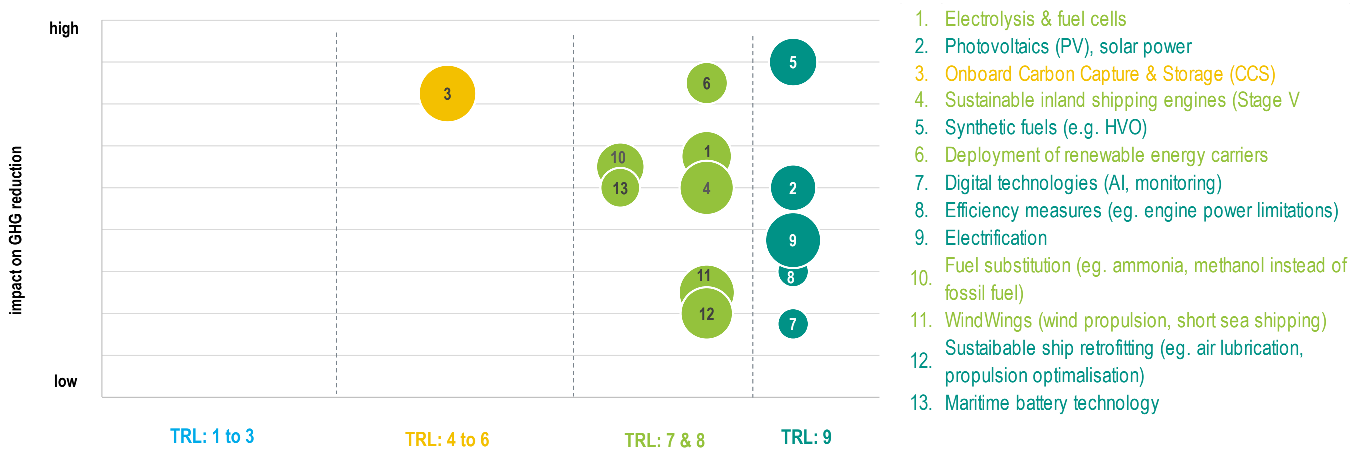
To achieve the set 2030 and 2050 climate targets, renewable and low-carbon fuels must account for between 6-9% of the energy mix in 2030. By 2050, this should then be between 86-88% of the fuel mix for maritime transport. The Dutch government supports the proposal to make the shipping sector more sustainable.

Reduction strategy for the sector with current and future available low-carbon technologies

Inland, maritime and coastal shipping has several ways at its disposal to reduce GHG emissions. Broadly speaking, these include changing the energy carrier, modifying the ship's design, optimising the voyage, upgrading on-board machinery and using after-treatment measures. The choice of energy carrier is by far the most important and impactful way to achieve short-term results. To reduce the sector's GHG emissions, energy consumption must decrease, thus improving energy efficiency. Also, cleaner types of energy carriers must be used, such as the use of renewable and low-carbon fuels.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

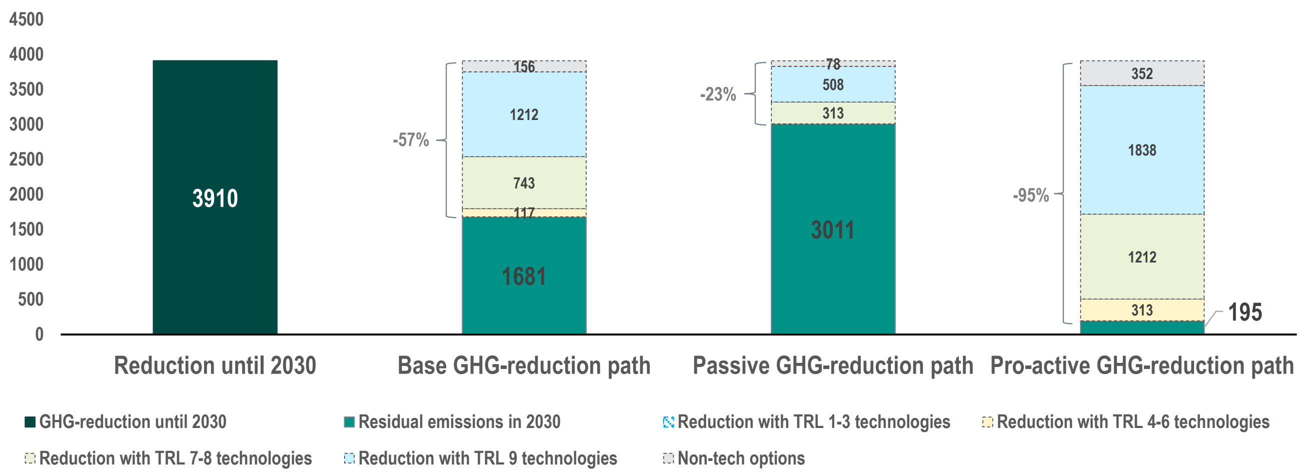
When determining the most appropriate decarbonisation technique, it is important to consider the type of vessel and its age. In any case, it is clear that increased use of renewable fuels and the introduction of energy efficiency measures (e.g. via smart navigation) are going to characterise the carbon-free future of waterborne transport. However, fuel substitution is not an easy task. This is because most alternative fuels have a lower energy density than the fossil variant. As a result, larger tanks are needed on board - resulting in less payload - or a modification of the ship's structure. These are interventions that require a lot of capital. This uncertainty may make shipowners more reluctant to replace current older ships and invest in more sustainable vessels. In inland, maritime and coastal shipping, a more holistic approach to GHG emissions provides more insight, as the operation of a ship is only one aspect. Various analyses of the entire life cycle of a ship show that, in addition to the operation phase, many indirect GHG emissions also occur in shipbuilding, fuel production (and transport) and port activity.

Emission reduction potential up to 2030

From 2024, maritime and coastal shipping will fall under the EU Emissions Trading Scheme (EU ETS), inland navigation will not (yet). The FuelEU Maritime Regulation is a new regulation coming into force from 1 January 2025 that imposes requirements regarding energy consumption on board, thereby helping to reduce GHG emissions. This should improve the GHG intensity of energy used by 2% over the whole of 2025 compared to 2020 and increase to 75% by 2050. Besides available low-carbon technologies, government policies and the level of ambition in the sector are going to determine the GHG emission reduction path towards 2030. However, the transition will not be quick as several obstacles - such as capital intensity and the longer investment

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



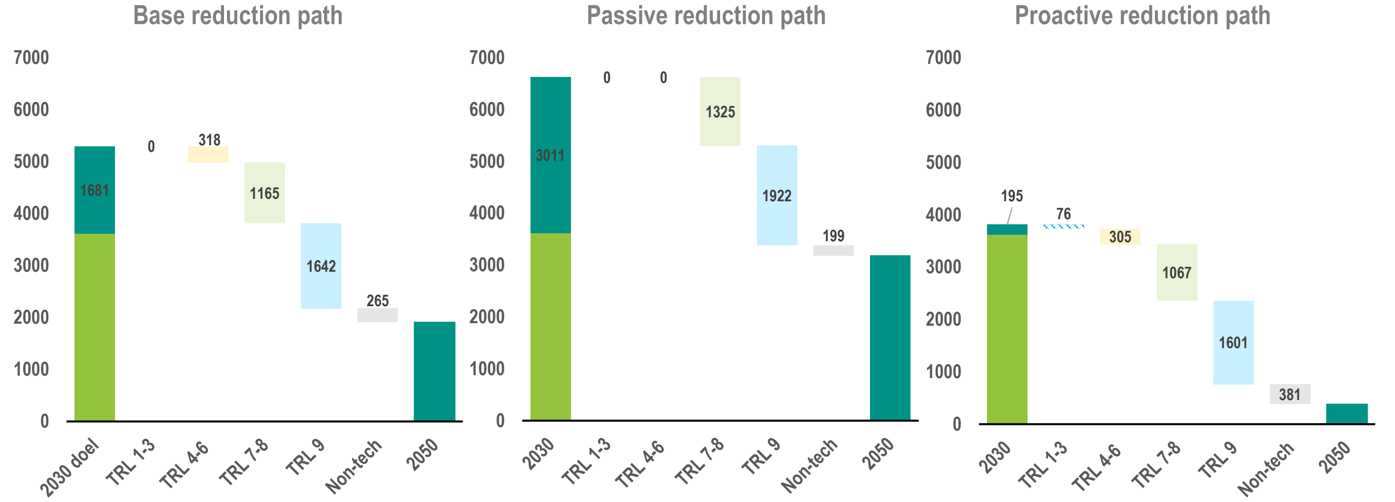
Source: CBS, ABN AMRO Group Economics

cycle - cannot be easily removed. This is reflected in our baseline scenario. The 2030 target is thus not achieved. In our proactive scenario towards 2030, we assume that there is much more supportive government policy and the level of ambition among entrepreneurs in the sector is also much higher. Then scaling up will take place faster. This is not the case in our passive scenario, creating a large backlog up to the 2030 target. The transition is slow because government incentive policies are relatively austere and entrepreneurs see no need to invest more than strictly necessary. The new technologies in TRL stages 4 to 8 are not capable of contributing much to reductions in the baseline and proactive scenarios.

Emission reduction potential 2030-2050

The sustainable future of waterborne transport remains uncertain. This is due to the complexity of deploying alternative fuels, the required investments associated with them and the investments in infrastructure, retrofitting vessels and scaling up R&D activities. Compared to other modes of transport, inland navigation offers advantages such as high transport volume, cost effectiveness and its environmentally friendly nature. However, the high dependence on diesel engines and associated emissions underline the urgent need for more sustainable solutions. Then, in the long term, the choice of fuel, the structure of the power system and the rate of growth of shipments will become increasingly important for achieving GHG emission reduction targets.

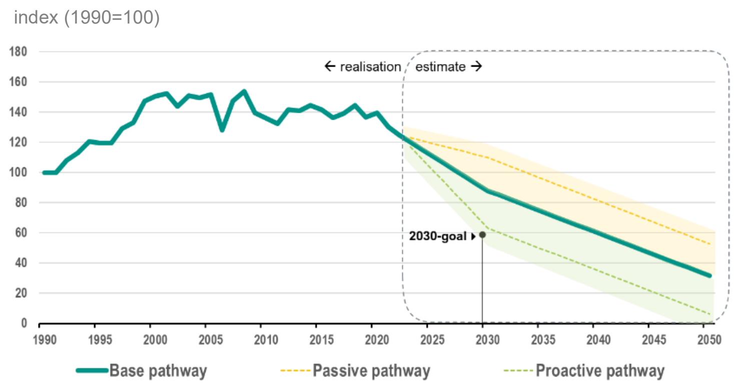
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

Our proactive scenario shows the path in GHG emissions at the time when actual companies invest and become much more sustainable. Here, we assume that the technologies in TRL 4 to 8 will also make a meaningful contribution to the emission reduction path between 2030 and 2050. The 2050 climate target is almost reached in this scenario. In our passive scenario, this is far from the case. The necessary ambition lacks rich entrepreneurs and low-carbon investment lags hopelessly behind. Even in our baseline scenario, the sector does not reach the 2050 target. This shows that breakthrough technologies and further development of existing low-carbon technologies will be indispensable in this sector.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, waterborne transport reaches carbon neutrality after 2050. This could be the case by around 2056. But again, nothing is cast in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emission projection.

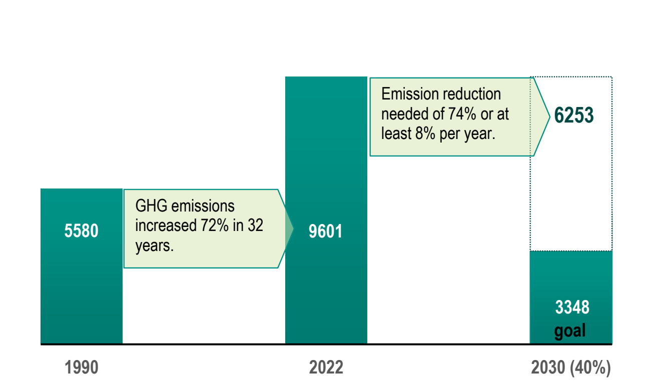
19. Transport by air

The industry's 2030 climate challenge

Strong growth of aviation in recent decades has increased its impact on the living environment, especially with the increase in GHG emissions. As a result, the sector is often part of the public debate. Air transport as a whole accounts for about 2-3% of global CO2 emissions, according to the International Air Transport Association (IATA). Aviation is also characterised by rapid growth in emissions, increasing by a factor of 6-7 between 1960 and 2018. This makes it one of the fastest-growing sources of emissions in the global economy (IPCC).

Sector greenhouse gas emissions and 2030 impact

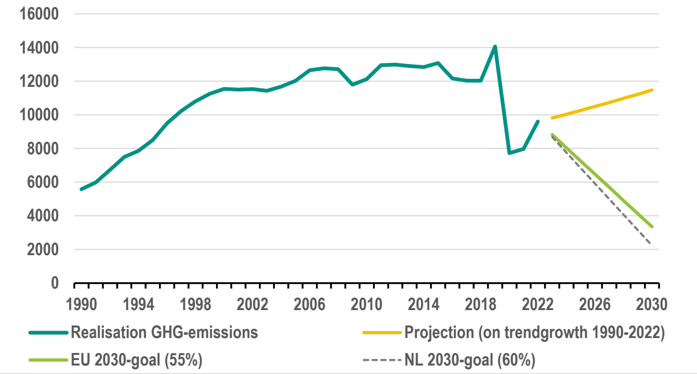
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

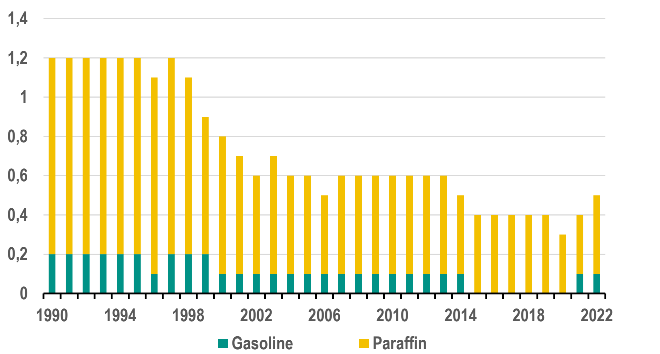
GHG emissions from aviation have increased rapidly over the past three decades. This is mainly because the number of air passengers across Europe and air cargo transport have increased sharply since the 1990s. However, the number of flights in 2020 decreased significantly due to the Covid-19 restrictions, which also resulted in a sharp decrease in GHG emissions. From 1990 to 2022, emissions increased by 72%, or 2.3% per year. With a necessary reduction of at least 8% per year in GHG emissions, the 2030 target is a long way off.

Source of emissions

Aircraft burn fossil fuel - particularly paraffin - releasing not only CO2 but also nitrogen oxides (NOx), methane, nitrous oxide and other by-products. Fuel consumption and emissions depend on fuel type, aircraft type, engine type, engine load and altitude.

Energy-delivery domestic aviation

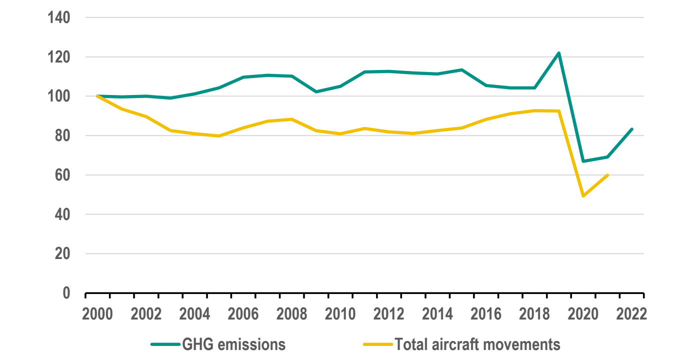
PJ



Source: CBS, ABN AMRO Group Economics

GHG emissions in the sector and aircraft movements

index (2000=100)



Source: CBS, ABN AMRO Group Economics

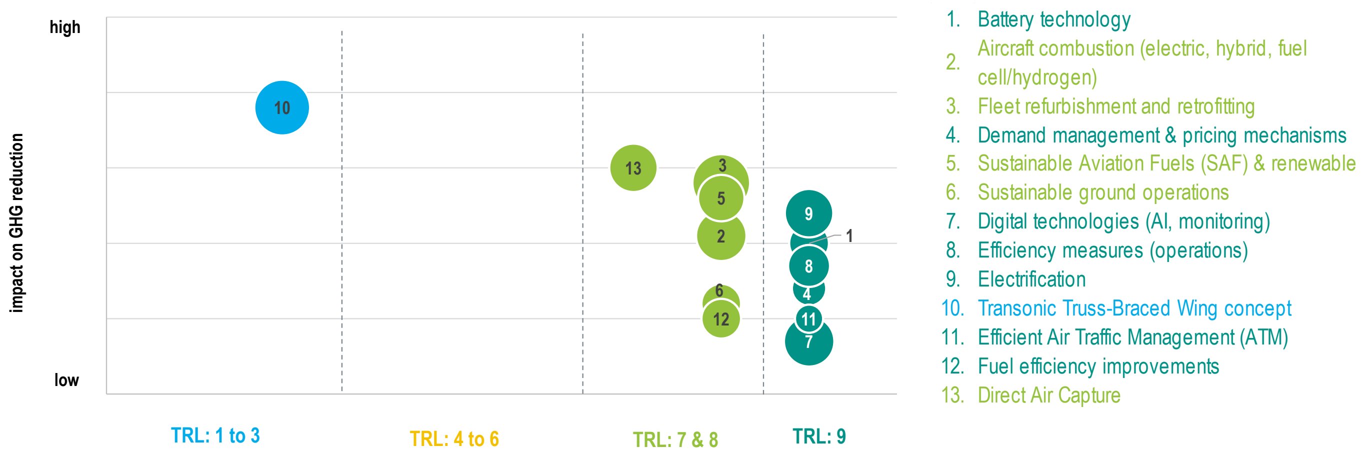
Action to reduce GHG emissions in the aviation sector to a greater extent depends on regulatory stringency and commitment from airlines. Some airlines have announced that they will not return to pre-Covid-19 aircraft movements. But not every airline will comply. Besides significantly reducing fuel consumption and promoting low-carbon technologies for aviation, encouraging government policies and regulatory legislation has a lot of influence to reduce GHG emissions. For example, regulation is going to help curb the growth of air travel, but it can also, for example, accelerate the low-carbon transition in airlines' ground operations. In a tentative EU agreement, there is going to be a 20% biofuel blending obligation in 2035 and 70% Sustainable Air Fuels (SAF) by 2050.

Reduction strategy for the sector with current and future available low-carbon technologies

The potential of many low-carbon technologies for the sector is relatively well known. However, uncertainties about the deployment of many technologies and future technologies are relatively high. There are also large differences in the deployment and potential of low-carbon technologies by aircraft type. For a comprehensive analysis, please refer to the *Destination 2050* report by European aviation industry interest groups. There are two main low-carbon technologies that are regularly discussed in the various publications around carbon-free aviation. These are flying electric (smaller planes) and sustainable alternative fuels. Battery technology has its challenges. For sustainable fuels, consider hydrogen, biomass-derived fuels or e-fuels (also called power-to-liquid or non-biogenic synthetic fuels).

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

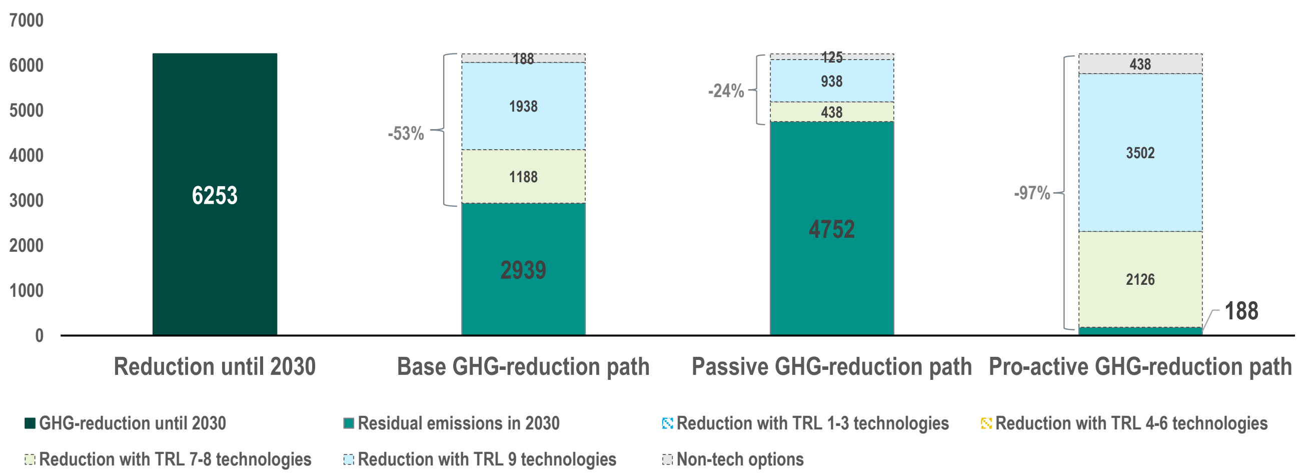
With Sustainable Aviation Fuels (SAF), results can be achieved in the short term. According to her report Destination 2050, SAF supply could increase from 3 Mt in 2030 to 32 Mt in 2050. This volume is roughly equivalent to 83% of the sector's total paraffin consumption. However, steps still need to be taken in scaling up SAF and this is not an easy task. Stocks of bio-based alternatives are relatively low and there is also a need to compete with other sectors in this. Direct Air Capture is also seen as an important technology for the sector to adopt. Their deployment is often in cooperation with partners, who purify air through large industrial fans on site. For long-haul flights, liquid fuel alternatives (such as batteries for electric aircraft or hydrogen as fuel) are more complex, unlike their use for regional flights. European cooperation in R&D programmes are crucial. Developing new (breakthrough) technologies for aviation will get off the ground much better and faster if hands are joined.

Emission reduction potential up to 2030

In the aviation sector, the lead time for implementing low-carbon technologies is relatively long. This means that GHG emissions reductions are slower than in sector where low-carbon technologies can be quickly deployed in processes. The sector is also capital-intensive and - like so many other subsectors in the transport sector - has a longer investment cycle. As a result, the transition to decarbonisation is likely to be delayed towards 2030.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

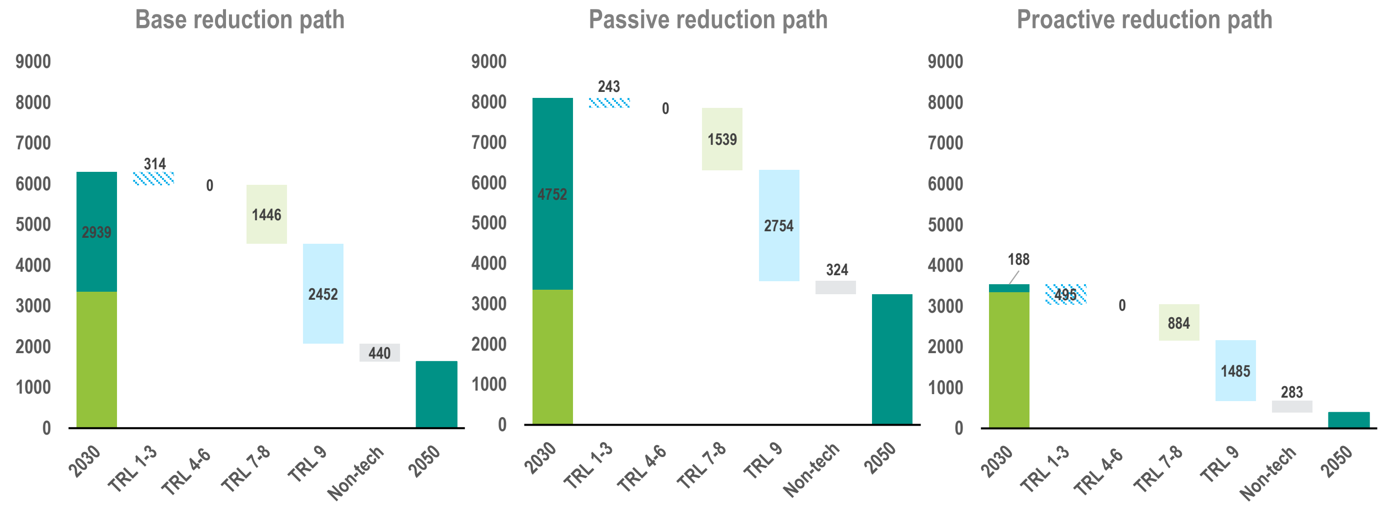
In any case, it is clear that the sector will decarbonise more in the years until 2030. However, it is almost essential that, on the one hand, the transition in this sector is accelerated by stricter government policies and, on the other hand, in doing so, it also receives partial support from the government to make that transition. Among other things, the path of abolishing free emission rights for the aviation sector in the coming years is known: 25% in 2024, 50% in 2025 and 100% from 2026 onwards. This means that from 2026, emission rights will be fully auctioned under the European Emissions Trading Scheme (EU ETS). For airlines, this means they will have to invest much more in low-carbon technologies in the coming years.

In our baseline scenario, we assume that 53% of the 6,253 million kg CO2-eq. up to 2030 can be reduced as a result of upcoming renewals of the existing fleet, efficiency improvements around all airline operations and increased electrification therein. The deployment of renewable fuels is still too limited in this scenario to make a meaningful contribution. This is the case in our proactive scenario, but still not 100%. It is still too early for that. In our passive scenario, the transition is proceeding relatively slowly because government incentive policies are relatively austere and airlines see no need to invest more than strictly necessary.

Emission reduction potential 2030-2050

Towards 2050, further development of aircraft and engine technology is going to make aviation more-and-more carbon-free. Fleet replacement between 2030 and 2050 for more efficient and low-carbon variants - such as hydrogen-powered aircraft and hybrid-electric aircraft for regional use - will also help the sector stay on the carbon-free path.

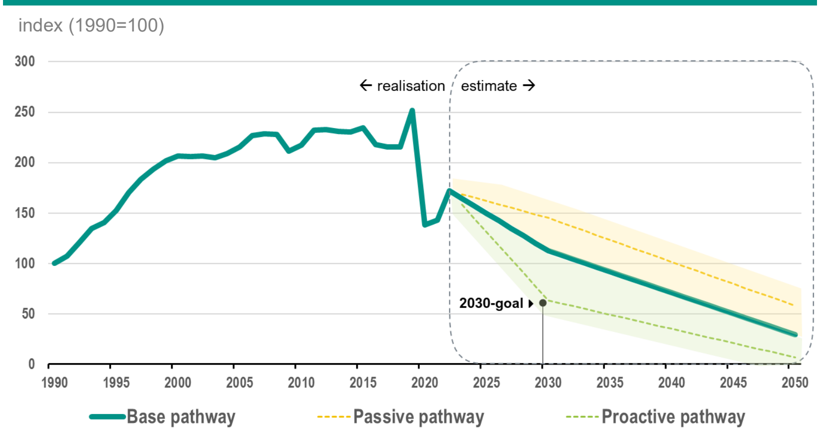
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

Without free allowances, the low-carbon transition accelerates. This is reflected in every scenario. We assume that technologies in TRL 1 to 3 will also make a meaningful contribution to the emissions reduction pathway between 2030 and 2050. It ensures that in our baseline scenario the reduction in GHG emissions is relatively high. Our proactive scenario shows the path in GHG emissions at the time when actual companies in the sector maintain a higher level of ambition after 2030. However, the climate-neutral 2050 target is not achieved. In our passive scenario, the 2050 target is not reached either.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, air transport reaches carbon neutrality after 2050. This may be the case around 2057. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

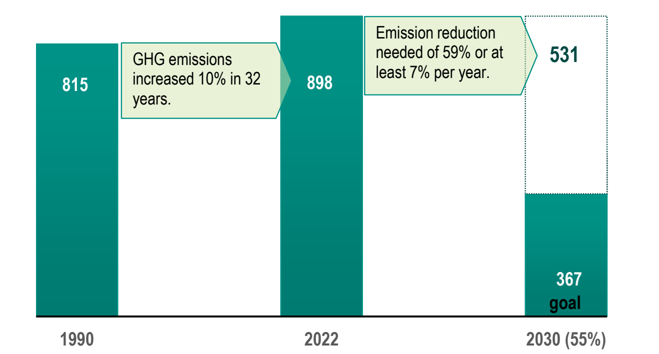
20. Hotels & Restaurants

The industry's 2030 climate challenge

The hospitality industry has over 76,000 businesses in the Netherlands. These are mainly SMEs. About 85% of these businesses are eating and drinking establishments (such as restaurants, fast food), while 15% are accommodation providers (such as hotels, campsites). The sector has the potential to influence many links in the value chain. Through targeted sustainable choices, the sector can, for example, shape food and raw material use and energy consumption sustainability.

Sector greenhouse gas emissions and 2030 impact

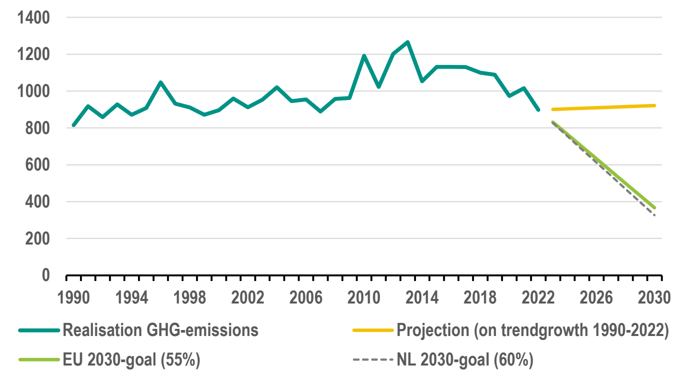
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

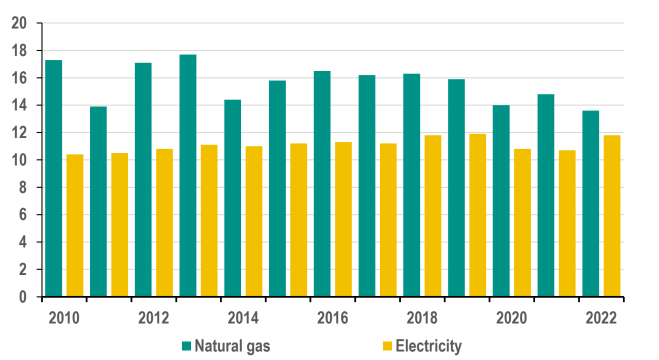
Hospitality businesses have seen a 10% increase in GHG emissions over the past 32 years. In 2022, GHG emissions are still above 1990 GHG emission levels. GHG emissions in the hospitality industry peak in 2013. After that, GHG emissions decline in an erratic pattern. To reach the 2030 target, the sector needs to achieve at least 7% GHG emission reductions every year until 2030.

Source of emissions

Direct GHG emissions produced by businesses in the sector come mainly from on-site combustion of fuels for heating (rooms and water), cooling and cooking, as well as GHG emissions from fuels consumed for vehicles owned by the hospitality business. For each of the hospitality subsectors - such as hotels, pubs, restaurants, campsites, snack bars, etc. - the largest source of emissions may differ. However, for the sector as a whole, natural gas is the main energy carrier, followed by electricity. A more holistic approach is needed to get a good picture on the origin of GHG emissions. Indeed, most GHG emissions occur 'upstream' in the value chain through the production of hospitality goods and services and transportation. To ultimately achieve climate neutrality, cooperation with partners in the value chain is a sensible approach. This allows retail and wholesale businesses to have a much greater impact on GHG emission reductions from a much larger part of the economy.

Energy-delivery Hotels & Restaurants

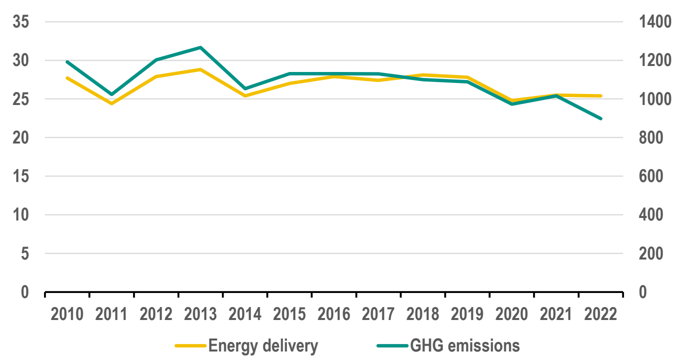
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use

PJ mln kg CO2-eq



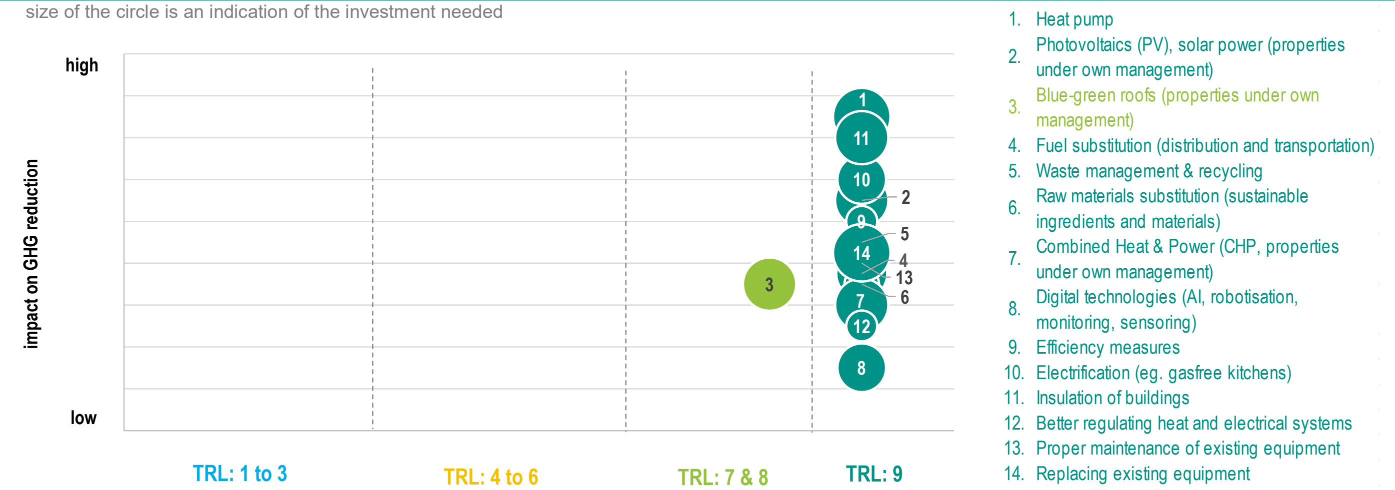
Source: CBS, ABN AMRO Group Economics

The trend in electricity consumption has been almost stable since 2010, with only minor volatility between 10 and 12 PJ. In gas consumption, there is a bit more variability over the years. The total energy consumed has a direct relationship with greenhouse gas emissions. Reducing gas consumption in particular will contribute significantly to lower GHG emissions.

Reduction strategy for the sector with current and future available low-carbon technologies

To reduce GHG emissions, low-threshold measures can be taken, which can have a great impact on the carbon footprint over time. For instance, food and beverage companies can use or source ingredients, products or services with a low carbon footprint. This can be done, for instance, by engaging mainly locally or regionally with suppliers. Furthermore, premises can be equipped with energy-saving equipment and/or renewable energy. Reducing food waste and the waste stream remains a hot topic in the sector. This requires behavioural change. Catering companies can actively influence consumers' buying behaviour and encourage them to make sustainable choices.

Available low-carbon technologies by TRL and emission reduction impact



Source: ABN AMRO Group Economics

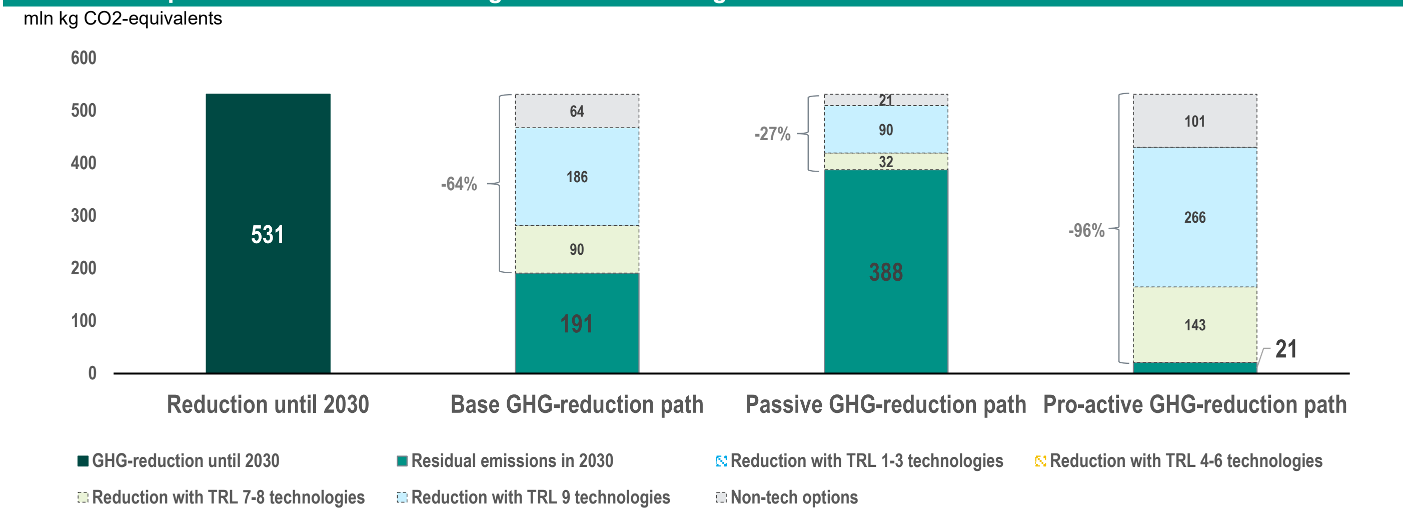
Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

Many of the emission reduction options in this sector are at the TRL 9 stage and have already proven themselves. The technologies or options that on balance have the highest emission reduction potential also tend to require relatively large investments. These include, for example, the installation of heat pumps, solar panels and electrification. Here, having the hospitality properties under own management is a prerequisite. Other measures in the matrix also contribute to lower emissions, but have a slightly lower reduction potential. Consider, for example, efficiency measures and control equipment. On 1 July 2017, the Approved Measures List for the Hospitality Industry came into force. Companies that consume more than 50,000 kWh of electricity or more than 25,000 m3 of gas per year must report all energy-saving measures to the RVO. The measures relate, for example, to refrigeration or freezer units or cold rooms in large professional kitchens. Proper maintenance of equipment is also very effective.

Emission reduction potential up to 2030

Collectively, businesses in the hospitality industry have only a marginal contribution to total annual greenhouse gas emissions. Yet the sector has much to gain from actively reducing its carbon footprint in the coming period. Indeed, climate change poses a risk to hospitality businesses. For instance, acute physical risk factors - such as drought, floods, forest fires or environmental disasters - can have a significant impact on business activities. These extreme climate and environmental events can cause the loss of premises and assets, severely disrupt supply chains and cause commodity prices to skyrocket. This calls for increased investment in sustainability.

Indicative impact of low-carbon technologies on the 2030 target



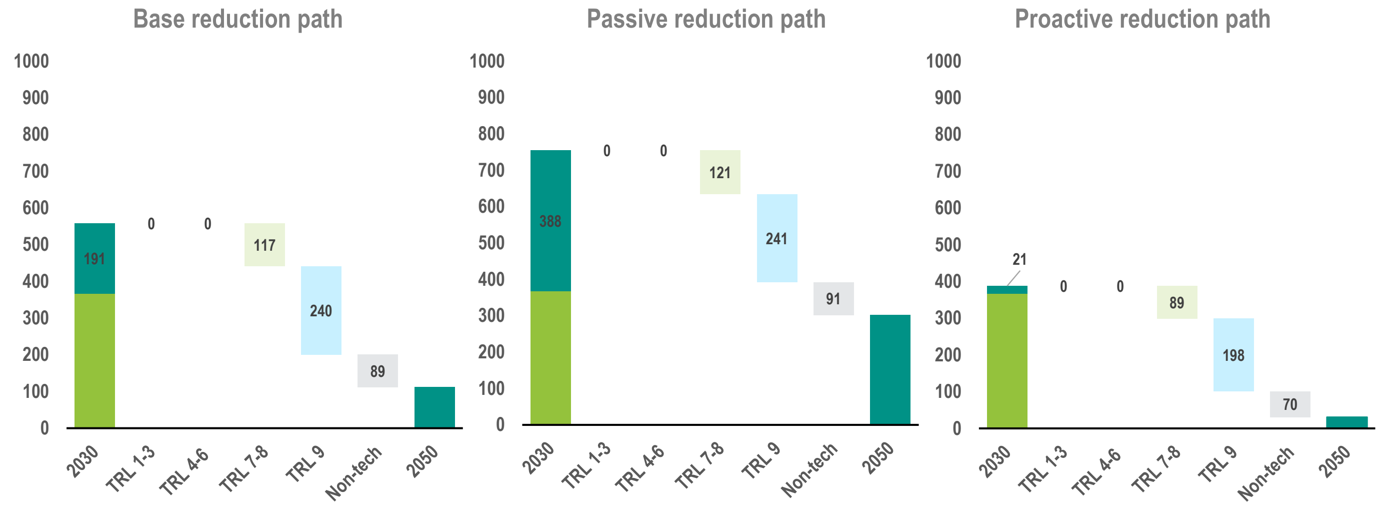
Source: CBS, ABN AMRO Group Economics

However, a major obstacle for the hospitality industry to become more sustainable are sometimes the relatively high investments required for this acceleration. In the baseline scenario, we assume that not only the deployment of heat pumps on a larger scale will contribute up to 2030, but also that more building insulation will be done. Often, however, hospitality entrepreneurs do not own the premises, causing delays in making buildings more sustainable. In our proactive scenario, we assume that the owners of hotel and catering premises have a high level of ambition to make them more sustainable. Government support will kick start sustainability faster. In our passive path, we assume that businesses are unable to sufficiently catch on to the transition. This is because of the high investments in sustainable technologies, in a sector where margins are relatively low.

Emission reduction potential 2030-2050

Decarbonising the hospitality industry is possible, but this will require, among other things, influencing consumer behaviour for greater awareness and closer cooperation with suppliers in the supply chains, such as partners in agriculture, food industry and hospitality services (such as cleaning services). This is a relatively complex process but can contribute positively to GHG emission reductions in the long term. Switching to renewable energy and installing a heat pump are also central in the hospitality sector for reducing GHG emissions in the longer term. Our proactive scenario shows the path in GHG emissions at the time when actual companies in the sector maintain a high level of ambition beyond 2030. It will require a lot of investment in sustainability, but then the 2050 climate target will be achieved. In our passive scenario, the 2050 target will not be reached. The necessary ambition and public financial support are missing in this case. This leaves low-carbon investment and sustainability in the sector hopelessly behind.

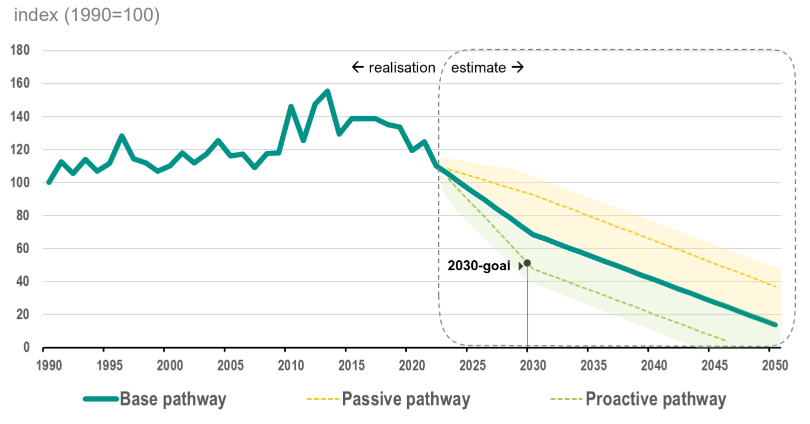
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

If we assume our baseline scenario in terms of emission reduction and the net-zero technologies available in the sector, our calculations show that the sector is also not going to meet the set target for 2050, although a significant amount of GHG emission reduction can be achieved. Indeed, the sector has enough decarbonisation technologies at its disposal.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, the hospitality industry reaches carbon neutrality after 2050. This could be the case around 2053. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emission projection.

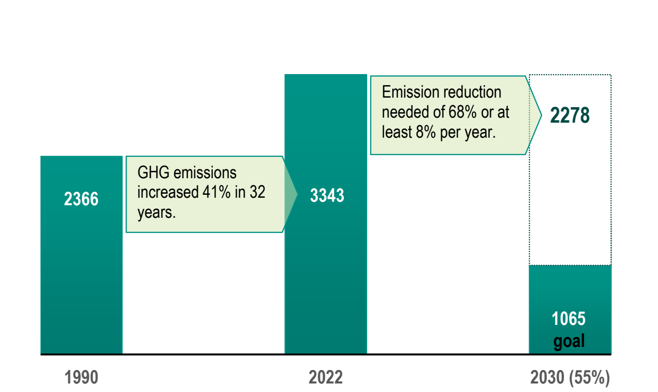
21. Business Services

The industry's 2030 climate challenge

The service sector has a large number of, often small, companies. Collectively, they make only a marginal contribution to total annual greenhouse gas emissions. However, it is an important sector for the Dutch economy, accounting for 14% of total value added. Despite its relatively low carbon footprint, the service sector benefits from actively reducing GHG emissions. Indeed, climate change poses risks for many service providers. For instance, acute physical risk factors - such as drought, floods, forest fires or environmental disasters - can impact business operations. Service providers with operations or customers, for example, suffer material damage or lose revenue due to extreme weather. Damage to energy infrastructure due to extreme weather events can also lead to higher energy prices.

Sector greenhouse gas emissions and 2030 impact

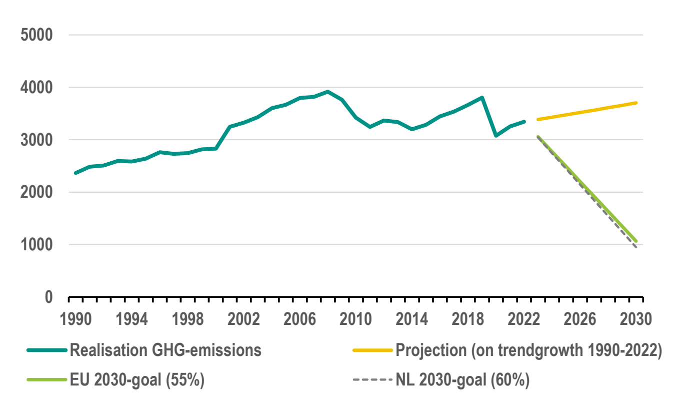
mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

2030 pathway in greenhouse gas emissions for the sector

mln kg CO2-equivalents



Source: CBS, ABN AMRO Group Economics

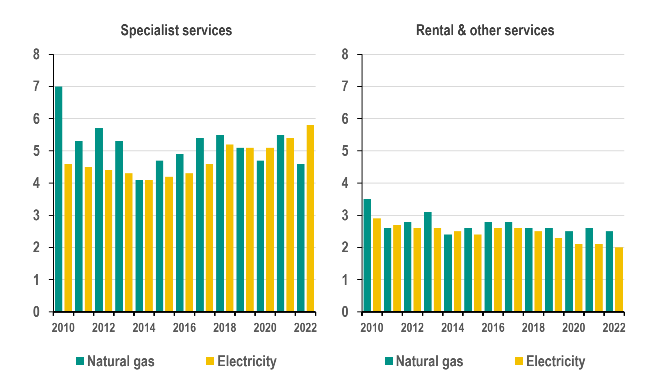
The service sector has made relatively little progress in GHG emission reduction over the past 32 years. Indeed, from 1990 to 2022, GHG emissions increased by 41%. To reach the 2030 climate target - which is 55% below 1990 GHG emission levels - the sector needs to reduce its GHG emissions by at least 8% annually until 2030.

Source of emissions

Many daily activities of companies in business services mainly consume electricity for lighting, cooling of computer rooms, construction equipment and appliances, as well as fuel consumption for transportation and heating of rooms. As a result of these energy-related activities, the sector emits greenhouse gases. The trend in energy consumption in the sector and the trend in GHG emissions largely run parallel.

Energy-delivery by subsectors

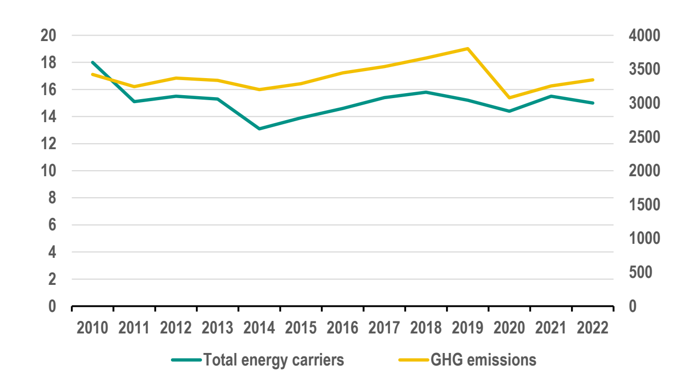
PJ



Source: CBS, ABN AMRO Group Economics

Sector trend GHG emissions and energy use

PJ
mln kg CO2-eq



Source: CBS, ABN AMRO Group Economics

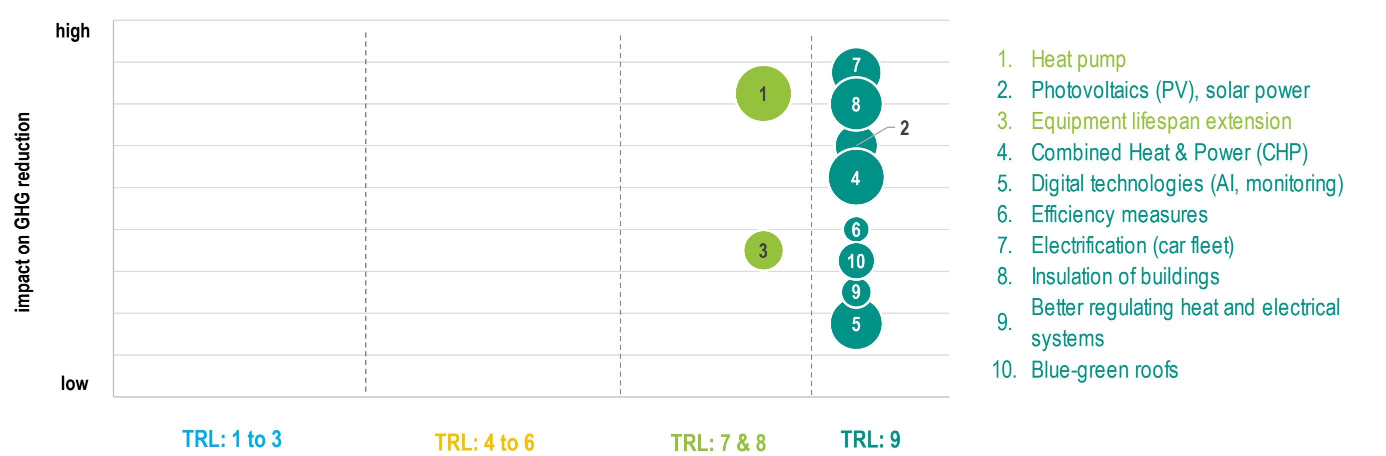
Specialist services (legal, consulting, architectural, advertising agencies) consume the most energy, with an emphasis on natural gas. However, the difference with electricity consumption is small. Rental and other services (employment agencies, travel agencies, cleaning, security), consume on average only half as much energy, partly because often more work is done on site at the client's premises instead of in their own offices. In this sector, there is a marginal difference between the amounts of natural gas and electricity consumption. Direct emissions from the service sector are, for example, fuel combustion in business equipment, such as cars. An example of indirect emissions is electricity, the generation of which takes place at another location. Another example is emissions from travel (flying) for business meetings.

Reduction strategy for the sector with current and future available low-carbon technologies

For companies in the service sector, many emission reduction opportunities relate to facilities or transport. Some service providers have innovative forms of cooperation with public and private parties in their supply chain, such as suppliers (upstream) and customers (downstream). Think here, for example, of collaborating with environmentally conscious partners in the supply chain or setting up internal sustainability initiatives with external parties. Companies in the service sector can try to promote sustainability in the chain by making their own more sustainable choices in their operations, but also by influencing, for instance, supply chains, customers and employees.

Available low-carbon technologies by TRL and emission reduction impact

size of the circle is an indication of the investment needed



Source: ABN AMRO Group Economics

Note: TRL stands for Technical Readiness Level: this represents the stage in which a new decarbonisation or emission reduction technique is at. Here, stage 1 represents the start of development and discovery. And stage 9 represents commercial readiness and that the technique can be deployed on a larger scale.

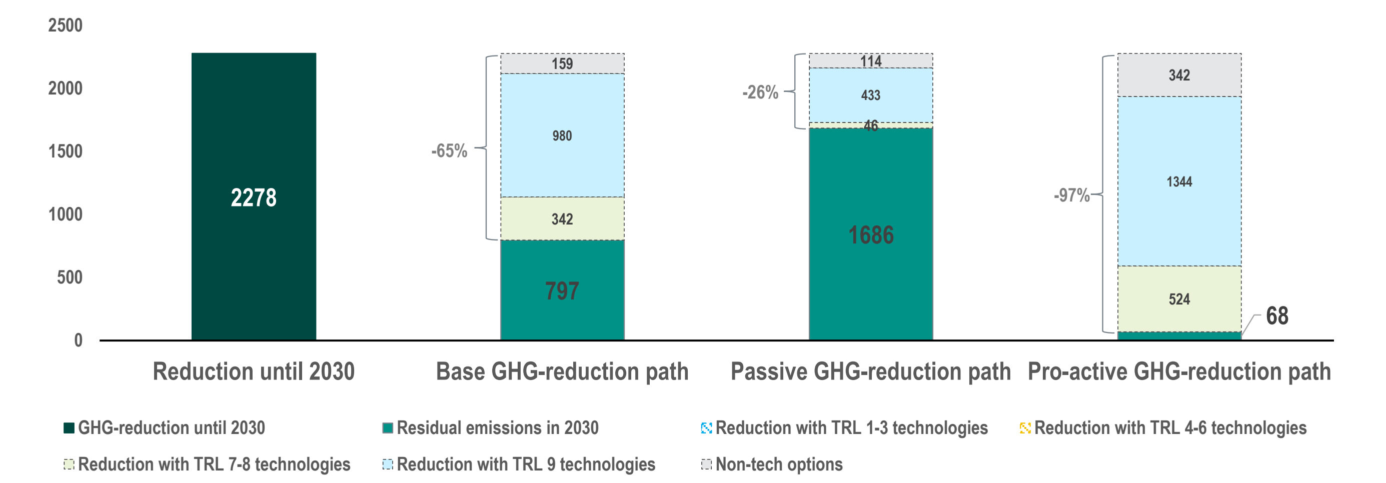
Business service providers have a wide range of different emission reduction options. These options range from sustainable purchasing (e.g. computers or other equipment with a green label or purchasing green energy) to implementing all kinds of efficiency measures for business processes or energy consumption. Within business services, fixed workplaces have given way in recent years to flexible workplaces, quiet rooms and central function rooms. Employees have started to work from home a lot. With this, waste flows and energy consumption within companies have become less intensive, thus slightly reducing the carbon footprint. Less paper has also been used, making way for many more digital information carriers. On balance, the CO2 effect of this is relatively low, but even small initiatives help.

Emission reduction potential up to 2030

In our baseline scenario up to 2030, we assume that further abatement progress is relatively slow. After all, the sector is at a much higher level of GHG emissions than in 1990. In other words, the real sustainability and emission reduction pathway has yet to begin. In the baseline scenario, we assume that heat pump deployment will make a relatively limited contribution until 2030. In our proactive scenario, that contribution is much larger. In the passive path, we think companies do not have the ambition level to join the transition. In the proactive scenario, there are much more incentives to become more sustainable. Here, we assume that the use of heat pumps will gain momentum, but also that much more is done in terms of building insulation and in-house generation of renewable energy.

Indicative impact of low-carbon technologies on the 2030 target

mln kg CO2-equivalents



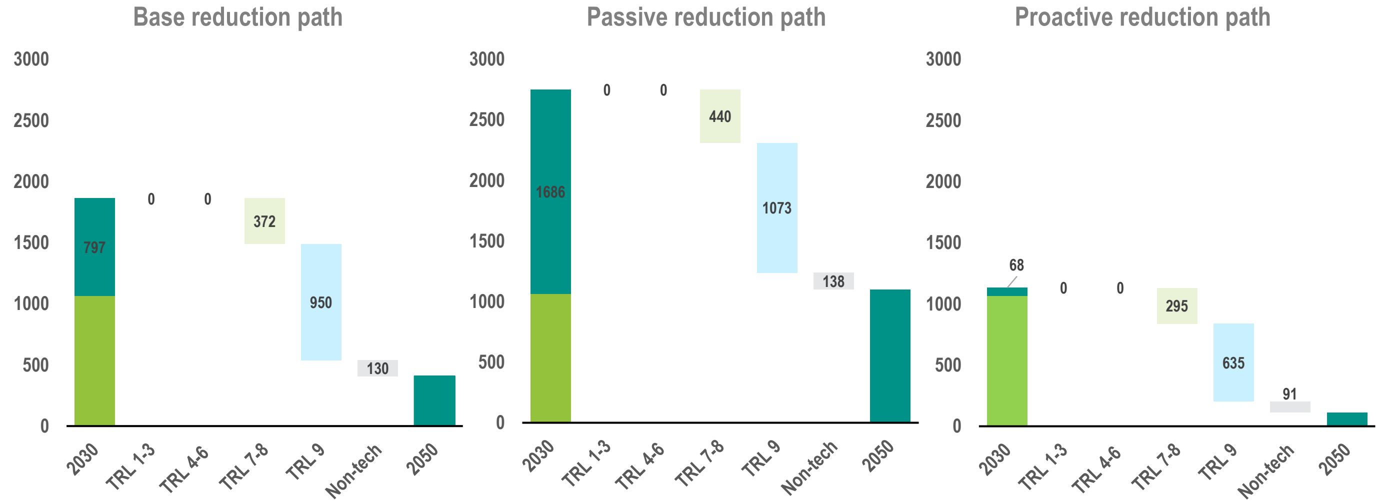
Source: CBS, ABN AMRO Group Economics

Emission reduction potential 2030-2050

Having a climate policy helps companies in the service sector to stay committed to minimising their carbon footprint in the long term. A company-level climate policy sets out, for example, how the company will monitor key climate indicators, how to reduce energy consumption and how to promote efficient energy use in premises. Policies can also be formulated on business travel, resource use (paper, water, office supplies), waste flows and reuse & recycling. To structurally comply with all environmental targets, it helps to proactively report externally and internally on the company's environmental performance.

Towards the carbon-neutral goal in 2050, regulations are likely to become increasingly stringent, also for companies in business services. Companies in the sector will thus be more-and-more encouraged to have a low-carbon strategy. To stick to the climate-neutral target until 2050, more service providers will have to invest in low-carbon technologies and ways of working. In our post-2030 proactive scenario, we assume that service providers have a high level of ambition to further reduce GHG emissions. The 2050 climate target is almost reached. In our passive scenario, the 2050 target is not reached. The necessary ambition and other incentives are missing in this case. This leaves low-carbon investment and sustainability in the sector hopelessly behind.

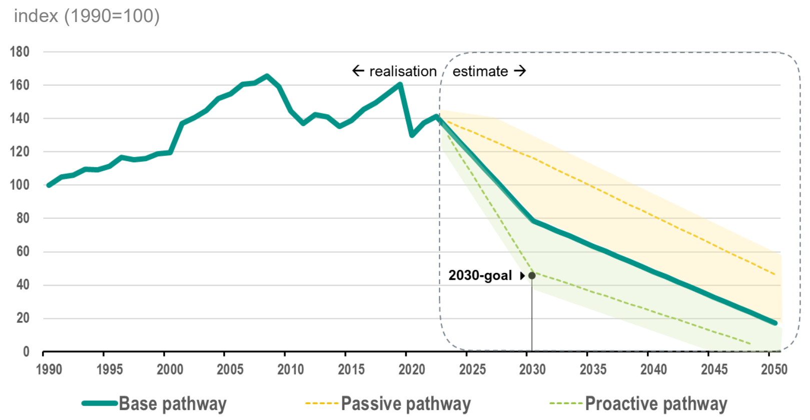
Emission reduction 2030-2050 in three pathways (in mln kg CO2-equivalents)



Source: CBS, ABN AMRO Group Economics

If we assume our baseline scenario in terms of emission reduction and the net-zero technologies available in the sector, our calculations show that the sector is also not going to meet the set target for 2050. For that, the GHG emission reduction gap is too high. This path is still independent of breakthrough technologies that might be introduced after 2030.

Emission reduction pathways towards 2050



Source: CBS, ABN AMRO Group Economics

With today's net-zero knowledge, retail and wholesale will achieve carbon neutrality after 2050. This could be the case around 2052. But again, nothing is set in stone. Innovative net-zero technologies may well be successfully introduced in the coming years, which could greatly improve our emissions projection.

Annex I

Decarbonisation technologies

In this appendix, we outline the available decarbonisation technologies, in the following categories: 1) electrification, 2) energy efficiency, 3) renewable energy, 4) building insulation & sustainability, and 5) feedstock substitution & transition. In each of these categories, we discuss the possibilities broadly, referring to existing publications or websites for more information on the technology at a more detailed level. We have also added a residual category 'combination decarbonisation technologies'. These are related to many other technologies.

In an earlier ABN AMRO publication, we listed the 11 most crucial decarbonisation technologies. The technologies are constantly evolving due to limitations and challenges. The list is therefore not exhaustive and will also change over time. You can find the list **here** (source: ABN AMRO). Below is an overview of the technologies by category and by sector.

Available decarbonisation technologies in general terms:

- **Electrification:**
  Electrification involves replacing an energy or heat source with fossil-free electricity. E.g. electric cars or trucks instead of one that runs on petrol, gas or diesel. But also electric heating (e-boiler, high-temperature heat pump) instead of oil or gas boilers. Many parts of energy-intensive industry have processes which need to reach high temperatures. That's is the main source of energy consumption. For achieving lower temperatures, electrification is less complex. Heat pumps and electric furnaces are relatively easy to implement in the production process for this purpose. Electrification usually requires high investments. More on the basics of electrification, please click **here** (source: IEA).

  It is clear that electrification is going to play a bigger role in the energy transition. To realise an acceleration in electrification, it is important that governments, grid operators, industry representatives and entrepreneurs, the energy sector and other stakeholders cooperate more intensively and, above all, co-invest in infrastructure and capacity. Large amounts of renewable electricity will be needed in the coming years, requiring a lot of space on the grid. According to the *TNO* study 'Electrification is crucial for a future-proof and sustainable industry' (October 2021), this is a feasible task. You can find the report **here** (source: TNO).

  Although all kinds of energy sources can generate heat and steam, fossil-fired boilers are still dominant in the industrial process. As a result, these boilers are a major source of GHG emissions. Decarbonising the demand for industrial heat and steam through electrification using low-carbon electricity can thus contribute significantly to reducing GHG emissions. Research by *McKinsey & Company* shows that electrically powered equipment is only slightly more energy-efficient than the conventional option. The advantage of electric-powered equipment is that maintenance and investment costs are lower. Another advantage is that when carbon-free electricity is used, GHG emission reduction is higher.

  Space heating or process heat is usually done by burning fossil fuels. A regular heat pump uses energy from the ground, outside air or groundwater to heat (commercial) spaces. An industrial heat pump mostly uses (process) residual heat. This residual heat is upgraded and reused in industrial processes inside or outside the company. It is an economical and sustainable technology. The use of heat pumps seems like an easy-to-implement decarbonisation solution. However, it always requires customisation. Operational feasibility and installation costs vary greatly due to factors such as the condition of a building, the complexity of the production process, the size of the heat distribution & current infrastructure and the degree of insulation of the commercial buildings. For more information on heating technologies, see **here** (source: ABN AMRO).

Electrification is also reflected in the decarbonisation of mobility. Several options are available for this. Dutch government policy is that every new car sold from 2030 onwards must be a zero-emission car. This could be a battery-electric car or a fuel-cell electric car. Faster introduction of fleet electrification through incentives, more affordable electric vehicles and stricter emission targets for combustion engine vehicles are crucial to reduce emissions faster. More background on fleet electrification can be found **here** (source: ABN AMRO).

- **Energy efficiency:**

  Energy efficiency is often seen as the low-hanging fruit because there are many ways companies can start doing this from tomorrow onward. Think of simple interventions like installing LED lighting or saving energy by not heating unused rooms. But it can also go further than this, requiring more effort and investment. Think of product redesign (packaging, less use of raw materials), the use of residual heat (for other internal processes or to other companies), digitalisation of processes (process efficiency through monitoring & sensoring).

  Energy efficiency can be achieved in many different ways. Measures can vary widely in degree of impact on reducing energy consumption and GHG emissions. The government also has an important role here. In the transport sector, for example, it can promote sustainable mobility and low-carbon transport alternatives more, such as rail, cycling, walking or shared mobility. Once this use intensifies, less energy is consumed on balance. And so renovation of existing buildings in the built environment - where the biggest challenge for the sector lies - is going to help improve energy performance. Drafting incentive and support policies is going to help accelerate the pace of renovation.

  As of 1 July 2023, the government has tightened the energy-saving obligation for companies and institutions to accelerate energy saving. The measure applies to entrepreneurial businesses in the Netherlands. Companies and institutions with annual consumption from 50,000 kWh electricity or 25,000 m3 natural gas (equivalent) have an information obligation and must report on initiatives. For large energy users in certain sectors with annual consumption of 10 million kWh of electricity or 170,000 m3 of gas (equivalent) or more, there is an obligation to investigate. More details on the directive can be found **here** (source: RVO).

  For energy-intensive industry, energy costs weigh relatively heavily in international competitiveness. With higher energy prices, the industry has introduced more energy efficiency measures. The sector was already achieving good results in this area, improving energy efficiency almost every year. However, the pace is still generally slow. The *Netherlands Environmental Assessment Agency* (PBL) has made an overview of energy efficiency measures and opportunities in the Dutch manufacturing industry. PBL also identifies a number of obstacles: financial barriers, labour shortages, lack of knowledge and skills, lack of urgency of efficiency among companies, validation of technologies and timing. This report can be found **here** (source: PBL).

  As part of the *European Green Deal*, there is an energy efficiency directive. This directive was recently updated and adopted, to get the EU 'Fit for 55'. The directive introduces a series of measures to accelerate energy efficiency. It contains a legal obligation for EU countries to prioritise energy efficiency in policy-making, planning and investment. Greater energy efficiency is going to reduce energy costs for companies, as well as greenhouse gas emissions. The focus on energy efficiency will increase in the coming years, especially in major energy-consuming sectors, such as transport, the built environment and energy-intensive industry. But the ICT sector is also getting more attention in this perspective because of the strong growth in the number of data centres. The details of this new directive can be found **here** (source: European Commission).

- **Renewable energy:**

  In this category, the primary focus is on the production of renewable energy on own premises or on site, such as with solar or wind power, geothermal, hydropower, biomass. Investments relate to solar panels on company premises, solar parks, wind farms and so on.

Fossil energy sources are, on balance, largely exhaustible or finite resources. With renewable energy, however, sources can be inexhaustibly replenished, such as wind, sun, earth, hydropower and biomass. Moreover, the big advantage is that it is low-carbon energy in the end. This makes renewable technologies profitable from both economic and environmental perspectives. Investing in the production and deployment of renewables is thus the cornerstone of the energy transition.

Solar energy is an important renewable source for the energy transition. Globally, solar energy is the fastest-growing clean technology. By 2022, solar capacity reached 224 GW or 13% of total renewable capacity worldwide. ABN AMRO's background analysis covers current and emerging technologies and looks at how far we are from an ideal world. The analysis is preceded by some basics about solar technology, before discussing the various solar technologies, other emerging technologies and applications. The publication is **here** (source: ABN AMRO).

Wind power is also an important strategic source of renewable energy. Climate change and the priority given to energy security by some countries, such as the European Union, have put wind energy at the top of the list as a strategic renewable energy source. Europe is considered to have an abundance of wind energy. With the *REPowerEU* plan, the European Union aims to achieve a 39% share of renewable energy in the European electricity mix by 2030. This target was further increased to 42.5% in May 2023. To reach this target, wind power capacity in the EU needs to increase by 129 GW in the period 2023-2027, on top of the current 255 GW already installed. Globally, and according to the *Global Wind Energy Council* (GWEC), wind power capacity reached 906 GW by the end of 2022, growing 9% year-on-year. GWEC further predicts that 680 GW of new capacity will be added between 2023 and 2027. Wind power thus continues to play a vital role in the energy transition. In an earlier analysis by ABN AMRO, we elaborate on the opportunities and challenges for wind power investments. The publication can be found **here** (source: ABN AMRO).

Geothermal energy is heat energy from the earth. Geothermal springs are existing reservoirs of hot water or man-made reservoirs. The springs have different temperatures and vary in depths below the earth's surface. These underground geothermal reservoirs of steam and heated water can be used to generate electricity and other heating and cooling applications. *Geothermie Nederland* is committed to promoting the investment climate in geothermal energy and confidence in this technology as a sustainable source. For more information on geothermal energy, click **here** (source: Geothermie Nederland).

According to *European Biomass Industry Association* (**EIBIA**) there are 6 biomass processing technologies. These are based on: direct combustion (for power), anaerobic digestion (for methane-rich gas), fermentation (of sugars for alcohols), oil extraction (for biodiesel), pyrolysis (for biochar, gas and oils) and gasification (for carbon monoxide and hydrogen-rich syngas). Biomass is thus mainly produced from organic material. When this biomass is used to produce energy, carbon is released during combustion and returns to the atmosphere. As more biomass is produced, the same amount of carbon is absorbed, making modern bioenergy an almost emission-free fuel. According to *the International Energy Agency* (**IEA**), it is a major source of renewable energy, accounting for more than 6% of global energy supply.

- **Building insulation & -sustainability:**
This concerns commercial buildings in every sector. Insulation refers to making a building airtight, ensuring lower heat demand, with less energy consumption as a result. Think in this perspective of floor insulation, facade insulation, roof insulation or insulated double glazing. Many insulation measures require large investments and are often radical measures. Incidentally, it also happens that the company has no direct influence on making premises more sustainable because, in many cases, the premises are not under its own management and ownership lies with a third party.

A chain approach can help kick-start the transition to a climate-neutral built environment. This means a more sector-wide transformation throughout the entire life cycle of the built environment, with building owners, producers of building materials, installers, energy companies and municipalities cooperating and coordinating intensively. The government should be the lubricant in this chain approach. This means that they commit to: clear and transparent building codes and energy standards that apply for a longer period of time, short procedures around licensing and sufficient financial incentives to make the climate-neutral goal attainable for every owner, user and resident.

- **Raw materials substitution & -transition:**
  This covers techniques such as fuel substitution and replacement of raw materials in the production process for sustainable variants. These can sometimes be major changes, often involving relatively high investments. The use of other more sustainable fuels and raw materials can have a major impact on the way the production process is set up (process redesign). This concerns new fuel technologies.

  Fossil fuels can be replaced by less polluting synthetic fuel alternatives. Renewable diesel and biodiesel can replace petroleum diesel. E-methanol, bioethanol or solar-powered methanol can replace methanol, and green hydrogen can replace blue and grey hydrogen. However, these more sustainable fuels are expensive, most are limited availability and there are many other challenges.

  Replacing fossil fuels with fuels that produce fewer or no emissions seems simple. But in reality, it is a complicated undertaking. For a start, there are many different types of more sustainable fuels. Each fuel has its own characteristics and therefore different fuels are suitable for different applications. For example, fuels can be compared based on their emission intensity, energy density, storage requirements, safety, cost and fuel infrastructure and production. More information on trends in synthetic fuels is **here** (source: ABN AMRO).

  Resource- and energy-intensive industries can be one of the main contributors to the industrial transition that will ensure a low-carbon Europe. Industry needs to step up its efforts to develop and adopt low-carbon production processes and promote them in its complex supply chains. Decarbonisation of industry will directly depend on the availability of sufficient affordable low-carbon energy sources for low-carbon industrial production. The transition to a circular economy can also play a role for resource- and energy-intensive industries to reduce their energy and resource consumption.

- **Other combination technologies:**
  Then, finally, there are a number of other technologies that have a relationship with other technologies.

  Battery technology:
  Energy storage technologies refer to the use of grid-connected energy storage technologies to store excess energy when demand is low or supply is high and deliver it back to the grid when needed. It plays a role in stabilising the electricity grid. As more investment is made in renewable energy sources, such as wind and solar power, electricity systems become increasingly vulnerable due to their intermittent nature. The greater the share of renewables in the energy mix, the greater the need for storage capacity. Therefore, storage is expected to play a vital role in the energy transition by providing security and flexibility. The first thing that comes to mind when you think of energy storage is the use of electrochemical batteries. Other (innovative) solutions to store energy are also emerging with a number of promising technologies. An earlier ABN AMRO analysis looks at recent developments in energy storage technologies, their associated pros and cons and their potential role in the transition. This publication can be found **here** (source: ABN AMRO). In another analysis, we look specifically at existing and emerging battery technologies and highlight the advantages and disadvantages of the technologies. This publication can be found **here** (source: ABN AMRO).

  Carbon Capture & Storage (CCS):
  Carbon capture and storage (CCS) is essential for the energy transition, but still has a very small share of CO2 reduction technologies. In an analysis by ABN AMRO, we look at the different layers of carbon capture technologies. We also discuss how the different techniques of CCS play a crucial role in improving the technologies and lowering the overall CCS cost. Currently, CCS is one of the more expensive technologies to decarbonise carbon dioxide. The publication is available **here** (source: ABN AMRO).

  Fuel cell:

A fuel cell uses the chemical energy of hydrogen or other fuels to produce electricity cleanly and efficiently. When hydrogen is the fuel, the only products are electricity, water and heat. Fuel cells work like batteries, but they do not go flat and do not need recharging. They produce electricity and heat as long as fuel is supplied. A fuel cell consists of two electrodes-a negative electrode (or anode) and a positive electrode (or cathode)-clamped around an electrolyte. A fuel, such as hydrogen, arrives at the anode and air at the cathode. In a hydrogen fuel cell, a catalyst (such as platinum) at the anode separates hydrogen molecules into protons and electrons, which follow different paths to the cathode. The electrons pass through an external circuit, creating a current of electricity. The protons migrate through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce electricity. with oxygen and the electrons to produce water and heat. More information on fuel cells can be found **here** (source: ABN AMRO).

Heat:
Heating is usually done by burning fossil fuels. There are several ways to reduce fossil use for heat. We can keep burning something. But then the fuel or mass has to be replaced by a more sustainable and low-emission fuel or mass. The availability and production of these fuels are still limited and not enough to replace fossil fuels. There are other sources to generate heat namely the sun (via solar thermal collectors), the ground, air and water (via heat pumps). The options are available, but the costs are still high compared to burning fossil fuels. There is another challenge related to heat pumps. It is likely that the EU will further tighten regulations to reduce the use of fluorinated gases (F-gases) used as refrigerants in heat pumps. This could hamper the rollout and/or acceptance of heat pumps. Waste heat is another heat source that is mainly wasted. The potential of waste heat for industry and district heating is considerable. Finally, renewable electricity can be converted into heat for households and industry. More information on heat can be found **here** (source: ABN AMRO).

ABN·AMRO

Annex II

Sources consulted

Introduction

This appendix lists all sources consulted by sector. These can be websites or databases, but also reports from national or international industry organisations, consultancy firms, research institutes, knowledge institutes, NGOs, governments and annual reports or reports from companies in sectors that have taken steps towards decarbonisation. Much use was also made of analyses by ABN AMRO Group Economics.

Cross-sectoral sources:

The basis of this report is the ABN AMRO report 'Decarbonisation strategies for sectors' from October 2022. Much information on the different decarbonisation technologies by sector from that report can be found in this publication. Another important source - especially for the industry sector - is PBL & TNO's MIDDEN project. The industrial decarbonisation technologies outlined in the approximately 40 reports of the MIDDEN project have been used as a source for this report.

Other cross-sectoral sources:

- ‘Decarbonization: Status, Challenges, and Policy Options for Carbon Capture, Utilization, and Storage’ by Government Accountability Office (GAO); September 2022
- ‘Energy efficiency options in the Dutch manufacturing industry’ van Planbureau voor de Leefomgeving (PBL); August 2023
- ‘Waterstof voor klimaatneutrale warmtevoorziening in bestaande bouw’ van TNO; March 2020
- ‘The net-zero transition: What it would cost, what it could bring’ van McKinsey; January 2022
- ‘Decarbonising Homes in Cities in the Netherlands: A Neighbourhood Approach’ van OECD; 2023
- ‘Klimaat- en Energieverkenning 2023: Ramingen van broeikasgasemissies, energiebesparing en hernieuwbare energie op hoofdlijnen’ van PBL (e.a.); 2023
- ‘Kansen en kwetsbaarheden in een wereld in beweging: Toekomst van de Nederlandse industrie’ van TNO; October 2023
- ‘Anders consumeren om klimaatdoelen te halen: Een verkenning van manieren om het systeem te veranderen en hoe iedereen daaraan kan bijdragen’ van TNO; February 2023
- ‘Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach’ van IEA; 2023 update
- ‘Evaluatie energie-investeringsaftrek, periode 2017-2021’ van SEO Economisch Onderzoek; 2022
- ‘Industrial Innovation: Pathways to deep decarbonisation of Industry: Part 1: Technology Analysis’ van ICF Consulting Services Limited & Fraunhofer ISI; January 2019
- ‘Mitigating GHG-emissions in hard-to-abate sectors’ van PBL & Univeristeit Utrecht; July 2022
- ‘Technology pathways in decarbonisation scenarios’ van A. De Vita (e.a.), ResearchGate; June 2018
- ‘Europe’s Path to Net Zero Emissions’ van Intereconomics; 2021
- ‘Sectoral pathways to net zero emissions’ van Institute for Sustainable Futures; 2020
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Our approach and methodology:

Sector selection (appendix): The choice of these sectors is based on a number of indicators that are important for the GHG emission reduction pathway to 2050, such as: the share in total GHG emissions of the sector, the average growth in value added of the sector over the last 20 years, the share of SMEs, the required emission reduction, the number of decarbonisation technologies available in the sector and the feasibility of climate targets for the sector. The introduction to the 21 sector depths briefly describes the definition of the three scenarios used (basic, passive and proactive).

Emission reduction pathways: The emission reduction pathways we have presented in this report are based on our own calculations (as far as possible) and our own estimates. Our calculations are mostly based on external publications, such as from the MIDDEN project (industry, PBL/TNO), GHG reduction roadmaps made by national or international industry organisations or interest groups and NGOs, publications by consultancies or scientific publications. In some cases, own estimates are also the basis of the different emission reduction paths in sectors towards 2050. Own estimates were sometimes necessary, because in some cases the relevant data for further calculations were missing. To paint as complete a picture as possible regarding the impact on the Dutch economy using the chosen sectors, we made estimates. The basis of the estimates were, for example, experiences in other sectors with certain decarbonisation technologies, qualitative interpretations in external publications (also scientific), the results of decarbonisation efforts with certain technologies of companies in sectors so far and sector expertise and practical experience of colleagues within ABN AMRO.

Starting points: Broadly speaking, the following factors underpin our emission reduction paths towards 2050:
- The historical GHG emission reduction path of sectors from 1990 onwards (CBS): Past efforts broadly indicate what the feasibility of the 2030 target might be. From this, it can be partly concluded whether the 2030 and 2050 benchmarks can be met.
- The availability of preconditions associated with an emission reduction pathway, such as investment in infrastructure or the availability of charging stations or the availability of skilled personnel.
- The stringency and scope of government policies in sectors. GHG emissions from sectors with many large companies covered by the EU ETS, for example, will tend to decrease at a higher rate than in sectors where this is not the case.
- The availability and number of decarbonisation technologies at the TRL-9 stage by sector, their potential impact on GHG emissions and the level of investment in them. These TRL-9 technologies have the greatest impact on the pathway to 2030. For the technologies in stages 7 and 8, we assume that their potential is more medium-term. The technologies in TRL stages 1 to 6 have limited impact towards 2030, but these have the potential to make the difference in the path between 2030 and 2050.
- The financial position of companies in the sector. For example, low-margin sectors will invest less in technologies that require relatively high

Limitations of our approach and methodology:

Our emission reduction paths arrive at linear trajectories to the 2030 climate targets and between 2030 and 2050. The use of these linear trajectories is a simplification. In reality, such trajectories never run linearly. For instance, the implementation of new technologies never runs linearly, but has different phases from the start-up phase, to early growth, to advanced growth and to maturity and eventually saturation. This trend affects the final trajectory.

As indicated earlier in this report, the holistic approach to climate issues in sectors is missing and we only make a statement on scope 1 emissions. With such an approach, it is easier to get a grip on this complex issue. After all, sectors are highly interconnected, not only nationally but often internationally as well. With a holistic view - providing insight into scope 1 to 3 emissions - the complexity of climate issues will become more insightful.

Our estimates are based on our own assumptions in case of outdated or missing quantitative and/or qualitative relevant information. These assumptions are made by us and are therefore arbitrary.

Developments are happening rapidly in making the economy more sustainable. Innovation is moving fast and the impact of breakthrough technologies is difficult to analyse. The technologies we have included in this report are not all-encompassing and undoubtedly important ways to reduce GHG emissions are missing here. With the available knowledge and resources at our disposal, we have attempted to provide as complete an overview as possible of all decarbonisation technologies in sectors.