1. Executive summary

1.1 Introduction

This is Sweden's Eighth National Communication (NC8), which summarises the progress Sweden has made to meet its obligations under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Emissions of greenhouse gases in Sweden, excluding emissions and removals from land use, land use change and forestry (LULUCF), have decreased with 35 % over the period 1990–2020 and are expected to continue to decrease.

As part of the EU, Sweden takes on a quantified, economy-wide emission reduction target jointly with all other Member States both under UNFCCC and the Kyoto Protocol for the period 2013–2020. For the EU, the Kyoto commitment is the same as the Convention target except that it also includes LULUCF and excludes aviation emissions. The Swedish commitment under the Kyoto Protocol is the Member State share of the EU Effort Sharing Decision (ESD), where Sweden has committed to reducing emissions in sectors covered by the ESD by 17 % compared with 2005 emissions. For the LULUCF sector under the Kyoto Protocol, Sweden will account for the mandatory activities: afforestation, reforestation, deforestation and forest management.

1.2 National circumstances

Factors affecting a country's current and future levels of greenhouse gas emissions and removals include population, climate, energy and transport systems, industrial structure, and the economy. Sweden extends in a south-south-westerly/north-north-easterly direction from latitudes 55 to 69 degrees north and from longitudes 11 to 23 degrees east, with a land area of 406,550 km^2. Urban land make up 3 % of the land area, while productive forest land account for 58 %, farmland 8 %, wetlands 12 %, alpine areas, subalpine woodlands and rock surface, 17%, and other land 2%[1] (Swedish University of Agricultural Sciences, 2021). Inland water systems total more than 40,000 km^2, or more than 9% of Sweden's total area. Southern Sweden is low-lying, with agricultural land predominating in the far south. The only real mountain chain, with peaks rising to over 2,000 m above sea level, is along the Norwegian border in the north-west.

[1] Five year average 2018

Sweden's proximity to the North Atlantic and prevailing south-westerly to westerly winds result in a climate that, for the latitude, is mild in the winter months. The northernmost part of the country, however, has a sub-Arctic climate with long, cold and snowy winters. In the period 1961–90 the mean temperature in January was 0 °C in southernmost Sweden, while the coldest northern valleys had −17 °C. The daily mean July temperature was approximately 17 °C in south-eastern Sweden and just over 10 °C in the north. The mean temperature was about 1° higher in the years 1991–2020 than in 1961–90. The largest rise, over 2°, took place in the northern parts of Sweden in winter. Overall, owing to the rise in temperature, the densely populated areas (including Greater Stockholm) have undergone a shift from a cold-temperate to a warm-temperate climate.

Sweden has an open, trade-oriented economy. In 2020, the nation's gross domestic production (GDP) was SEK 4.98 trillion or close to SEK 481,000 per capita. Natural resources, such as forest and iron ore, are a basis for industrial production and, along with the engineering industry, have brought about a strongly export-oriented economy. Since 1990, exports have grown faster than imports and the trade balance has been positive. In 2019, exports accounted for 47 % of GDP. Main export industries are machines, vehicles, pharmaceuticals and chemicals, wood products, electronics and minerals.

The Swedish energy system is partly based on domestic sources of renewable energy such as water, wind and biofuel. In addition, a large proportion of the energy supplied is dependent on imports such as nuclear fuel for electricity production in nuclear reactors and fossil fuels like oil and natural gas for the transport system. Swedish electricity production is based largely on hydropower and nuclear power, but the expansion of wind power is steadily increasing as well as the use of biofuel for electricity and heat production. Total final energy use has increased by 20 % since 1970 and has been stable at approximately 520-560 TWh for the past ten years. Of total electricity production in 2019, hydropower accounted for 39%, nuclear power also 39% and wind power 12 %, while biofuels and fossil-based Combined Heat and Power production made up the remaining 10%.

Sweden has a mixed industry, characteristically based more on raw materials than many other countries. For example, the extensive forest industry (wood products, paper, and pulp) and the iron and steel industry are based on domestic natural resources. Indeed, the forest industry and iron and steel industry, together with the chemical industry, have long been an important

part of the Swedish industry, and today contribute significantly to the nation's exports. The manufacturing sector is important to the economy, accounting for nearly 20 % of GDP in terms of value added in the private sector in 2019.

Domestic transport is dominated by road traffic. Several factors affect greenhouse gas emissions from traffic, especially transport volume and the technology used. Transport activity for passengers and goods alike has increased since 1970. Vehicle kilometers travelled has increased for passenger vehicles, lorries and motorcycles since 1990, whilst buses/coaches have remained relatively stable. In terms of greenhouse gas emissions, the rapid rise in passenger travel has been offset by more energy-efficient cars and increased use of renewable fuels, which have resulted in a decrease in emissions per passenger-kilometer. The efficiency of freight transport also improved in the 1990s, but this trend has since leveled off. In 2019, fossil fuels accounted for 77 % of the energy used by domestic transport, while the remainder consisted of biofuels and electricity.

Sweden's forest land amounts to 27.9 million hectares hectares (ha). Of the total forest area, 23,5 million ha is regarded as productive forest, corresponding to 58 % of the total land area. Accordingly, there is also 4.4 million ha of unproductive forests (11 % of total land area). It is for the total forest area that greenhouse gas emissions and removals in forests are reported.

1.3 Greenhouse gas inventory

In 2020, total greenhouse gas emissions (excluding LULUCF) in Sweden was 46.3 million tonnes of carbon dioxide equivalents (Mt CO_2-eq.). Between 2019 and 2020 the total greenhouse gas emissions decreased by 9 %, largely due to the COVID-19-pandemic. Total emissions have decreased by 25.1 Mt CO_2-eq, or 35 %, between 1990 and 2020. Emission levels have varied between a low of 46.3 Mt CO_2-eq. in 2020 and a high of 77.3 Mt CO_2-eq. in 1996. The net sink attributable to the land use, land-use change and forestry (LULUCF) sector has varied over the period but has generated annual net removals in Sweden during the whole period 1990-2020. In 2020 total net removal from the sector was estimated to 40 Mt CO_2-eq.

In 2020, emissions (excl. LULUCF) of carbon dioxide (CO_2) amounted to 36.5 Mt CO_2 in total, which is equivalent to 79 % of total greenhouse gas emissions, calculated as CO_2-eq. Emissions of methane (CH_4) accounted for 4.1 Mt of CO_2-eq. (about 9 % of total emissions), emissions of nitrous oxide (N_2O) 4.6 Mt (9 %), fluorinated greenhouse gases (HFCs, PFCs and SF6) 1 Mt (2 %).

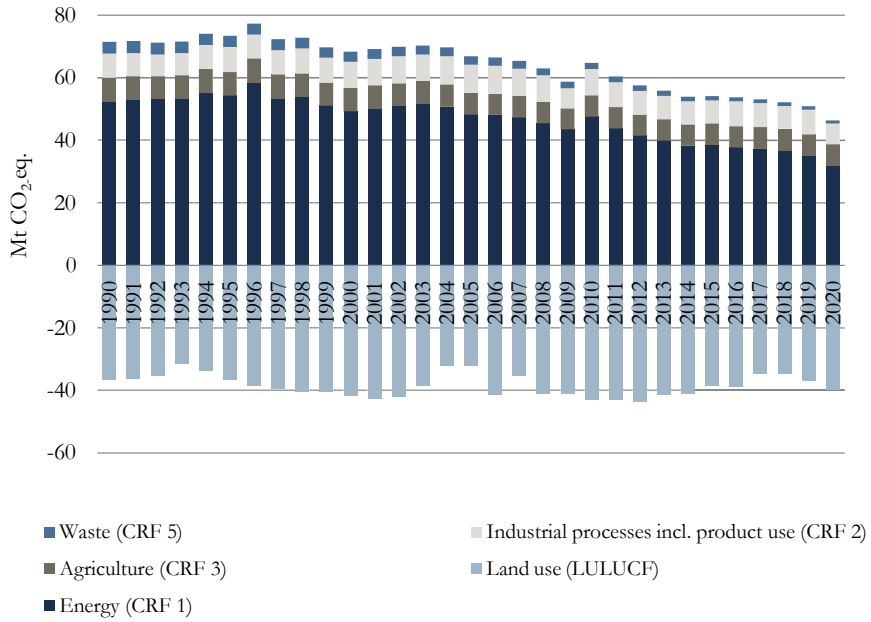


Figure 1.1 Total greenhouse gas emissions and removals in Sweden 1990-2020

Since the late nineties there has been a decreasing trend in Sweden's greenhouse gas emissions. The largest reductions in absolute terms are due to a transition from oil-fuelled heating of homes and commercial and institutional premises to electricity, e.g. heat pumps and district heating. Increased use of biofuels in district heating generation and industry has also contributed to the reductions together with reductions in landfilling of waste. Fluctuations in production levels of manufacturing industries following changes in the economic development of specific industries have also had significant impacts on the national trend.

1.4 Policies and measures

Sweden's climate strategy has progressively developed since the late 1980s. To provide a clear structure for environmental efforts in Sweden, the

Riksdag (the Swedish Parliament) has adopted 16 environmental quality objectives. One of these, Reduced Climate Impact, forms the basis for climate change action in the country. The interpretation of the objective mirrors the Paris agreement, "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. Sweden will work internationally towards global efforts to address this goal."

In 2017, the Riksdag adopted a national climate policy framework for Sweden. The climate policy framework consists of a Climate Act, national climate targets and a climate policy council. The climate policy framework is the most important climate reform in Sweden's history. It creates order and stability in climate policy and sets long-term conditions for the business sector and society at large. The Act imposes responsibility on the current Government, and on future governments, to pursue a climate policy that is based on the national climate targets and to provide clear feedback on the progress. As a result, Sweden now have long-term climate targets (see Figure 1.2) and a council that independently reviews climate policy. The reform is a key component of Sweden's efforts to live up to the Paris Agreement.

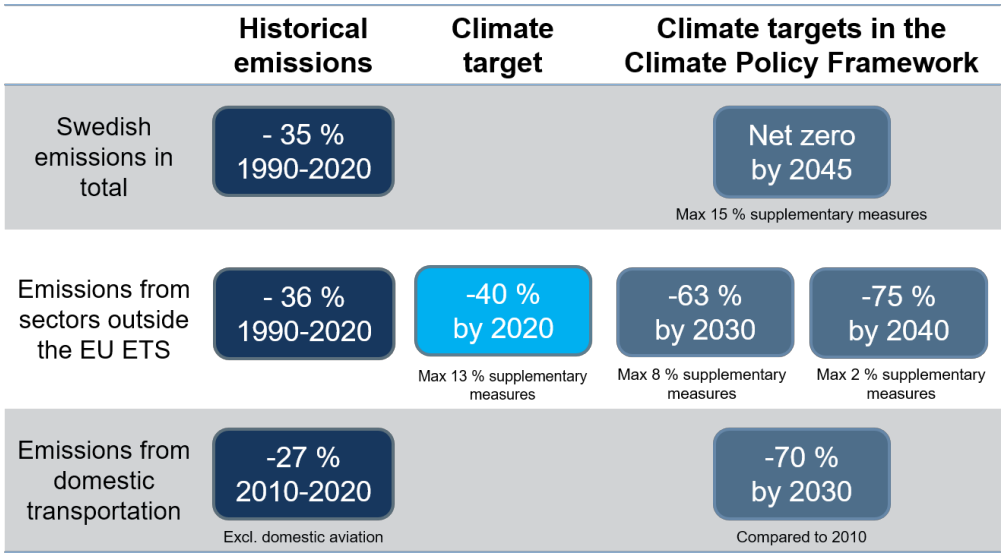


Figure 2. Sweden's national targets included in the climate policy framework.

The climate policy is also set out in two previous Government Bills, entitled *An Integrated Climate and Energy Policy*, passed by the Riksdag in 2009. The first of these Bills sets a national milestone target for climate, calling for a 40

% reduction in emissions by 2020 compared with 1990. The target applied to activities not included in the EU Emissions Trading System (EU ETS) and was more ambitious than Sweden's commitment under the Effort Sharing Decision (ESD) implementing the EU Climate and Energy Package.

Sweden has introduced a range of policies and measures directly or indirectly affecting greenhouse gas emissions. The emphasis in the country's climate strategy is on the use of general economic instruments. However, many instruments which interact with carbon dioxide tax and emissions trading have also been adopted to achieve other policy goals than the climate objective, such as energy policy objectives.

Since the early 1990s, two key instruments in reducing Swedish emissions have been the energy and carbon taxes. These taxes have been supplemented with other instruments, such as an electricity certificates system, technology procurement, public information campaigns, a CO_2-based annual vehicle tax and investment grants. Legislation including bans, standards and urban planning also plays a part in curbing emissions. EU-wide policy instruments, in particular CO_2 emission performance standards for new vehicles and the EU ETS, are also important in Sweden.

In the budget proposal for 2022 (Govt. Bill 2021/22:1), the Government proposed measures to ensure that Swedish industry will retain its leading position in the climate transition, to contribute to infrastructure that leads to a more sustainable society and to accelerate work to transition to a more circular economy and a greener everyday life. At the same time, developments in recent decades have been defined by a framework for spatial planning and other long-established instruments in Sweden. Of particular importance are investments from earlier decades in expanding district heating networks, public transport systems and the carbon-free production of electricity.

1.4.1 Cross-sectoral policy instruments

Alongside the energy and carbon dioxide taxes, a set of other cross-sectorial policy instruments are applied in Sweden, such as grants (local climate investment program), climate communication, and research and development. A local climate investment program was introduced in 2015 and has since been scaled up. In total, SEK 7.7 billion has been granted for investments within the program (as of November 2021). Examples of investments that can be granted support are charging infrastructure for

electric vehicles, biogas plants, infrastructure for biofuel and changes from fossil oil to biofuel or district heating.

In order to achieve net zero emissions by 2045, and enable negative emissions thereafter, a national center for carbon dioxide capture and storage has been established at the Swedish Energy Agency.

The government has decided on a national strategy for electrification. The strategy will contribute to a fast, smart, and economically efficient electrification. In the strategy, the government takes a holistic approach to the conditions in the energy sector, including a plan on how to tackle obstacles, to enable increased electrification. Means has been allocated to enable the implementation of the strategy to meet society's needs and expectations. Among other things, the Government intends to set up an electrification council to support the implementation of the electrification strategy.

The Swedish Government has adopted the objective to make Sweden one of the world's first fossil-free welfare states. This ambition requires a mobilisation of the entire society, not least municipalities, cities and business. To that end the government has launched the Fossil-Free Sweden initiative which mobilises and supports key actors in their climate efforts by providing a platform for dialogue, cooperation and inspiration between themselves and the Government. A national coordinator, appointed by the government, is the link between the actors and the government in efforts to remove obstacles and create conditions to speed up the reduction of greenhouse gas emissions.

Public investment in climate-related research and development has increased in recent years and aims at creating better prerequisites for achieving the substantial longer-term emissions reduction required. Swedish climate-related research covers a broad spectrum, from natural sciences to humanities, but places an emphasis on technical and scientific research and development. Three important research areas are energy, transport, and industry, for which the Government has decided to grant extensive funding.

1.4.2 Energy sector

The production of district heating has risen approximately 50% since 1990. At the same time, emissions from this source have been significantly

reduced, as the expansion largely has been achieved by the increased use of biofuels. The carbon tax is one of the main factors behind this trend - the aggregate level of taxes on fossil fuel use in the sector has risen steadily since 1990 - but the electricity certificate system has also been important in phasing out fossil fuels in the sector. Since 2005, most combustion installations for power and heat production have been included in the EU ETS, which also is a key policy instrument for the sector.

Several policy instruments target energy use in homes and commercial and institutional premises. These include building regulations, energy performance certificates, the EU Energy Labelling Directive, Energy Efficiency Directive and the Ecodesign Directive, which results in energy savings by helping to eliminate the least energy-efficient products There are several initiatives for wind power expansion as well as support for installations of solar power systems and systems for storage of self-produced electricity. With the aim to reduce greenhouse gas emissions private individuals are, since 1 January 2021, eligible to a tax reduction for installation of green technology including solar cells, systems for storage of self-produced electricity and at home charging stations.

1.4.3 Industrial sector

Total emissions from combustion in manufacturing industries as well as from industrial processes are trending downward. Instruments primarily affecting combustion emissions from the industrial sector include the EU ETS, energy and carbon dioxide taxes, the electricity certificates system and the Environmental Code.

Greenhouse gas emissions from industrial processes show an overall decreasing trend since 2006. These processes are regulated by the Environmental Code's requirement to use the best available technology. Other instruments affecting process related emissions include the EU ETS, the Energy Step, Energy Audits and the Industrial Leap. The Industrial Leap is a long-term reform which began in 2018 and continues until 2040. It consists of a government scheme that aims to support development of technology and processes to reduce the process-related greenhouse gas emissions in Swedish industry.

The Government is introducing a reversed auction where the winning company (the company offering the most cost-efficient solution) will receive operating aid to BECCS (Bio-Energy with Carbon Capture and Storage)

facility. In 2021 a state green credit guarantee was introduced to facilitate major industrial investments that contribute to achieving the goals in the Environmental quality objectives system and the Climate Policy Framework.

1.4.4 Transport sector

Emissions from domestic transport, where road transport dominates, increased after 1990, reaching a peak in 2007. They have been declining since then, but this decline has slowed since 2013. The decrease in emissions since 2007 can be attributed to policy instruments introduced both nationally and at the EU level. The most significant ones include carbon dioxide emission EU performance standards for new vehicles, vehicle taxes and vehicle fuel taxes and more recently, a greenhouse gas emission reduction obligation for petrol and diesel. These have resulted in more energy-efficient vehicles and a greater use of renewable fuels.

Several policies and measures aimed at the transport sector has been or is in operation. These include climate investment program granting support for infrastructure for the introduction of electrical vehicles, a bonus–malus system for light-duty vehicles, and a tax on air travel and a reduction obligation scheme for aviation with the aim to reduce the climate impact of aviation. Companies and municipalities are also eligible to apply for climate premiums for electric and other low-emission heavy-duty vehicles. In 2018 an environmental compensation scheme was introduced to stimulate railway transports of goods.

Greenhouse gas emissions from domestic transport (excluding domestic flights) amounted to 15 million tonnes of CO_2 equivalent in 2020, which is a decrease of 10% compared to 2019. Road traffic accounts for by far the largest share (about 95%) of emissions from transport in the country, of which passenger cars account for about 63% and heavy and light trucks account for about 30 %. Compared to 1990, emissions from domestic transport (excluding domestic flights) have decreased by 21%. The reduction in emissions is mainly a result of an increase in the share of biofuels while at the same time making vehicles more energy efficient.

The emission reduction obligation, implemented in 2018, establishes an obligation on petrol and diesel suppliers to reduce life-cycle carbon dioxide emissions, by gradually increasing blending with sustainable biofuels. The reduction obligation scheme contributes to reduction of fossil fuels in road transport.

When it comes to the rate of electrification of cars the latest statistics show a significant increase in sales of electric cars (+105 % in 2021) and plug-in hybrids (+18 % in 2021) in Sweden. In 2020, the share of electric cars and plug-in hybrids sold in Sweden was about 31 percent of sales of passenger cars. In 2021, the share had risen to 45 percent of new car sales, which is the highest share among EU member states. When the bonus–malus system was introduced in 2018, the proportion was eight percent.

1.4.5 Waste

Methane emissions from landfill sites have declined significantly since 1990 and are expected to continue falling sharply over the next ten years. According to preliminary statistics from the Swedish Environmental Protection Agency, emissions from waste have decreased by 4.6 per cent in 2020 compared to the previous year. Behind this development are the landfill bans and taxation of landfilling of waste, which were introduced in the early 2000s. Demand for waste as a fuel for district heating has also strongly encouraged diversion from landfill to incineration.

An analysis of the combined effect of policy instruments influencing methane emissions from landfill sites showed that, in a scenario based on instruments decided on at the time of the analysis, emissions would end up around 1.9 Mt CO_2 eq. lower in 2020 than in a scenario based on 1990 instruments.

1.4.6 Agriculture and forestry

According to the Strategic plan for the implementation of the common agricultural policy in Sweden 2023-2027 "climate-impacting emissions from the agricultural sector can be reduced but not completely removed". Measures, mentioned in the Strategic plan, where agriculture can contribute to reduced climate impact include becoming more resource efficient per unit produced, increasing carbon storage in soil and contributing to increased production of renewable energy. Greenhouse gas emissions from Swedish agriculture have fallen since 1990. As yet, there are relatively few economic policy instruments directly targeting greenhouse gas emissions in this sector.

However, the Government has taken several initiatives to reduce fossil fuel use in farming, and to increase awareness and encourage the use of measures to curb emissions of greenhouse gases from manure and fertiliser management and from land use. An Official Report of the Swedish Government (SOU 2021:67 Vägen mot fossiloberoende jordbruk) was

published in 2021 with proposals on how to reduce the agriculture sector's dependence on fossil fuels. Apart from using CAP[2]-funding, investments in the agricultural sector have been granted funds from the Local Climate Investment Program (described in chapter 4). In 2021 the European Parliament, the Council of the EU and the European Commission agreed on the reform of the CAP. The new CAP for the period 2023-2027 aims to support the transition towards sustainable agriculture and forestry in the EU and to contribute to the goals of the European Green Deal. 40% of the CAP budget will have to be climate relevant (European Commission 2021).[3]

In 2020 the Government decided on a new support scheme for re-wetting previously drained wetlands, which aims at providing climate benefits while also strengthening biodiversity, balance water flows, increase the addition to ground water and reduce eutrophication. The investment in re-wetting measures is estimated to contribute to an emission reduction of 0.08-0.18 million tonnes of CO_2-equivalents per year, depending on which land is re-wetted.

1.4.7 Flexible mechanisms under the Kyoto Protocol

The Swedish Program for International Climate initiatives was launched in the early 2000s and has led to emission reductions in developing countries while generating emission reduction units for Sweden. Throughout the program, Sweden has supported over 90 bilateral projects through CDM and JI and has participated in 11 multilateral carbon funds. By the end of 2020, 91 bilateral projects and 11 multilateral funds[4] had generated emission reductions equivalent to approximately 31 Mt CO2 -eq. In total, SEK 1,8 billion had been granted by the end of 2020. The number of active initiatives is steadily decreasing. The program is expected to close by 2025 with final payments in 2022.

All projects are carried out in developing countries, and priority has been given to projects in least developed countries (LDCs), small island developing states (SIDS) and in Sub-Saharan Africa. Overall, the program

[2] Common Agricultural Policy
[3] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/new-cap-2023-27_en

[4] Future Carbon Fund (FCF), Asia Pacific Carbon Fund (APCF), Transformative Carbon Asset Facility (TCAF), Carbon Initiative for Development (Ci-Dev), Carbon Partnership Facility (CPF), Pilot Auction Facility for Methane and Climate Change Mitigation (PAF), Umbrella Carbon Facility Tranche 2 (UCF T2), Prototype Carbon Fund (PCF), Multilateral Carbon Credit Fund (MCCF), Testing Ground Facility (TGF) and Partnership for Market Readiness (PMR).

supports climate projects in more than 50 developing countries. Most of the projects are in renewable energy, energy efficiency and waste management.

Sweden has decided to cancel all emission reduction units received up until the end of 2019. The cancelled international credits have not been used to fulfil commitments under the Kyoto Protocol. Instead, the financial support related to cancelled international credits has been reported as climate finance.

1.5 Projections and the total effects of policies and measures

The projections with existing measures are based on the policies and measures adopted by the EU and the Riksdag (the Swedish Parliament) as of 30th June 2021 together with an assessment of future trends.

The projection results indicate a gradual decline in total emissions of greenhouse gases (excluding LULUCF) over the projection period. By 2030 and 2040, aggregate emissions are projected to be 39 % and 45 % lower respectively, than in 1990. The LULUCF sector contributed to an annual net removal of carbon dioxide in Sweden during the period 1990–2020 and is expected to continue to do so during the projection period.

Table 1.1 Historical and projected emissions and removals of greenhouse gases by sector (million tonnes CO_2-equivalents).[5]

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Energy excl. transport	32.3	16.4	17.4	16.6	16.3	16.2	-49%	-50%
Transport	20.0	15.4	15.2	13.6	12.0	10.7	-31%	-46%
Industrial processes and product use	7.7	6.6	7.2	6.1	6.0	6.0	-20%	-22%
Agriculture	7.7	6.9	6.3	6.1	6.0	5.9	-20%	-22%
Waste	3.7	1.0	0.9	0.8	0.7	0.6	-79%	-83%
Total emissions	**71.4**	**46.3**	**47.0**	**43.2**	**41.0**	**39.4**	**-39%**	**-45%**
LULUCF	-36.6	-39.8	-39.3	-37.4	-38.4	-40.4	2%	10%

Over the projection period, the emissions from energy, transport, industrial

[5] National Inventory Report Submission 2021 were used when producing the projections. For th is Eighth National Communication the historical emissions and removals of greenhouse gases presented are based on National Inventory Report Submission 2022.

processes and product use, agriculture and waste are expected to decrease until 2040.

Emissions from the energy industries (electricity and heat production, refineries, and manufacture of solid fuels) are projected to decrease until 2040. Until 2040, production of electricity is assumed to grow more than consumption, resulting in a projected export of about 40 TWh by 2040.

The emissions from households and premises and from combustion in the agricultural, forestry and fishing sectors are projected to continue to decrease. The decline is mainly due to a continuing replacement of oil-fuelled boilers for heating and hot water purposes in households and premises with district heating, electric heating, heat pumps and biomass.

Combustion emissions from manufacturing industries are projected to decrease until 2040, because the use of biofuel and electricity is expected to increase at the expense of fossil fuels. The industrial processes and product use sector contributes greenhouse gas emissions from the materials used in industrial processes and the use of solvents, fluorinated greenhouse gases and other products. These emissions are projected to decrease slightly until 2035. The decrease is caused mainly by restrictions for the placing on the market of fluorinated greenhouse gases as in EU's F-gas regulation (EU) No 517/2014.

Emissions from domestic transport, especially from road transport, are projected to decrease until 2040 for several reasons. One is an assumed continuous improvement in the energy efficiency of the vehicle fleet due to EU CO_2 requirements that limit emissions from new cars and light-duty vehicles. Another reason for the decrease is a greater use of biofuels.

Methane emissions from landfills are projected to decrease until 2040. This decrease is mainly due to the ban on depositing combustible and organic materials in landfills.

Emissions from agriculture are estimated to decrease until 2040 as a result of a continuously declining cattle population. The reduced numbers of dairy cows are primarily a result of increased productivity, product pricing mechanisms and continuous adaptation to EU agricultural policy regulations.

The net removals for LULUCF are expected to slightly increase until 2040, mainly due to a increase in removals from forest land.

1.5.1 Progress towards meetings Sweden's commitment under the Kyoto Protocol

The EU has jointly committed to its UNFCCC target and implemented it internally through EU legislation targeting emissions up to 2020 (the 2020 EU Climate and Energy Package). Under this legislation, greenhouse gas emissions from the EU were to be reduced by 20% compared with 1990 by 2020. Emissions from installations included in the EU Emissions Trading System (EU ETS) were to fall by 21% between 2005 and 2020 for the EU as a whole. Emissions not covered by the trading system form part of the Emissions Sharing Decision. Sweden was to reduce its emissions in this sector by 17% between 2005 and 2020.

For the years 2013-2020, Sweden's ESD-emissions were lower than the ESD-targets. The surplus amount of emission units (AEAs) was over 5 million per year compared to the Swedish ESD target. The surplus for 2013-2019 were deleted and the government has proposed to the Swedish Parliament that the surplus for 2020 should also be deleted. Compliance for 2020 is planned to be performed in 2023.

1.6 Vulnerability assessment, climate change impacts and adaptation measures

In Sweden, extensive research is carried out on climate change and its current and potential future effects. Information from government authorities is freely available and open to everyone. Basis on climate change impacts is not always easy to use or understand for the uninitiated user. Efforts are underway to ensure that citizens and stakeholders receive relevant and useable information to enable further adaptation activities.

Research and modelling projects show that climate change will lead to temperature rise that will vary depending on location, with the most significant rise in temperature expected in the northern part of Sweden. The increase will be more substantial in winter than in summer, which will result in milder winters with decreasing snow cover. Average annual temperatures in Sweden already rise approximately twice as fast as the global average. Climate change will also result in changing precipitation patterns, with an expected increase in precipitation by 0–30 % by 2100, varying by location and scenario. The most pronounced increase will be during winter. During summer, rainfall in southern Sweden is expected to decrease, and increasing evaporation may lead to a shortage of drinking water in certain areas, especially in southeastern Sweden.

Natural and human systems in Sweden is and will be further affected by climate change in a number of ways. Heavy rainfall and cloudbursts are already causing significant economic damage, and deaths have occurred. The occurrence of extreme weather events is expected to increase. Climate change affects human health in various ways, but the magnitude of impacts on health is difficult to predict and varies with local preconditions and the vulnerability of the population. Climate disruption also has important impacts on agriculture, cultural heritage, forestry, housing, infrastructure, the natural environment and ecosystems, reindeer husbandry and many other aspects of Swedish society.

Efforts are being made to improve adaptive capacity, with several national authorities developing adaptation plans for their areas of responsibility. Adaptation plans are also in place at the regional level, and in many municipalities. Awareness of the importance of adaptation has increased and has resulted in significant progress in implementing adaptation measures of the last few years.

Adaptation to climate change spans many different sectors. Thus, it is important to consider adaptation measures with multiple and cross-sectoral benefits as well as those involving conflicting targets.

1.7 Financial Resources and transfer technology

Climate change is the defining issue of our time and a top priority for the Swedish Government. Sweden has a long history of support for work on climate change issues in developing countries, in an array of sectors and on a long-term basis but has raised its ambitions further since the adoption of the Paris Agreement.

A large number of Swedish actors, such as ministries, government agencies, state-owned companies, non-governmental organisations, universities and the private sector assist in climate change-related cooperative actions and activities such as providing grants and innovative finance, technology transfer, research and various forms of capacity development. There are several different forms of cooperation, policy instruments and support, including efforts to mobilise additional private finance.

Environment and climate change constitute one of the key areas of the policy, one of three top priorities of the Government, and in addition an environment and climate change perspective shall be integrated in all

Swedish development cooperation. The policy highlights that Sweden will support low and middle-income countries' accession to and implementation of commitments under the climate convention, and the implementation of their Nationally Determined Contributions under the Paris Agreement.

Sweden is one of the largest per capita donors in the world to the financial mechanism under the UN Framework Convention on Climate Change – the Green Climate Fund (GCF) and the Global Environment Facility (GEF) – as well as to other key multilateral climate funds, such as the Adaptation Fund. Sweden is one of few OECD DAC members to have met, and even far exceeded, the UN international development aid goal of 0.7 % of gross national income (GNI). There is broad Parliamentary support, to continue delivering 1 % of Sweden's GNI to Official Development Assistance (ODA).

Sweden's bilateral climate change efforts focus on climate-vulnerable countries, such as Bangladesh, Bolivia, Burkina Faso, Kenya, Mali, Mozambique, Somalia and Tanzania. African countries are among the main recipients of Swedish bilateral climate finance in general. Sweden increased its bilateral climate finance substantially from 2017 to 2019. More specifically, the overall increase was 45 %. In 2020, the bilateral climate finance dropped with 14 % due to delays and reallocation of funds as a result of the Covid-19-pandemic as well as quality assurance of data. Between 2017 and 2020, the financial support to mitigation increased by 40 % while support to cross-cutting initiatives increased by 20 %. The financial support to adaptation increased with 20 % during the same period and continues to constitute a significant proportion of the climate finance (39% in 2020).

Capacity-building and institutional development is central for development and is a fundamental entry point in all of Sweden's development cooperation. Sweden provides extensive support to climate change capacity building, with different approaches and in cooperation with different type of actors. This diversity is needed to respond to different partner countries' or organisations' specific needs and contexts. The majority of the climate finance support that Sweden provides through Sida therefore has capacity building integrated into the core of its operations.

1.8 Research and systematic observation

The societal impacts of the COVID-19-pandemic have resulted in a reduction in private-sector investment in Research and Development

(R&D). The Swedish government has consequently decided to significantly increase public R&D funding as part of the government's latest Research and Innovation bill for the period 2021-2024 "Research, Freedom, Future – knowledge and innovation for Sweden". The bill proposes to strengthen the seven national ten-year research programmes, including the national research programme for the climate.

Sweden participates in several international research projects and initiatives. Regionally, Sweden collaborates within the framework of the Nordic Council of Ministers (NCM) in which Nordic countries work together in areas related to environment and climate. In January 2019, the Nordic Prime Ministers issued a joint commitment to work towards a carbon-neutral Nordic region and to demonstrate leadership in the fight against global warming. This joint effort underpins much of the Nordic collaboration in research initiatives. The NCM action plan for Vision 2030, running from 2021 to 2024, focuses on carbon neutrality and climate adaptation; sustainable production; sustainable consumption; and international co-operation on climate change and the environment.

On the European level, Sweden participates in the EU Research and Innovation programme Horizon Europe (2021 - 2027), the world's largest research and innovation initiative with a total budget of around €100 billion. Horizon Europe aims to strengthen green growth and competitiveness and has clear global objectives to combat climate change and contribute to sustainable development. In 2020, Forte, Formas, the Swedish National Space Agency, the Swedish Energy Agency, the Swedish Research Council and Vinnova were asked to develop a strategy for how Sweden should strengthen its participation in Horizon Europe.

Sweden participates in the European Strategy Forum on Research Infrastructure (ESFRI), European Polar Board, European Incoherent Scatter Scientific Association – Tromsö (EISCAT) and several EU projects via various funders and providers. Within the context of climate research, Sweden participates in the Joint Programming Initiative JPI Climate, where Swedish funding agencies and researchers actively contribute to a common strategic research agenda. Via Stockholm University, Sweden leads the EU-funded Horizon 2020 project FORCeS (2019-2023). FORCeS aims to study the magnitude of aerosol radiative forcing caused by anthropogenic emissions, which is crucial in order to increase confidence in climate projections.

Regarding global collaborations, Sweden has been an active supporter of the Intergovernmental Panel on Climate Change (IPCC) from its start. Swedish researchers and organisations are participants or partners in global research activities and organisations. These include the World Climate Research Program (WCRP), International Science Council (ISC), International Arctic Science Committee (IASC), Science Committee on Antarctic Research (SCAR), International Ocean Discovery/Drilling Program (IODP), Global Biodiversity Information Facility (GBIF), US National Science Foundation, Future Earth, Science Europe, Global Research Council (GRC) and International Institute for Applied Systems Analysis (IIASA). Within the Arctic Council, Sweden is active in most of the assessments that are produced by the Arctic Monitoring Assessment Program (AMAP) in collaboration with the Arctic countries.

1.8.1 Systematic observation

Systematic climate observation includes various measurements in meteorology, hydrology, terrestrial aspects and oceanography. SMHI operates networks for these on a national level in Sweden. In addition, other monitoring research infrastructures exist that can contribute to more systematic and coherent information on the changes in marine and land-based systems. National infrastructure includes the Integrated Carbon Observing System (ICOS) and The Swedish Infrastructure for Ecosystem Science (SITES)

Through the Swedish Research Council, Sweden participates in several international research infrastructures related to climate, such as ICOS - European Research Infrastructure (ICOS-ERIC), GBIF, the Integrated Ocean Drilling Program, (IODP), International Continental Scientific Drilling Program (ICDP) and Life Watch.

Sweden also participates in coordinating observations in the Arctic and Antarctic through the organisations Inter-Agency Standing Committee (IASC) and the Scientific Committee on Antarctic Research (SCAR). SMHI and SU participates in the Integrated Arctic Observation System (INTAROS), which seeks to extend, improve and unify existing observation systems across the Arctic.

1.9 Education, training and public awareness

Achieving the goals of the Paris Agreement will require major structural changes and the participation of the whole of society in climate change

transition. This presupposes that there is a strong commitment and a broad understanding of the climate issue among the public. It also presupposes that people from all parts of society are enabled to contribute. The possibility of achieving the goals of the Paris Agreement is therefore strongly linked to increased awareness and participation in issues related to climate change.

In the year 2020 the Swedish government made a national stocktake of opportunities and conditions for Sweden's implementation of Article 12 of the Paris Agreement. The stocktake was performed in line with the UNFCCC ACE Guidelines. Some conclusions of Swedens opportunities and conditions are:

Education and learning play a key role in strengthening society's preparedness and ability to act in the face of climate change. Sustainable development is well integrated into syllables and curricula for preschool, primary school and upper secondary school. There is strong support for sustainability issues including climate issues in the governing documents. Many schools work with the issues and that education materials hold a good standard. Both training programmes and education material are offered both on a national, regional and local level.

The higher education institutions' assignments for education and practical learning in climate related issues are partly expressed in the Higher Education Act and the Higher Education Ordinance, which state that they must promote sustainable development in their activities, and that sustainable development must be part of various educations. Several higher education institutions have also adopted their own governing documents, for example on how climate related issues are being included as part of compulsory or elective courses in programs.

Awareness of climate change is generally very high in Sweden. A vast majority of the Swedish public also state that is very or quite important to take societal actions to reduce the impacts of climate change. The Swedish people are interested in information about climate change, and they want the information to come from authorities, researchers or news media. A large majority of the Swedish public also state that they themselves can act to reduce climate change.

Many government agencies have an articulated task to provide information around climate change within their areas to the public. Several of them work

actively with websites, social media, webinars and digital tools to enhance public access to information and public participation. The principle of openness is central to the Swedish legal system. It means that the public, both individuals and representatives of the media, have the right to insight into and access to information about the state's and municipalities' activities.

The Swedish government has regular interactions with the civil society, and supports the civil society in various ways, for example financially and through cooperations like Drive for Democracy[6].

2. National circumstances

2.1 Government structure

Sweden is a parliamentary, representative democracy that is ruled by a government headed by a prime minister. The Government is appointed by a popularly elected parliament, the Riksdag, which is elected every four years. As the national legislature, the Riksdag controls the Government and government agencies, and must approve political decisions such as Swedish climate and energy policies. The Government implements Riksdag decisions, submits new proposals (Bills) to the Riksdag, directs state administration and represents Sweden in the European Union.

Swedish public administration is organised at central, regional and local levels. The central level consists of several agencies[7] serving as the Government's expert bodies and implementing the policies adopted by the Riksdag and Government. For regional and local public administration, there are 21 county administrative boards and 290 municipalities, and some central government agencies have regional offices. Swedish municipalities are autonomous, with boards and councils elected by their respective citizens in separate elections.

As for fulfilling commitments under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, it is the Riksdag that decides (based on Government Bills) and the Government and its agencies that are responsible for implementing the decisions. County administrative boards and municipalities play a key role in climate policy, since they shape and implement plans for e.g., land use, energy management, transport and waste. Many Swedish municipalities are actively engaged in pursuing targets and following action plans to limit greenhouse gas emissions and adapt society to climate change.

2.2 Population profile

The population of Sweden at the end of 2020 was 10.4 million, with 21 % aged up to 17 and 20 % 65 and over (Table 2.1). Since 1990, the mean annual growth rate has been 0.6 % and by 2030 the population is expected to reach 10.9 million. Average population density is 25.5 inhabitants per km^2, ranging amongst Swedish counties from under 3 per km^2 in northern

[7] In 2021 there were 346 government agencies in Sweden (Statistics Sweden 2021c). There are also local authorities and various companies that exercise public authority.

Sweden to 127 per km² in the south. Stockholm's county has a population density of 367 inhabitants per km² (Statistics Sweden 2021a, 2021b).

Table 2.1 Sweden's population profile, with projections (Statistics Sweden 2021a, 2021b).

	1990	2000	2010	2018	2019	2020	Annual increase, 1990 – 2020 (%)	Annual increase, 2009 – 2020 (%)	2030	2040
Population (million)	8.59	8.88	9.42	10.23	10.33	10.38	0.6	1.0	10.85	11.30
Aged up to 17 years (% of population)	21.9	21.8	20.4	21.1	21.1	21.1			19.7	19.0
Aged 65+ years (%of population)	17.8	17.2	18.5	19.9	20.0	20.1			22.0	23.4
Population density (inhabitants/km²)	21.0	21.6	22.9	25.1	25.4	25.5			26.6	27.8

2.3 Geographic profile

Sweden extends in a south-south-westerly/north-north-easterly direction from latitudes 55 to 69 degrees north and from longitudes 11 to 23 degrees east, with a land area of 406,550 km². Urban land makes up 3 % of the land area, while productive forest land account for 58 %, farmland 8 %, wetlands 12 %, alpine areas, subalpine woodlands and rock surface, 17%, and other land 2%[8] (Swedish University of Agricultural Sciences, 2021). Inland water systems total more than 40,000 km², or more than 9% of Sweden's total area (including sea water, SCB 2021d). Southern Sweden is low-lying, with agricultural land predominating in the far south. The only real mountain chain, with peaks rising to over 2,000 m above sea level, is along the Norwegian border in the north-west.

Land rise (postglacial rebound) is taking place in most of Sweden because of the melting of land ice after the last ice age but has ceased in the far south (see Fig. 2.1).

[8] Five year average 2018

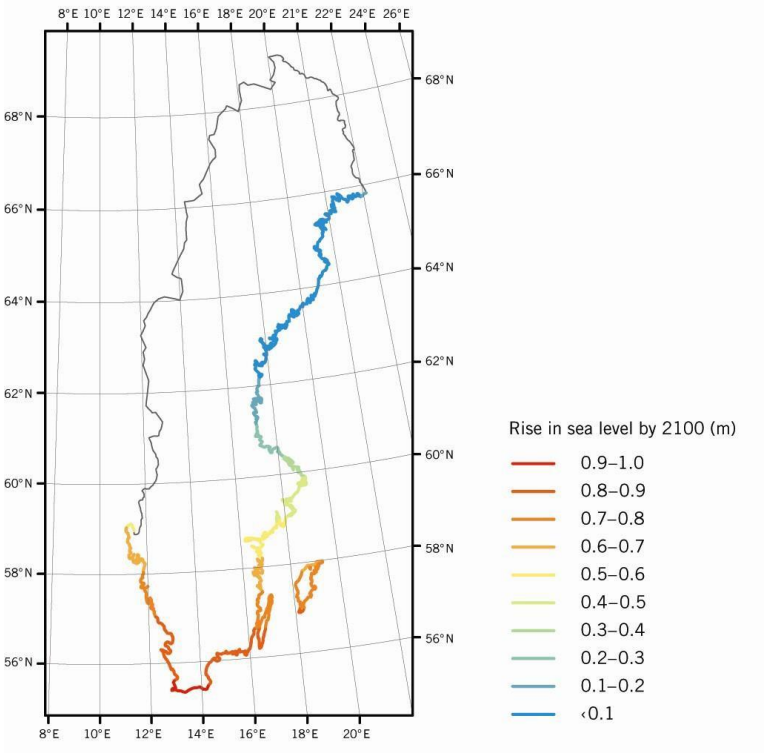


Figure 2.1 Net effect of rise in sea level (minus land rise) in Sweden, assuming a global sea level rise of 1 metre in 100 years. The land rise estimates are based on the Swedish National Land Survey's model NKG2005LU (Ågren & Svensson 2007).

Rising sea levels are causing substantial erosion along the south coast, which is characterised by easily eroded soils. Climate change due to future increases in atmospheric temperature will accelerate erosion through rising sea levels.

Forest land is an important natural resource that provides scope for biobased energy supply. In the past 50 years, farmland has successively given way to other land uses, mainly forest land. This has resulted in reduced emissions from agriculture and increased carbon sequestration in forest biomass. Besides forests, another key natural resource is iron ore, a pillar of Swedish industrial production. Abundant flowing watercourses are a significant resource for hydropower production.

2.4 Climate profile

Sweden's proximity to the North Atlantic and prevailing south-westerly to westerly winds result in a climate that, for the latitude, is mild in the winter months. The northernmost part of the country, however, has a sub-Arctic climate with long, cold and snowy winters. In the period 1961–90 the mean

temperature in January was 0 °C in southernmost Sweden, while the coldest northern valleys had −17 °C. The maximum daily mean July temperature was approximately 17 °C in south-eastern Sweden and just over 10 °C in the north.

Passing low-pressure systems bring precipitation that is fairly copious all year round, but heaviest in the summer and autumn. Annual precipitation is some 500-1,000 mm. Since most low-pressure systems move in across the country from the west or south-west, the western parts of Sweden receive the most precipitation. Locally, in the mountains near the Norwegian border, precipitation reaches 1,500–2,000 mm a year. The lowest annual precipitation, just under 400 mm, falls along the eastern coasts.

The mean temperature was about 1° higher in the years 1991–2020 than in 1961–90. The largest rise, over 2°, took place in the northern parts of Sweden in winter. Overall, owing to the rise in temperature, the densely populated areas (including Greater Stockholm) have undergone a shift from a cold-temperate to a warm-temperate climate. In the long term, this should entail a reduced incidence of winters with heavy snowfall. However, there may still be major variations from year to year. Winter 2019/20 was the warmest of all winters since 1860 followed by that of 2007/08, while those of 2009/10 and 2010/11 were the coldest since the late 1980s. Precipitation has increased slightly in most of the country. The differences in temperature and precipitation between the periods 1961–90 and 1991-2020 are illustrated in Figs. 2.2 to 2.4 (SMHI 2021).

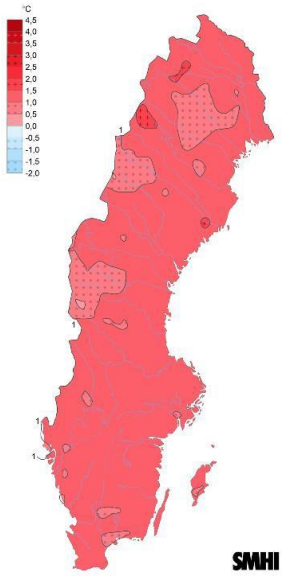


Figure 2.2 Difference in annual mean temperature between 1991-2020 and 1961–1990 (°C).

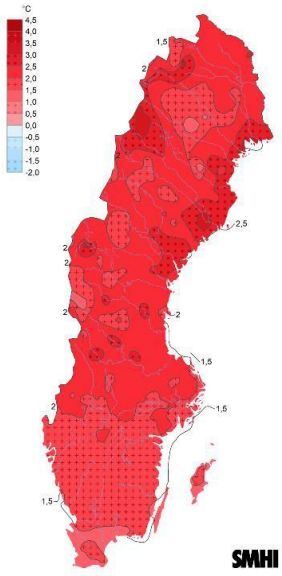


Figure 2.3 Difference in mean winter temperature between 1991-2020 and 1961–1990 (°C).

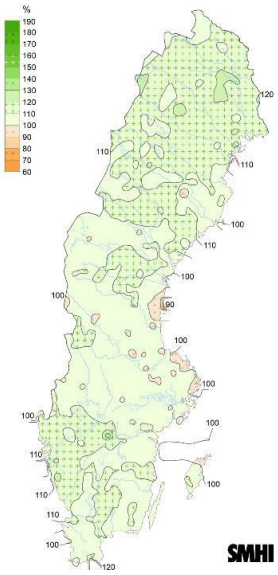


Figure 2.4 Difference in annual precipitation between 1991-2020 and 1961–1990 (%).

Extremely severe storms with widespread windthrow (uprooting of trees) are rare, and trends are difficult to identify. In January 2005, however, there was a storm with hurricane-force winds in the south of Sweden, with by far the most extensive windthrow for 100 years. Just two years later, southern Sweden was hit by another violent storm. These storms caused a temporary reduction in carbon sequestration in forest biomass.

The relatively cold climate entails high energy requirements to heat buildings for most of the year. Heating requirements are dependent on outdoor temperature, wind conditions and insulation, and vary from one year to the next. Fossil fuels in district heating have been gradually replaced by, for example, biofuels. However, fossil fuels still serve as a complementary fuel source which can lead to increased emissions during colder winters. The average temperature in Sweden in 2020 was the highest since measurements began. This combined with a phase-out of fossil fuels led to a decrease of greenhouse gas emissions within the heating and power sector by 46% percent compared with 1990.

Annual precipitation and run-off to the large rivers in north-west Sweden have a major bearing on the water inflow volume for Swedish hydropower production. Hydropower accounts for nearly half of Sweden's electricity production, varying between 50 and 80 TWh per year (Swedish Energy Agency 2021a).

2.5 Economic profile

Sweden has an open, trade-oriented economy. In 2020, the nation's gross domestic production (GDP) was SEK 4.98 trillion or close to SEK 481,000 per capita, placing the nation among the richest countries in the world.

From 1990 to 2019, the economy grew by an average of 2.2 % per year (see table 2.2). Since 1990, the economy has suffered from four recessions. In the early 1990s, GDP fell three consecutive years because of a combined crisis in finance and real estate. Ten years later the economy suffered when the dot-com bubble burst. In 2008, the global financial crisis hit Sweden. In 2009, the economy shrunk more than 5 %, only to bounce back up again in the following year. Finally, the COVID-19 pandemic in 2020 caused a reduction in GDP of 2.8%. In the lead up to the pandemic, between 2017 and 2019, the average GDP growth rate was 2.0 %.

Natural resources, such as forest and iron ore, are a basis for industrial production and, along with the engineering industry, have brought about a strongly export-oriented economy. Since 1990, exports have grown faster than imports and the trade balance has been positive. In 2019, exports accounted for 47 % of GDP. Main export industries are machines, vehicles, pharmaceuticals and chemicals, wood products, electronics and minerals.

Table 2.2 GDP by expenditure, at constant prices, reference year 2015 (Statistics Sweden 2021e, World Bank 2021)

	1990	1995	2000	2005	2010	2015	2018	2019	Growth, 1990– (%/year)	Growth, 2017- (%/year)
GDP (SEK m)	2482998	2579685	3076995	3502765	3826205	4260470	4547336	4637655	2,20	3,33
GDP per capita (SEK)	289036	291902	346400	387142	406370	432490	444502	449055	1,62	2,22
GDP per capita (PPP, USD 2017)	34 157	34 234	40 625	45 440	47 791	50 929	52 349	52 851	3,57	2,43
Imports (SEK m)	611280	694596	1059082	1216289	1397605	1702358	1933770	1974941	4,39	5,15
Exports (SEK m)	536781	734956	1143753	1444767	1582295	1864670	2072751	2196577	5,20	4,74
Private consumption (SEK m)	1189153	1171236	1393371	1549898	1754421	1961665	2097193	2112297	1,92	2,36

Public consumption (SEK m)	839586	890600	927610	953510	1022388	1095716	1147301	1150364	1,17	2,38

On the production side, just over 70% of Swedish GDP stems from the private sector, whereas the public sector contributes under 30%. Within the private sector, services dominate with 68% of the value added, manufacturing industries 18%, construction 8%, utilities 3%. Value added from primary production (agriculture, forestry, fishing and mineral extraction) is 2% (Statistics Sweden 2021e).

2.6 Energy

The Swedish energy system is partly based on domestic sources of renewable energy such as wind and biomass. In addition, a large proportion of the energy supplied is dependent on imports such as nuclear fuel for electricity production in nuclear reactors and fossil fuels like oil for the transport system. Swedish electricity production is based largely on hydropower and nuclear power, but the expansion of wind power is steadily increasing as well as the use of biofuel for electricity and heat production.

Sweden's final energy use can be divided into three user sectors. In the industrial sector, energy is mainly used to operate processes. This sector primarily uses biofuels and electricity. The transportation of people or goods within the country requires energy in the form of various fuels or electricity. Energy use within transportation is dominated by oil products in the form of fossil-based petrol, diesel and aviation fuel although bioenergy has increased in recent years. The residential and service sector mainly uses energy in the form of district heating, electricity, oil or biofuels (see Fig 2.5, Swedish Energy Agency 2021a).

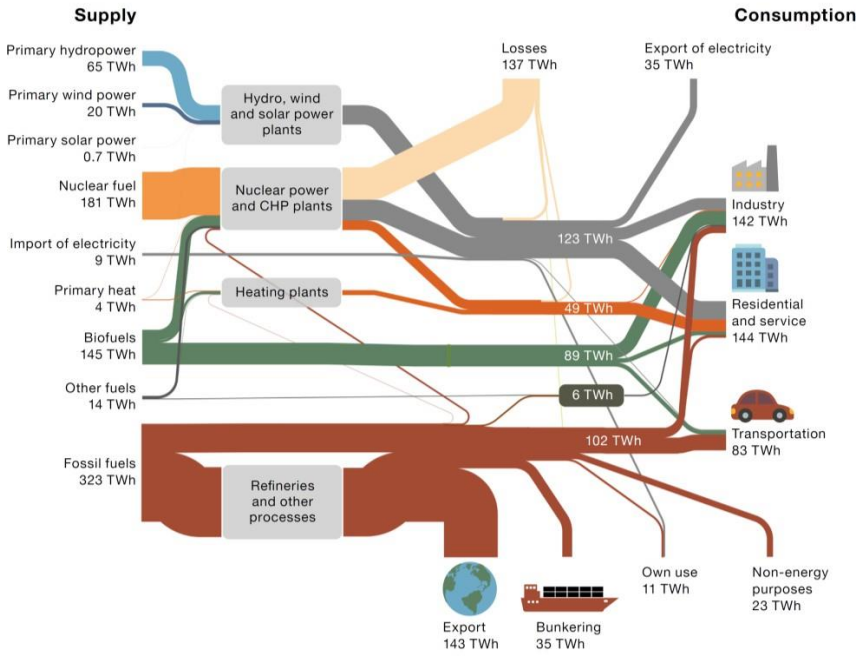


Figure 2.5 Sweden's energy system (Swedish Energy Agency 2021a).

2.6.1 Energy supply and use

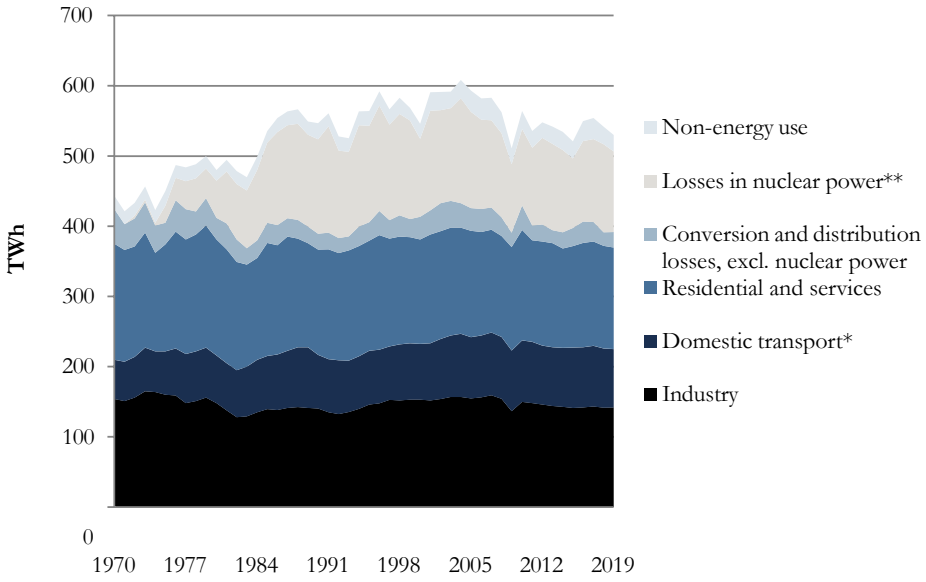
Total energy supplied in Sweden has shown a rising trend since 1970, from some 450 TWh to about 500-600 TWh from the mid-1990s (see Table 2.3). A high proportion of this increase represents conversion and distribution losses associated mainly with nuclear power production, and the remainder goes to final use. The composition of the energy supply in this period has been transformed, with crude oil largely being superseded by nuclear power and biofuels.

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
TPES (TWh)	553	578	551	595	581	525	561	562	561	548
TPES (MWh) per capita	64	65	62	66	62	53	56	56	55	53

Table 2.3 Sweden's total power energy supply (TPES)

Total final energy use has increased by 20 % since 1970. The main increase can be derived from an increase in nuclear power losses as nuclear power was commissioned during the 1970s and 1980s. Excluding these losses, total final energy use has been relatively stable during this period. For the past ten years final energy use has been stable at approximately 520-560

TWh. However, there has been differing trends amongst remaining sectors. Industry and residential property and services have seen a decrease in energy use of 8 and 13 percent respectively. This is despite growing industrial production and an increase in aggregate heated floor space of homes and commercial and institutional premises, pointing to energy efficiency increases in both sectors. Energy use from domestic transport on the other hand has increased by nearly 50% during this period (see Fig 2.6, Swedish Energy Agency 2021a).

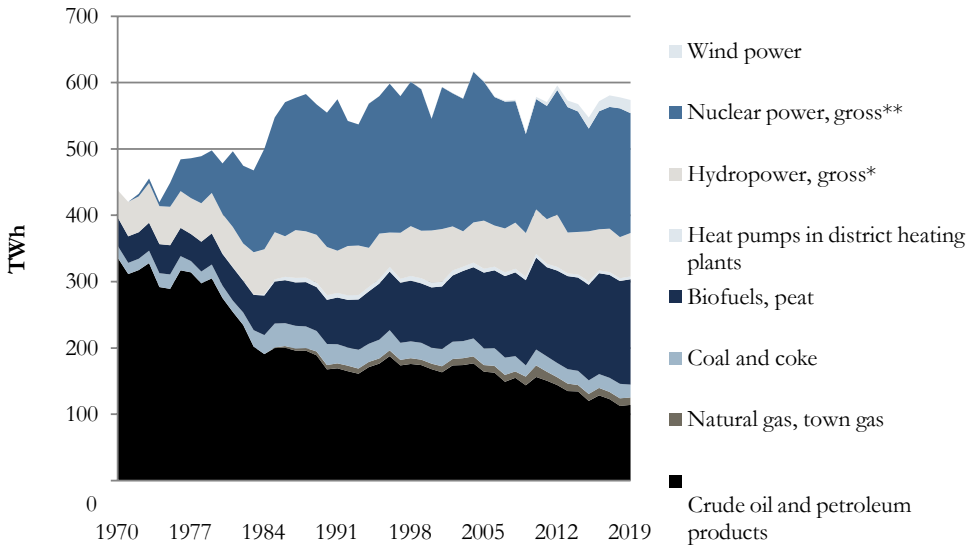


* Data up to and including 1989 include international flights.
** According to the method used by the United Nations Economic Commission for Europe (UNECE) to estimate supply from nuclear power.

Figure 2.6 Sweden's TPES in 1970–2019, including conversion and distribution losses (Swedish Energy Agency 2021a).

Sweden's total primary energy supply (TPES) is based on domestic supply of energy from biofuels, hydropower and, to a lesser extent, ambient heat from heat pumps, and on imported energy carriers such as uranium, oil, natural gas, coal and biofuels (see Fig. 2.7).

In the early 1970s, an energy policy was introduced to reduce Sweden's dependence on oil. Over 65 % of petroleum products have now been largely superseded by non-fossil energy sources, and with national incentives, the share of bioenergy in Sweden's TPES has risen to nearly 30%.



* Incl. wind power up to and including 1996.
** According to the method used by UNECE to estimate supply from nuclear power.

Figure 2.7 Sweden's energy supply in 1970–2019, excl. net electricity exports (Swedish Energy Agency 2021a).

A major shift has taken place in energy supply to homes and to commercial and institutional premises. A consistent, sustained policy to extend infrastructure for district heating production and distribution was pursued from the late 1960s to the mid-1990s. The main motive for this investment, which involved replacing numerous small heating plants with large, centralised installations to heat buildings, was to improve air quality in urban areas. The infrastructure for district heating was a precondition for environmentally sound heating of buildings based on biofuels. It was also essential to enable the national policy instruments for renewable energy to bring about the extensive phase-out of fossil fuels to heat buildings that has been achieved.

By 2019, production of district heating had risen by over 300% since 1970 and 45% since 1990 (see Fig. 2.8). At the same time, the share of biofuels (including waste and peat) in production had grown from 2% to 25% and 79% in 1970–90 and 1970–2019 respectively.

In addition to the extensive changeover from heating of individual buildings to district heating and from fossil energy to bioenergy for district heating

production, there has been a switch from oil to heat pumps or pellets in remaining homes and non-residential premises that are individually heated.

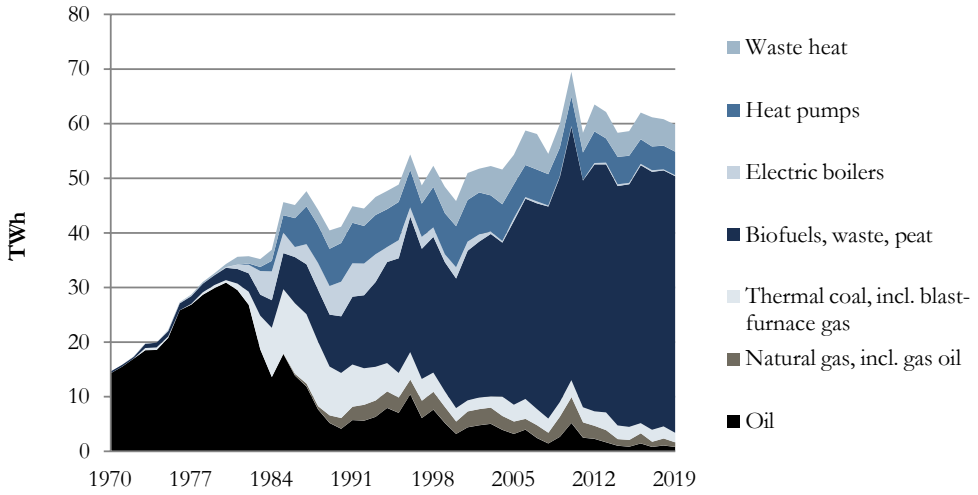


Figure 2.8 Energy supply for district heating, 1970–2019 (Swedish Energy Agency 2021a).

Between 1990 and 2019, the share of renewable energy in Sweden rose by 23 percentage points to 56% (see Fig. 2.9). The renewable energy sources contributing to this trend were hydropower, wind power, by-products used in the paper and pulp industry, and biofuels for district heating production.

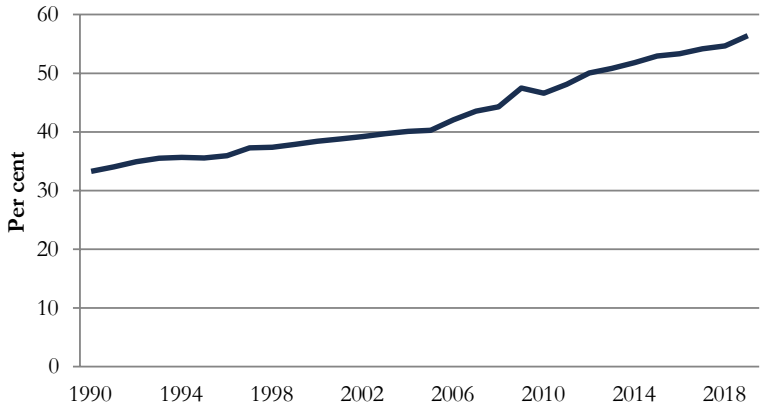


Figure 2.9 Share of renewable energy used in Sweden, 1990–2019 (Swedish Energy Agency 2021a).

Between 2000 and 2019, the price of light fuel oil rose by 178 % and heavy fuel oil rose by 187 % while that of wood chips remained relatively stable at a low level (see Fig. 2.10)[9]. Carbon dioxide and energy taxes had a substantial

[9] Light fuel oil is used for heating purposes, while heavy fuel oil is mainly used in larger heating plants

and ships.

impact on fossil fuel prices, which helped to make biofuels competitive for heat production in district heating and for heating individual buildings.

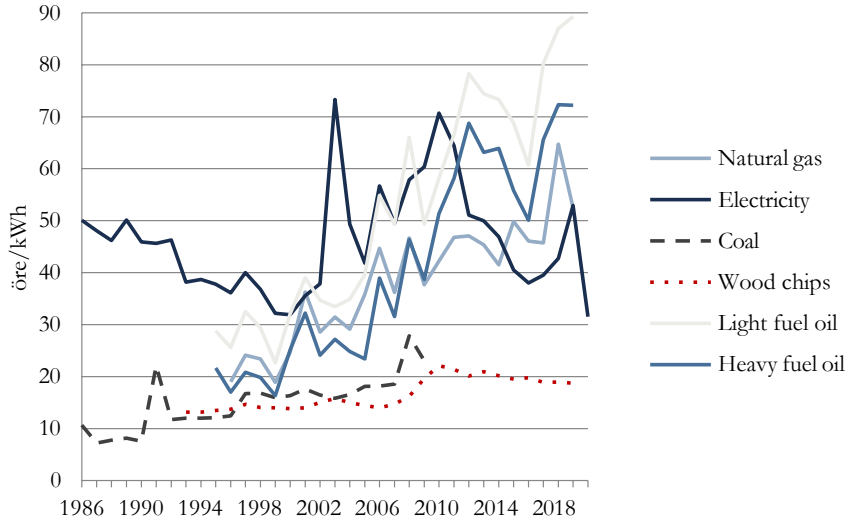
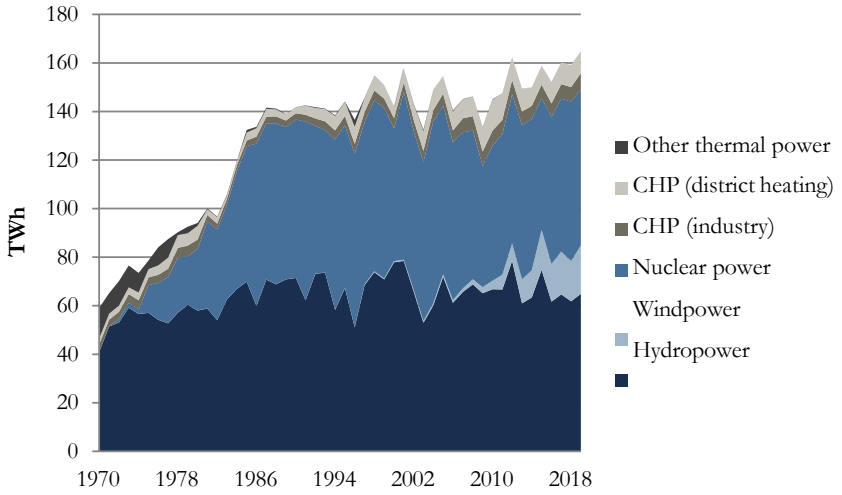


Figure 2.10 Real energy prices for industry in Sweden, including energy taxes, 1986–2020, expressed in SEK/kWh, 2019 prices (Swedish Energy Agency 2021a).

2.6.2 Electricity supply

Of total electricity production in 2019, hydropower accounted for 39%, nuclear power also 39% and wind power 12 %, while biofuels and fossil-based (CHP) production made up the remaining 10% (see Fig. 2.11). In the early 1970s hydropower, supplemented by oil-condensing power, dominated production. The expansion of nuclear and to some extent hydropower up to 1985 largely eliminated oil-fired power generation. Since then, the use of oil for electricity production has continued to decrease, except in 1996 – a cold year with extremely low water inflow for hydropower production – when decommissioned oil-condensing power plants were temporarily restarted. Ample natural watercourses for hydropower production, combined with national energy policy and investments in non-fossil-fuel-based power production such as nuclear power, have enabled Sweden to produce electricity by almost entirely fossil-free means.



* Wind power and hydropower are reported in the same category up to and including 1996.

Figure 2.11 Sweden's electricity production by power source, 1970–2019 (Swedish Energy Agency 2021a).

Between 1970 and 1987, electricity use rose by 7 % a year. The rise then slowed to an annual average of 0.5 % until 2000. In the subsequent decades, the figure fluctuated between 135 and 150 TWh. The Swedish electricity system is linked with the other Nordic systems, making efficient use of the Nordic countries' power plants possible. Consequently, Sweden's annual electricity balance alternates between net imports and net exports (see Fig. 2.12). In years of low precipitation and thus low hydropower production, and when nuclear power cannot be produced at normal capacity, the deficit is offset by electricity imports; and when Sweden has an ample supply of hydro and nuclear power, this country's electricity is exported to neighboring countries. In the 1990s, oil-based condensing power was used to compensate for hydro and nuclear power deficits.

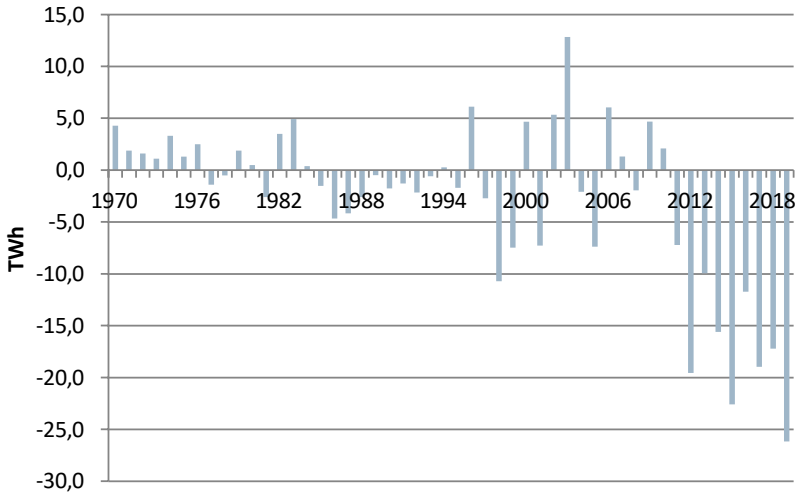


Figure 2.12 Sweden's annual net imports (+) and net exports (−) of electricity, 1970–2019 (Swedish Energy Agency 2021a).

2.7 Building stock and urban structure

2.7.1 Building stock and residential floor area

In 2020, there were 2,104,946 single-family houses for year-round occupation and 2,585,221 apartments in multi-dwelling buildings. Of the current stock of apartments, 73 % were built during or before 1980. Average floor space in single-family houses is 122 m². For multi-dwelling buildings, floor area is on average 68 m² (Statistics Sweden 2021f).

A 10.8% increase in the number of apartments and a 5.2% increase in the number of single-family houses took place between 2013 and 2020. Prior to 2013, the calculation of these two definitions were carried out differently and hence the numbers cannot be compared (Statistics Sweden 2021f). In 2020, average living space was 42m² per capita (Statistics Sweden 2017g). In 2021, industrial buildings contained floor space of 137 million m² (Statistics Sweden 2021h).

2.7.2 Energy use in buildings

Final energy use in residential and service-sector buildings, in which energy for heating predominates, decreased by 24% between 1990 and 2020 even after weather correction of energy use (Swedish Energy Agency 2021b). On the other hand, use of electricity for non-heating purposes in the residential and services sector increased slightly during this period for both domestic and business electricity usages (see Fig 2.13, Swedish Energy Agency 2021a).

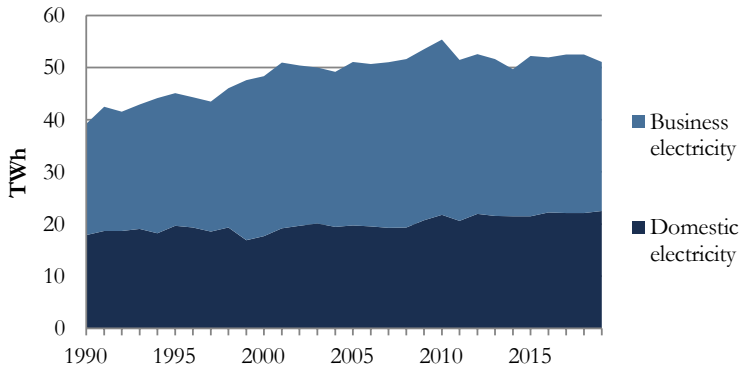


Figure 2.13 Electricity use in the residential and services sector 1990-2019. (Swedish Energy Agency 2021a).

The use of energy for heating and hot water has changed since 1990. As Fig. 2.14 shows, the use of oil has decreased sharply in single-family houses, in favor of district heating, biofuels and electric heating.

For multi-dwelling buildings, too, there has been a marked decrease in oil and increase in district heating (see Fig. 2.15). In this type of housing, district heating accounted for more than 90 % of energy use for heating and hot water in 2019 (Swedish Energy Agency 2021b). For commercial and institutional premises, the proportion of district heating was 78 % in 2019 (Swedish Energy Agency 2021b).

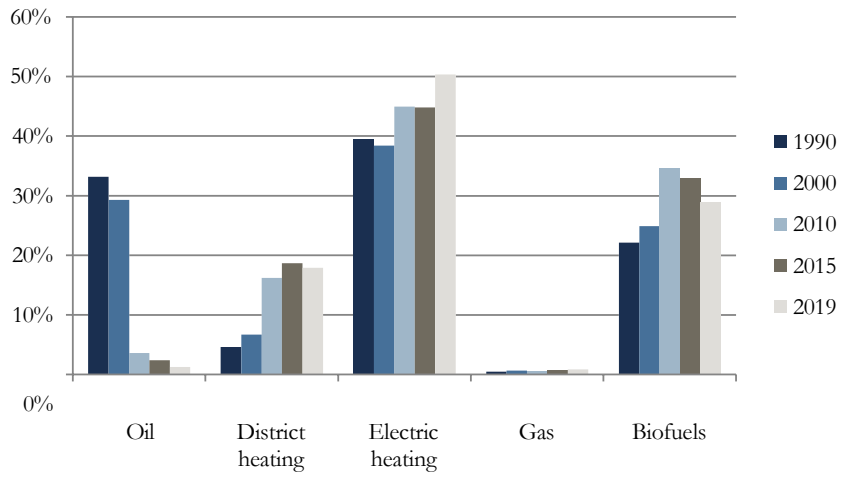


Figure 2.14 Use of energy for heating in single-family houses in 1990, 2000, 2010, 2015 and 2019 (Swedish Energy Agency 2021b).

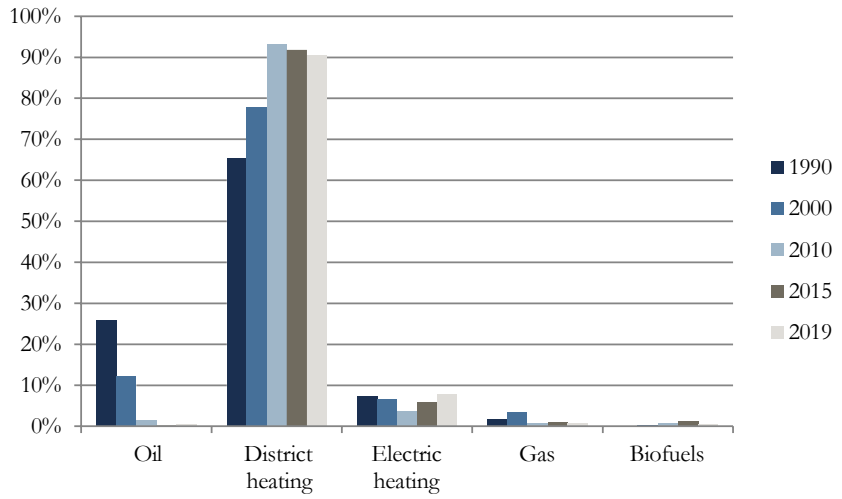


Figure 2.15 Use of energy for heating in multi-dwelling buildings in 1990, 2000, 2010, 2015, 2019 (Swedish Energy Agency 2021b).

2.7.3 Urban structure

In Sweden, as in other countries, migration from rural to urban areas is under way. In 2020, 88 % of the population lived in towns and cities. Urban areas amounted to 617,000 ha, which was 2% of Sweden's land area (Statistics Sweden 2021d). Between 1960 and 2005, the urban area increased by 54 % and the urban population by 47 %. From 2005 to 2020 these increases were 21% and 19% meaning that population density within urban areas decreased slightly. The increasing size of urban areas means that more land per capita is used for housing, infrastructure and services (Statistics Sweden 2021i)

2.8 Industry

Sweden has a mixed industry, characteristically based more on raw materials than many other countries. For example, the extensive forest industry (wood products, paper and pulp) and also the iron and steel industry are based on domestic natural resources. Indeed, the forest industry and iron and steel industry, together with the chemical industry, have long been an important part of the Swedish industry, and today contribute significantly to the nation's exports.

The manufacturing sector is important to the economy, accounting for nearly 20 % of GDP in terms of value added in the private sector in 2019 (Statistics Sweden 2021e). Following manufacturing, other sectors which contribute most to GDP in terms of value added are retail, real estate and

construction. Sectors with the most significant growth respectively since 1993 are manufacture of coke and refined petroleum products (although decreased by over 70% since 2011 peak), telecommunications, IT, electronics and vehicles. Different industries' contributions to the value added in the manufacturing sector in 2019 is shown in figure 2.16.

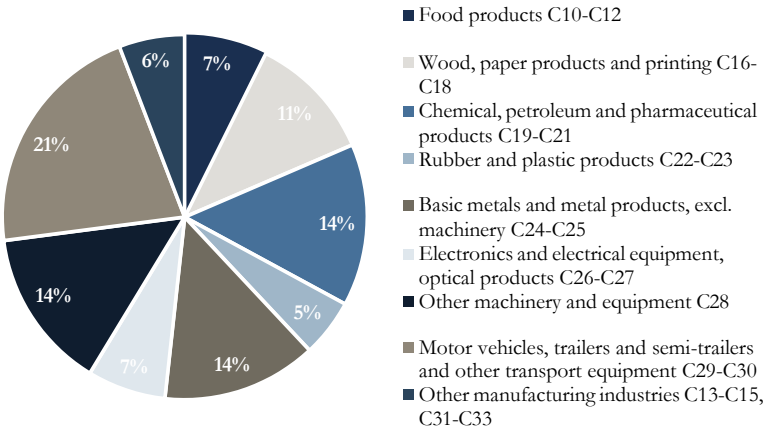


Figure 2.16 Distribution of value added in manufacturing industry, 2019. Swedish Standard Industrial Classification (SNI) designations in brackets (Statistics Sweden, 2021e).

2.9 Transport

Domestic transport in Sweden is dominated by road traffic. Several factors affect greenhouse gas emissions from traffic, especially transport volume and the technology used. Transport activity for passengers and goods alike has increased since 1970 (Transport Analysis 2021). Vehicle kilometres travelled has increased for passenger vehicles and lorries since 1990, whilst buses/coaches have remained relatively stable (see Figure 2.18, 2.19). There has been a substitution from lorries 3.5-26 tonnes towards lorries under 3.5 tonnes and over 26 tonnes. All motor vehicle types except motorcycles have seen a reduction in vehicle kilometers in 2020 because of the COVID-19-pandemic.

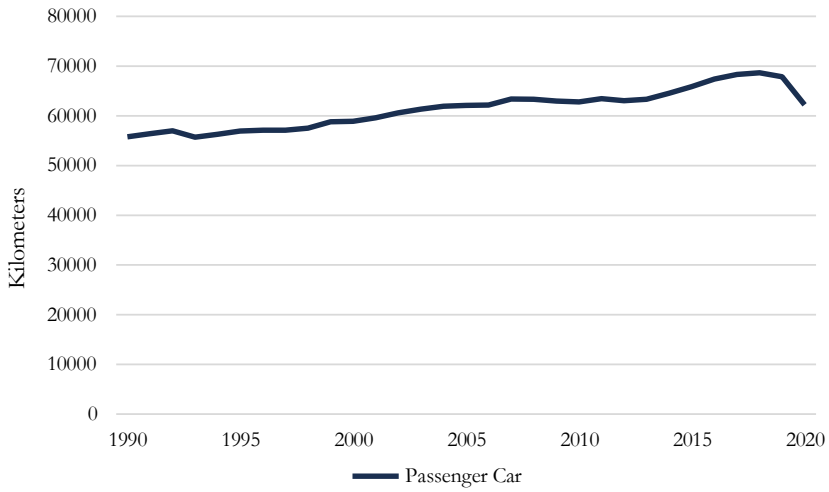


Figure 2.17 Vehicle kilometres on Swedish roads 1990-2020 for passenger cars (Transport Analysis 2021).

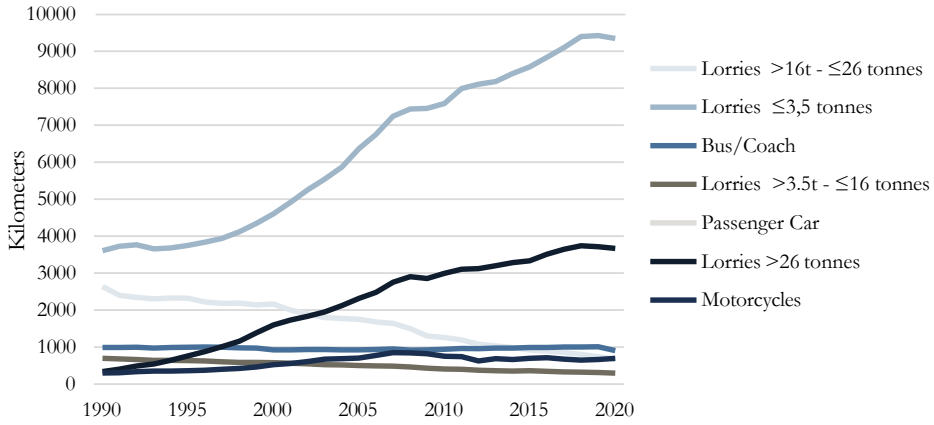


Figure 2.18 Vehicle kilometres on Swedish roads 1990-2020, lorries, bus/coach and motorcycles (Transport Analysis 2021).

In terms of greenhouse gas emissions, the rapid rise in passenger travel has been offset by more energy-efficient cars and increased use of renewable fuels, which have resulted in a decrease in emissions per kilometer.

In 2019, fossil fuels accounted for 77 % of the energy used by domestic transport, while the remainder consisted of biofuels and electricity (see Fig. 2.19). Use of petrol has been decreasing since 2002, partly owing to the blending of 5 % ethanol in the fuel, but also because of greater energy

efficiency and the growing market share of diesel vehicles in relation to

petrol-driven ones. More diesel vehicles and increased goods transport have, on the other hand, brought about a rise in the use of diesel as fuel.

Use of biofuels – biogas, pure and low-blend FAME (fatty acid methyl ester), ethanol and pure and low-blend HVO (hydrotreated vegetable oil) – amounted to 20 % of energy use by road transport in 2019. In 2020, this level rose to 23 %. The rise has been rapid since 2000, initially owing to low blends of ethanol in petrol and subsequently to a rise in the sale of E85 (containing 85 % ethanol) for flexible-fuel ethanol vehicles. Since 2005, there has been an increased blending of biodiesel in diesel fuel with a sharp increase in the use of low blended and pure HVO during the last few years. The electrification of transport is advanced, especially for road transport, where Sweden has the highest market share of plug-in electric vehicles in the new-car sales in the EU and the biggest electric bus fleet in the Nordics. Approximately, more than every second car sold in Sweden is a plug-in electric vehicle and in total constitute 9 % of the fleet.

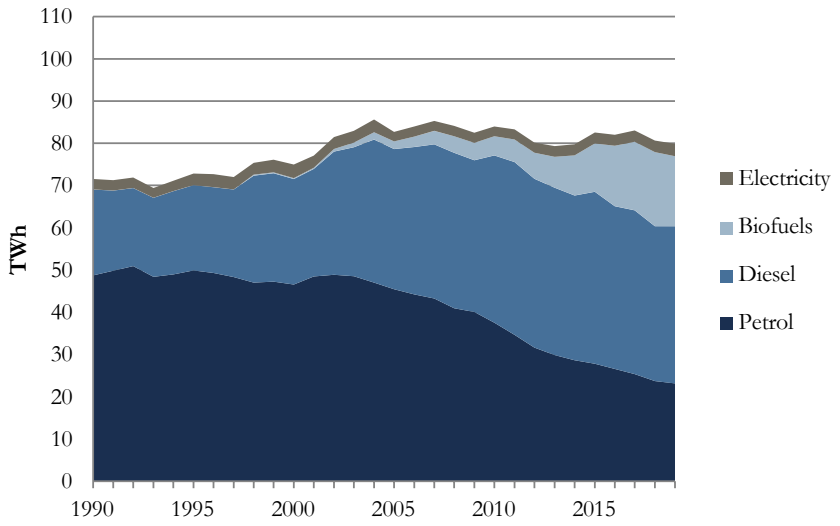


Figure 2.19 Use of petrol, diesel, biofuels and electricity in the domestic transport sector in Sweden (Swedish Energy Agency 2021a).

2.10 Waste

Approximately 139 million tonnes (Mt) of waste were generated in Sweden in 2018 (Swedish Environmental Protection Agency 2020). The categories with the largest volumes were the mining sector (104 Mt), construction sector (12.4 Mt), households (4.5 Mt) and service industries (2.1 Mt). Accordingly,

75% of the waste was generated in the mining and quarrying industry. The

aggregate volume is affected by economic trends and fluctuations. Larger quantities of waste mean that a growing amount requires management. However, since the material and energy content of waste are used to a higher degree and the technology of waste management has improved, the overall environmental impact of waste management has nonetheless decreased.

Owing to Sweden's policy objectives and associated instruments, landfilling of municipal waste has decreased sharply in the past decade to just under 1 % in 2020 (in 2001 the proportion was 23 %). The remainder is sent for materials recovery, incinerated with energy recovery or treated biologically (composted or digested, see Fig. 2.20).

Municipal waste per capita in 2020 was approximately 467 kg. The share of this that goes to material recovery is 33%, to incineration with energy recovery is 46%, biological treatment is 16% and landfills less than 1%. Materials recovery includes various categories of material, such as metal, paper, plastic and glass, and also use of waste for construction purposes.

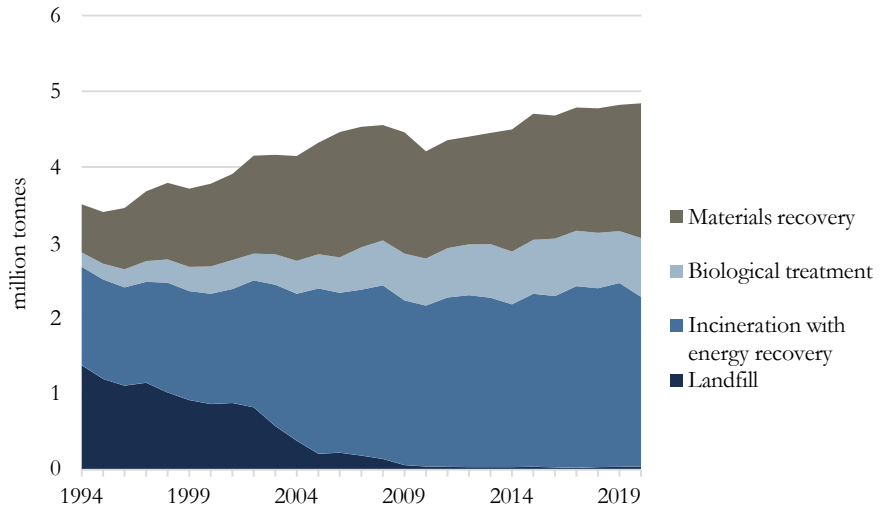


Figure 2.20 Volume trends of household waste (including construction material) treated in Sweden, 1994 – 2020.

Materials recovery from household waste has increased by 57% since 2001. In 2020, materials were recovered from 1.6 Mt (33 %) of household waste, of which just over 1.1 Mt consisted of packaging and recyclable paper (newspapers).

Biological treatment of waste primarily takes place at mixed-waste digestion plants and composting facilities. Smaller quantities of food waste are also received for digestion at sewage treatment plants. In food and slaughter waste digestion, both biogas and biofertiliser are obtained. The biogas is used mainly as a vehicle fuel, since there is a growing demand for renewable transport fuels and, moreover, using it in this way affords the greatest environmental benefit. Of the volume of biofertiliser produced, amounting to 1.8 million tonnes, 99.9 % was returned to farmland in 2020.

In 2020, there were 34 incineration plants for household waste. These plants produce both district heating and electricity. Roughly half of the heating and hot water requirements in Sweden's building stock ares met by district heating, and in 2020 waste incineration accounted for 18.6 TWh (roughly 25%) of the total heat energy supplied and a further 2.6 TWh of electricity supplied.

Recovery of methane gas takes place from 53 waste treatment plants. In 2020, 136 GWh of landfill gas was collected. 83 GWh of this was used for energy (80GWh for heating and 3GWh for eletricity) and the remaining 53GWh was flared to further reduce emissions of methane due to its higher global warming potential compared to carbon dioxide (Avfall Sverige 2021).

Reduced landfilling of waste and improved collection of landfill gas are factors that have contributed to a decrease in greenhouse gas emissions from the waste sector. Increased materials recovery generally means that both energy and materials are saved at the production stage, and this helps to reduce emissions further. In addition, waste incineration with energy recovery results in a reduction in the use of fossil fuels in the electricity and heating sectors.

2.11 Agriculture

The total area of agricultural land in Sweden in 2020 was 3.0 million hectares, which is equivalent to some 7 % of the country's total land area. Farmland comprises both arable and grazing land. The area under cultivation has shrunk by over 10 % since 1990 (Swedish Board of Agriculture 2021). The trend towards fewer, larger farming enterprises has been underway for many decades and the period 1990–2020 was no exception. The predominant use of arable land is cultivation of forage crops, green fodder and cereals. Since 2000, there has been a rise in cultivation of forage and green fodder crops at the expense of cereal growing (see Table 2.4).

The area of arable land left fallow, which shows annual variation, was slightly lower in 2020 than in 1990. Total crop production has fallen by some 5% since 1990 (see Table 2.5).

Table 2.4 Breakdown of agricultural land ('000 ha) (Swedish Board of Agriculture 2021).

	1990	1995	2000	2005	2010	2015	2019	2020	2021
Forage and green fodder crops	969	1067	929	1080	1193	1135	1161	1139	1124
Cereals	1336	1104	1229	1024	963	1034	993	1007	1000
Fallow land	176	279	248	321	177	163	132	138	146
Oilseed rape and turnip rape	168	105	48	82	110	95	106	98	106
Potatoes	36	35	33	30	27	23	24	24	24
Sugar beet	50	58	55	49	38	19	27	30	29
Legumes	33	12	37	41	46	59	44	48	50
Other crops	31	48	47	42	69	56	54	55	56
Unspecified arable land	..	..	80	32	11	6	11	11	11
Unused arable land	46	60	..	2	..	..	..	..	..
Total area of arable land	2845	2767	2706	2703	2634	2590	2551	2550	2546
Grazing land and hay meadows	332	425	..	513	452	450	461	464	464
Total area of farmland	3176	3192	..	3216	3085	3040	3012	3014	3010

Table 2.5 Crop production in Sweden (tonnes) (Swedish Board of Agriculture 2021).

	1990	2020	Change (tonnes)	Change, %
Forage and green fodder crops	4357870	4895100	537230	12
Cereals	6211300	5954500	-256800	-4
Oilseed rape and turnip rape	380090	339300	-40790	-11
Potatoes	1186100	877200	-308900	-26
Sugar beet	2775500	2027100	-748400	-27
Total crop production	14910860	14093200	-817660	-5

In 2021, there were 1.5 million cattle, 0.5 million sheep and lambs, and 1.4 million pigs (see Table 2.6). The number of cattle has fallen steadily since the 1980s and declined by 15 % in the period 1990–2021. The number of dairy cows has fallen sharply, while that of cows used for calf rearing has risen. Sheep and lamb production has increased, peaking in 2017. Pig numbers

continue to decline and have fallen by 40 % since 1990 (Swedish Board of Agriculture 2021).

As a result of increased productivity, the quantity of milk produced has not shown as large a decrease as the number of dairy cows (see Table 2.7).

Table 2.3 Livestock numbers ('000) (Swedish Board of Agriculture 2021)

	1990	1995	2000	2005	2010	2015	2019	2020	2021
Cows for milk production	576	482	428	393	348	340	306	303	302
Cows for calf rearing	75	157	167	177	197	184	210	207	210
Total, cows	651	639	595	570	545	524	516	510	512
Heifers, bulls and steers	543	596	589	527	513	488	500	480	476
Calves below 1 year	524	542	500	508	479	467	451	462	465
Total, cattle	1718	1777	1684	1605	1537	1480	1466	1453	1453
Ewes and rams	162	195	198	222	273	289	280	263	272
Lambs	244	266	234	249	292	306	269	238	252
Total, sheep and lambs	406	462	432	471	565	595	549	501	523
Sows and gilts	230	245	206	188	156	142	130	131	129
Pigs for slaughter	1025	1300	1146	1085	937	830	943	869	845
Piglets	1009	768	566	538	427	384	383	368	376
Total, pigs	2264	2313	1918	1811	1520	1356	1456	1368	1351
Horses		85		99	117			89	

Table 2.4 Livestock production (tonnes) (Swedish Board of Agriculture 2021).

	1990	2000	2010	2020	Change	Change, %
Milk	3 432 000	3 297 000	2862000	2 772 740	659260	-19
Beef	143 780	149 810	137 800	141 000	2780	-2
Pork	289 150	276 980	263 480	246 540	42610	-15
Mutton, lamb	4 880	3 180	4 070	3 920	960	-20

Total use of nitrogen mineral fertiliser has decreased since 1990 but recently increased again to similar levels (see Table 2.8, Statistics Sweden 2021j). One reason for this decline is decreasing cereal cultivation. Sales are also affected by changes in cereal and mineral fertiliser prices. The result in terms of greenhouse gas emissions from decreased use of nitrogen minieral fertiliser is lower release of nitrous oxide.

Table 2.5 Sales of mineral fertiliser expressed as nitrogen nutrient ('000 tonnes) (Statistics Sweden 2021j)

	1989/90	1994/95	1999/00	2004/05	2009/10	2014/15	2018/19	2019/20
Nitrogen (N)	225	198	189	162	168	190	183	215

Since 1990, the arable area, number of cattle and quantities of mineral fertiliser and manure used have decreased, with falling methane and nitrous oxide emissions as a result.

2.12 Forestry

Sweden's forest land amounts to 27.9 million hectares hectares (ha), according to the Swedish Forestry Act. Of the total forest area, 23,5 million ha is regarded as productive forest, corresponding to 58 % of the total land area. Accordingly, there is also 4.4 million ha of unproductive forests (11 % of total land area). It is for the total forest area that greenhouse gas emissions and removals in forests are reported. (Swedish University of Agricultural Sciences 2021)

47% of forest land is owned by individuals, 24% by privately owned limited companies, 6% by other private owners and 22% by state-owned limited companies, the central government, and other public owners (Swedish Forest Agency 2021).

The area of productive forest land formally protected from forestry amounts to 1,31 million hectares. This consists of 0,56 million hectares in subalpine regions, 0,26 million hectares in northern boreal regions, 0,21 million hectares in southern boreal regions, 0,23 million hectares in hemiboreal regions and 0,04 million hectares in nemoral regions (Statistics Sweden 2022).

Increased forest growth and demand for forest raw materials from the forest industry has led to an increase in felling during the period 1990–2019 (see Fig. 2.21). The volume felled varied greatly from year to year because of two storms, Gudrun (2005) and Per (2007). Gudrun, the more severe of the two, brought down some 80% of the normal annual volume felled in Sweden. Despite increased felling, the aggregate standing volume of timber rose from under 3.2 billion m^3 in 2003 to over 3.5 billion m^3 in 2018 (Swedish University of Agricultural Sciences 2021).

The area of regeneration felling in which harvesting residues were used for energy purposes was small at the beginning of the 1990s. Since then, it has successively expanded to some 70,000 ha in 2020 which corresponds to 33% of total felled area. Wood ash is recycled to forest land for the purpose of counteracting acidifying, nutrient-depleting effects on the soil that occur when biomass is removed. In 2020, ash recycling was carried out on less than 14,000 ha.

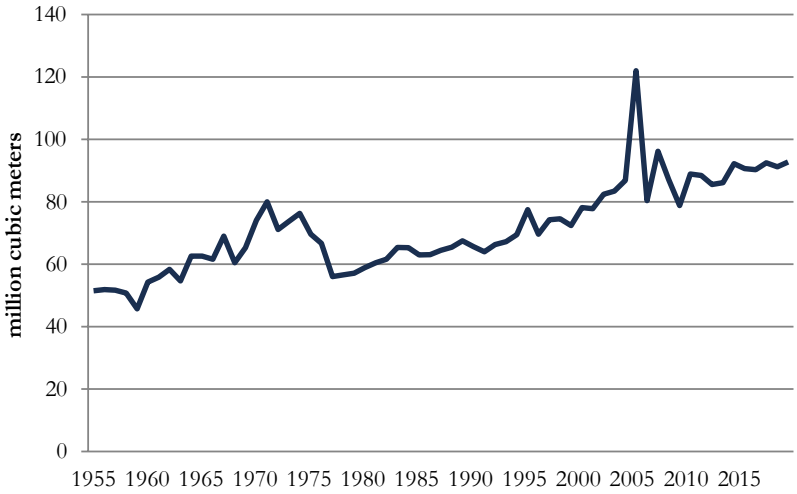


Figure 2.21 Estimated gross annual volume felled in Sweden 1955-2019 (Swedish Forest Agency 2021).

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3. Greenhouse gas inventory information

The information in this chapter is a summary of the 2021 inventory of emissions and removals of greenhouse gases for the years 1990 to 2020, submitted under the UN Framework Convention on Climate Change and the Kyoto Protocol (National Inventory Report Sweden 2022).[10]

3.1 Total emissions and removals of greenhouse gases

In 2020, total greenhouse gas emissions (excluding LULUCF) in Sweden were 46.3 million tonnes of carbon dioxide equivalents (Mt CO_2-eq.), see Figure 3.1. Between 2019 and 2020 the total greenhouse gas emissions decreased by approximately 9 %, largely due to the COVID-19-pandemic. Total greenhouse gas emissions have decreased by 25.2 Mt, or 35 %, between 1990 and 2020. Emission levels have varied between a low of 46.3 Mt CO_2-eq. in 2020 and a high of 77.3 Mt CO_2-eq. in 1996.

In recent years there has been a decreasing trend in greenhouse gas emissions in Sweden while at the same time there has been a strong economic growth, except for the global economic crisis in 2009, and a growing population. The largest reductions in absolute terms are due to a transition from oil-fuelled heating of homes and commercial and institutional premises to electricity, e.g., heat pumps and district heating. Increased use of biofuels in district heating generation and industry has also contributed to the reductions together with reductions in landfilling of waste. Fluctuations in production levels of manufacturing industries following changes in the economic development of specific industries have also had significant impacts on the national trend. The positive development is at least partly a result of dedicated policy including the CO2 tax, spatial planning processes and legislative initiatives.

Annual variations are largely due to fluctuations in temperature, precipitation and to the economic situation. The net sink attributable to the land use, land-use change and forestry (LULUCF) sector has varied over the period.

[10] For a summary of information on national greenhouse gas inventory information, see Annex 3.

In 2020 it amounted to nearly 40 Mt CO_2-eq.

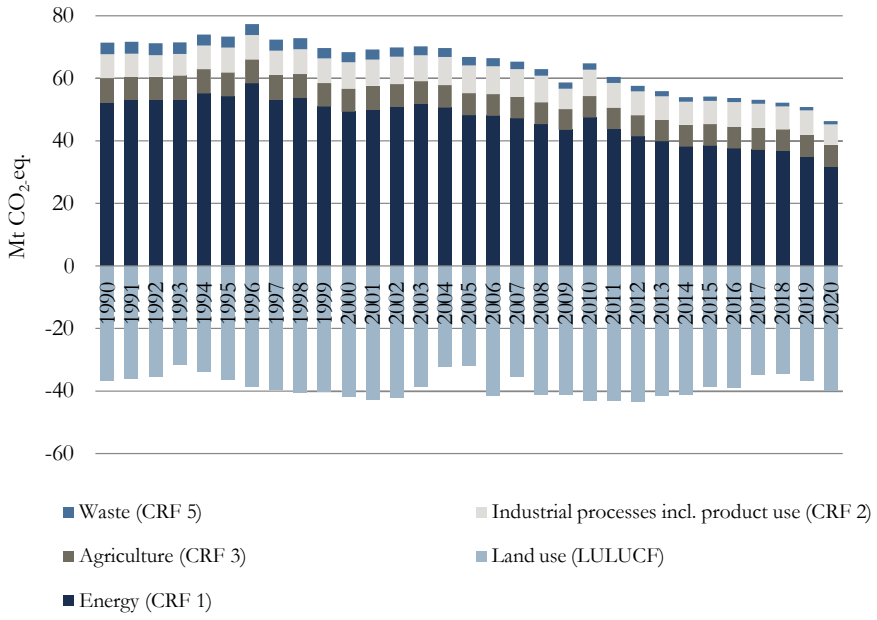


Figure 3.1 Total Greenhouse gas emissions 1990-2020 from different sectors.

In 2020, emissions (excl. LULUCF) of carbon dioxide (CO_2) amounted to 36.5 Mt CO_2 in total, which is equivalent to 79 % of total greenhouse gas emissions, calculated as CO_2-eq. Emissions of methane (CH_4) accounted for 4.1 Mt of CO_2-eq. (about 9 % of total emissions), emissions of nitrous oxide (N_2O) 4.6 Mt (10 %), fluorinated greenhouse gases (HFCs, PFCs and SF6) 1 Mt (2 %), see Figure 3.2. The shares of the different greenhouse gases have remained stable over the period 1990 to 2020.

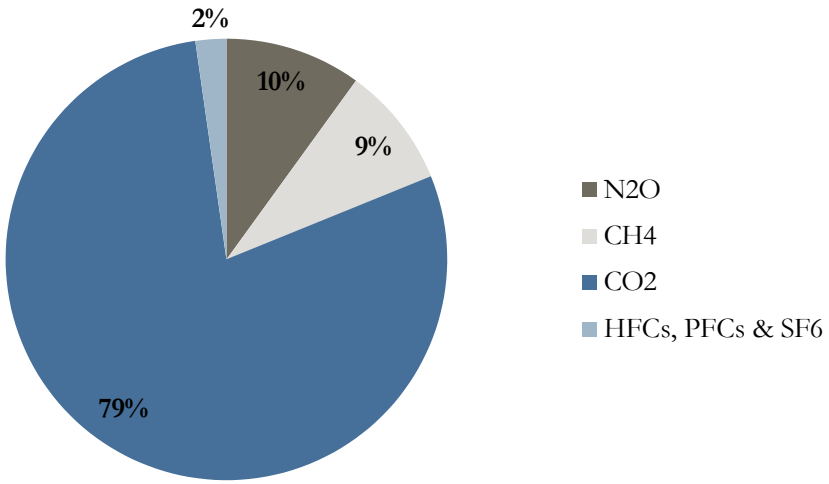


Figure 3.2 Greenhouse gas emissions in 2020 (excl. LULUCF) by gas, in carbon dioxide equivalent.

3.2 Emissions and removals of greenhouse gases by sector

The largest sources of emissions in 2020 was the energy sector (69 %), agriculture (15 %) and industrial processes and product use (14 %), as shown in Figure 3.3.

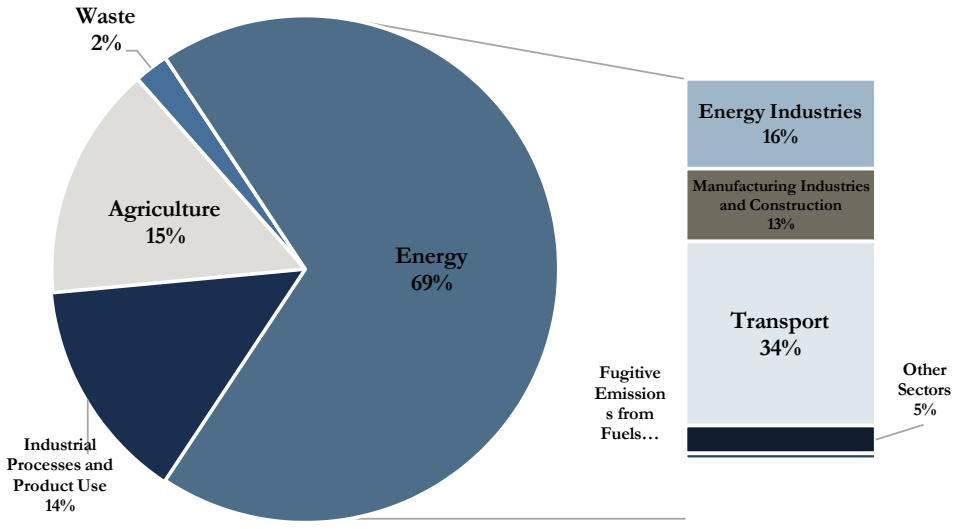
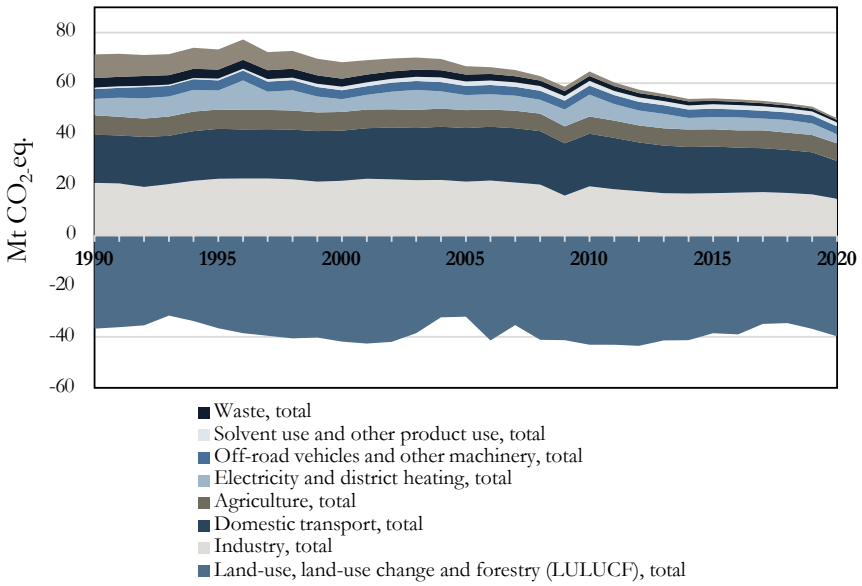


Figure 3.3 Greenhouse gas emissions in 2020 (excl. LULUCF), by sector.

BOX 1. 1 The Swedish national sectorial breakdown

The Swedish greenhouse gas inventories are published using a national sectorial breakdown for the purpose of tracking progress with national targets and tracking the effect of implemented policies and measures. The sectorial breakdown is designed to allocate emissions and removals in line with the design of national policies and measures. The aggregation of all industrial emissions in one main sector that is sub-divided by type of industry is the largest difference between the national sectorial breakdown and the IPCC sectors in the Common Reporting Format.



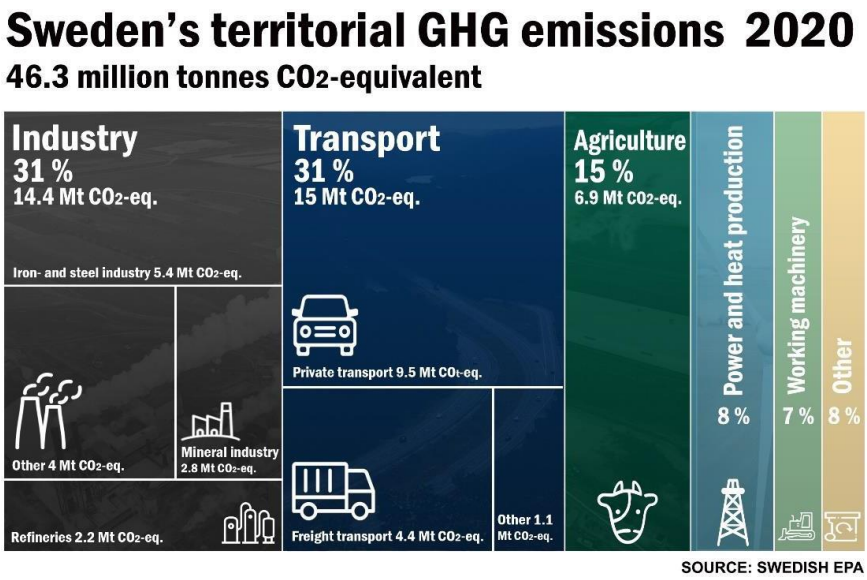
Emissions from **domestic transport** correspond to about one third of Sweden's total emissions (excluding LULUCF and international transport). The other main emission sources in Sweden are agriculture as well as electricity and district heating according to this breakdown. Emissions from domestic road transport correspond to 32 % of Sweden's total emissions and have decreased by 21 % since 1990. Emissions from domestic transport, a sector dominated by road transport, increased after 1990 and reached a peak in 2007. Since then, emissions have been declining as a result of a transition to sustainable biofuels and more efficient vehicles.

Emissions from **industry** corresponds to 31 % of Sweden's total emissions and have decreased by 31 % since 1990, while changes in the economic development of different industries have resulted in annual variations. The emissions reductions are mainly related to decreased use of oil due to shifts towards biofuels, mainly in the pulp and paper industry. New processes in the chemical industry have also contributed to the decreasing trend. Shifting production levels in response to changing economic conditions in certain industries significantly impacts the trend as well.

Greenhouse gas emissions from **agriculture** have been declining slowly and are now about 10 percent lower than in 1990. The decrease is mainly due to a reduced number of

animals and partly to a reduced use of mineral fertilizers. The number of dairy cows in Sweden has almost halved (47 %) since 1990. This has resulted in that methane emissions from dairy cows' feed digestion have decreased by about one third. Approximately 50 % of the sector's emissions are related to the production of animal foods such as meat, dairy products and eggs.

Electricity and district heating show a trend of decreasing emissions despite the increased demand for district heating. The decrease in emissions is due to a shift towards combustion of more waste and biofuels, and less fossil fuels. Combustion of industry-derived gases is allocated to the industry.



More information about the national breakdown including how different CRF-categories are allocated is available at:

- Sweden's territorial greenhouse gas emission (in Swedish).
- Detailed data and reference to CRF-categories (in English).

3.2.1 Energy industries

Energy industries are dominated by the electricity and heat production with by far the largest part of the emissions and the only subsector where emissions fluctuate over the years. The fluctuations between different years are large, due to the weather conditions' influence on the electricity and heat production (CRF 1A1a). In 2020, there was a decrease in emissions from the energy industries by 8 % compared to 2019. Sweden´s electricity and heat production is to a large extent composed by renewable energy and district heating is mainly based on biofuels and waste. Therefore, these emissions are

31 % lower than in 1990, even though the supply of district heating has increased with about 50 % in the same period.

Total emissions from energy industries (CRF 1A1) were 7.5 Mt CO_2-eq. in 2020 (Figure 3.4), which is 24 % lower than in 1990. Electricity and heat production (CRF 1A1a) account for the larger part of the emissions with 72 % (5.4 Mt CO_2-eq) in 2020. Emissions from Refineries (1A1b) and Manufacture of solid fuels (CRF 1A1c) amounted to 2.1 CO_2-eq in 2020.

Emissions from production of electricity and heat production totalled 5.4 Mt of CO_2-eq. in 2020. The emissions from electricity and heat production vary over time but have been reduced by 31 % between 1990 and 2020. There is a decrease in emissions in 2020 of 10 % compared 2019 due to decreased usage of fossil fuels and peat because of very warm weather, but also because of decisions by certain facilities to decrease the usage of fossil fuels or to not use certain fossil fuels at all following a tax increase for fossil fuels in combined heat and power production.

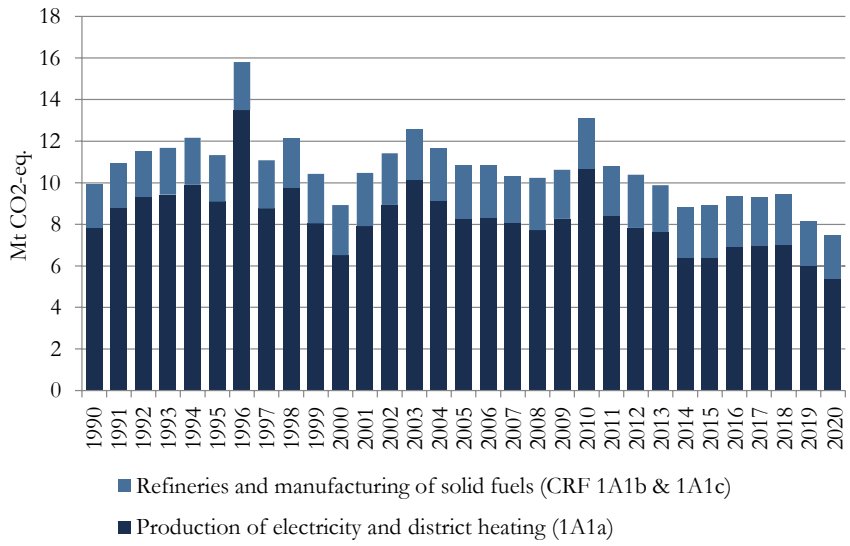


Figure 3.4 Greenhouse gas emissions 1990-2020 from the energy industries (CRF 1A1).

3.2.2 Residential and commercial/institutional

Greenhouse gas emissions from fuel combustion in the residential, commercial and institutional sectors were 79 % lower in 2020 compared to 1990 mainly due to a strong decrease in combustion of fossil fuels for heating in the residential and commercial/institutional sectors, see Figure

3.5. The emissions were approximately 2.3 Mt of CO_2-eq. in 2020. In comparison with 2019 the total emissions from the residential sector decreased by 3 %. Emissions from the commercial/institutional sector decreased with 8 % between 2019 and 2020. The emissions from agriculture, forestry and fisheries (CRF 1A4c) were 1.2 Mt CO_2-eq. in 2020, which is 37 % less than in 1990.

Emissions are primarily due to stationary combustion in homes, non-residential premises or within agriculture, forestry and fisheries. Emissions also come from mobile machinery, off-road vehicles and fishing boats (included in CRF 1A4c below). Oil-fired furnaces have been replaced by district heating, and electricity, including the increased use of heat pumps. Since emissions from stationary combustion for heating purposes have decreased significantly, the main emissions within the sector now come from non-road mobile machinery.

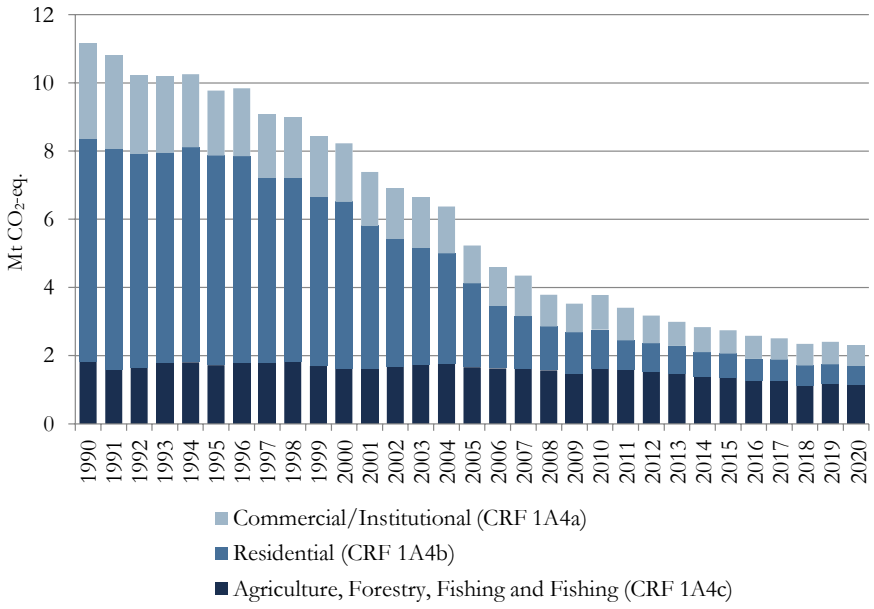


Figure 3.5 Greenhouse gas emissions 1990-2020 from combustion in the commercial and institutional, residential, and agriculture, forestry and fisheries sectors.

3.2.3 Industrial combustion

To cover all industry-related emissions it is necessary to include process emissions and emissions from combustion and fugitive emissions. These are to be reported under separate CRF (Common Reporting Format) categories according to UNFCCC guidelines.

The mining, iron and steel as well as pulp and paper industries are examples of historically important industries for Sweden. Emissions from combustion in manufacturing industries and construction were 6.1 Mt CO_2-eq. in 2020 (Figure 3.6). Emissions in 2020 were 44 % lower than in 1990. Emissions in 2020 decreased by 12 % compared to 2019. Although increasing slightly up until 1997, the emissions have a steady decreasing trend until 2014. The lower emissions in 2009 and higher emissions in 2010 were due to the financial crisis impact on production levels and their subsequent recovery. The decreasing trend is primarily related to a lower use of oil. Oil has been replaced by electricity or biofuels, partly depending on the difference in relative prices between electricity and oil.

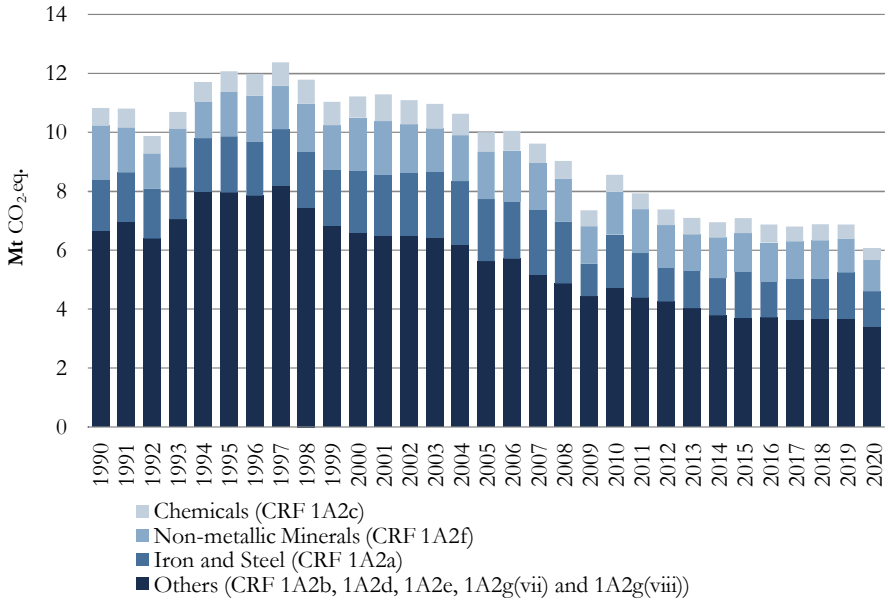


Figure 3.6 Greenhouse gas emissions 1990-2020 from industrial combustion.

3.2.4 Fugitive emissions

Fugitive emissions occur for example in processing, storage, and use of fuels, flaring of gas, transmission and distribution of gas. Emissions were around 0.49 Mt of CO_2-eq. in 2020, which is a decrease of 15 % compared to 2019, which already was at a low level compared to earlier years, see Figure 3.7. The decrese in emission during 2019 is mainly an effect of reduced production due to maintenance at two facilities. During 2020 demand from the sector has been low due to the COVID-19-pandemic, and therefor production has also been low. The increase of fugitive emissions from oil

(CRF 1B2a), observed in the time series from 2006, is related to the establishment of hydrogen production facilities at two oil refineries. In total, the emissions from CRF 1B are 38 % higher compared to 1990.

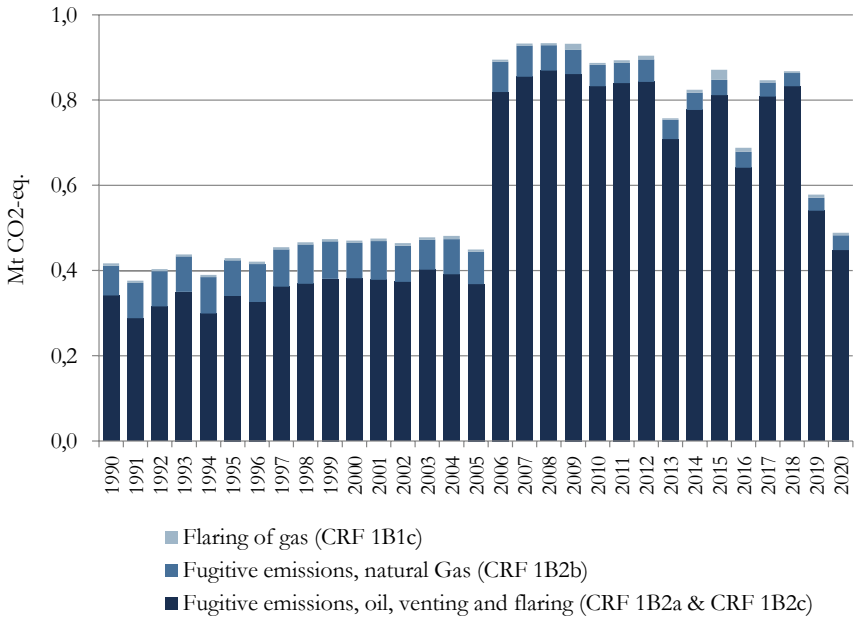


Figure 3.7 Fugitive emissions 1990-2020.

3.2.5 Industrial processes including product use

Emissions from the industrial processes and products use sector represented 14 % of the total national emissions in 2020, The main sources of emissions in the industrial processes and product use sector is the production of iron and steel (included in metal industry; 2C) and the cement and lime industries (included in mineral industry; 2A), see Figure 3.8. Greenhouse gas emissions from the industrial processes and product use sector have decreased by 14 % 2020 compared to 1990. Emissions from the sector did however increase during the 90's and early 00's but peaked in 2004 and has since had an overall decreasing trend with some interannual variations, see Figure 3.8.

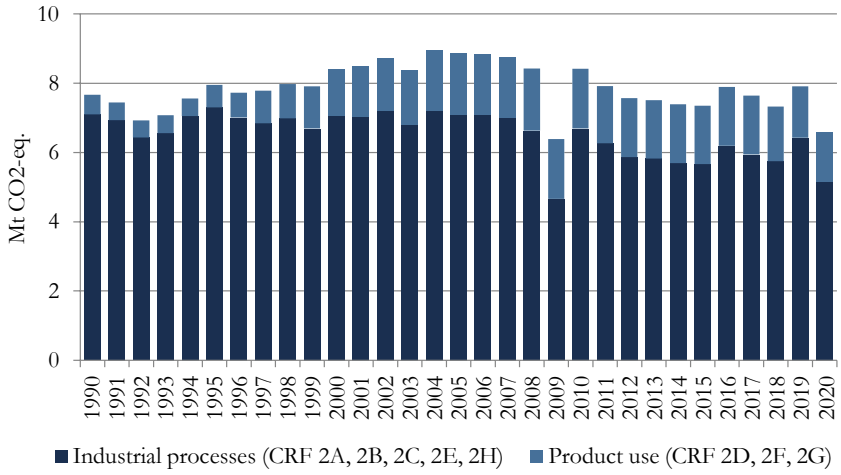


Figure 3.8 Greenhouse gas emissions 1990-2020 from industrial processes and product use.

Greenhouse gas emissions from industrial processes (CRF 2A, 2B, 2C, 2E, 2H) have many interannual variations, but show an overall decreasing trend since 1995. Between 2019 and 2020 emissions decreased with 20 %, which led to a decrease in emissions from industrial processes by 26 % in 2020 compared to 1990, see Figure 3.8. The decrease in emission in 2009 is explained by the financial crises. Greenhouse gas emissions from product use (CRF 2D, 2F, 2G) showed an increasing trend that has stabilised since 2004, with a small decrease. Nevertheless, greenhouse gas emissions from product use were about three times higher in 2020 compared to 1990. The increase in emissions is due to the phasing out of ozone depleting substances that was replaced by fluorinated gases. However, the emission trend is now indicating a decreasing trend in emission reductions.

3.2.6 Transport

In 2020, emissions of greenhouse gases from domestic transport totalled 15.4 Mt CO_2-eq., equivalent to a third of the national total. The total emissions of greenhouse gas emissions were 23% lower in 2020 compared with 1990, see figure 3.9. The reduction in emissions in the sector during the period is primarily because the proportion of biofuels used in road traffic has increased during the period, and that vehicles have become more energy efficient. However, the reduction in emissions has been dampened by an increase in traffic. Emissions from the transport sector decreased by 9 % between 2019 to 2020, which largely is a result of the reduced car traffic during the COVID-19-pandemic.

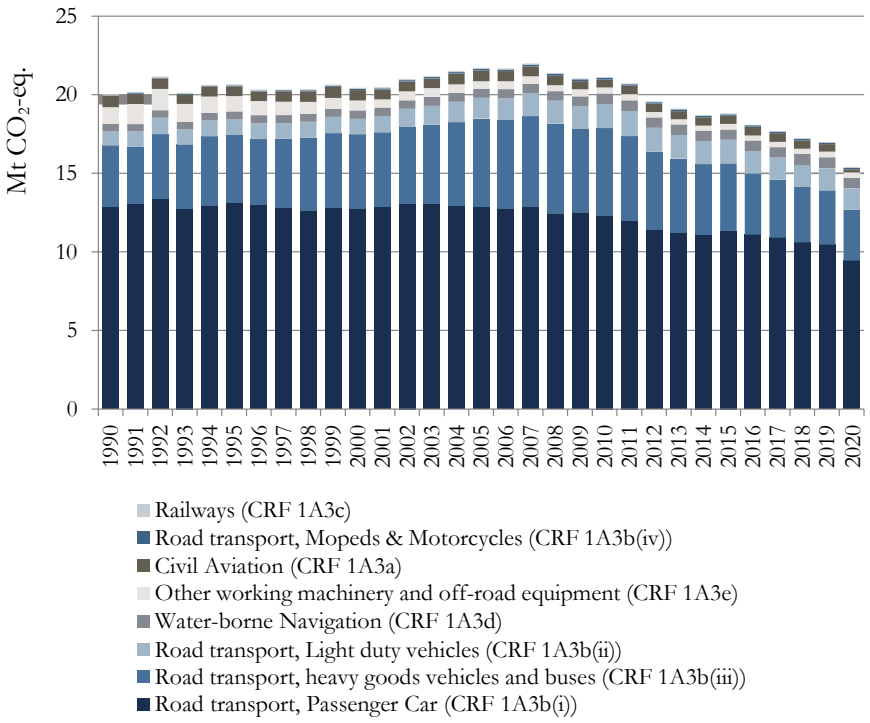


Figure 3.9 Greenhouse gas emissions 1990-2020 from domestic transport.

In addition to emissions from road transport, emissions from transport include emissions from domestic civil aviation, railways, national shipping as well as non-road mobile machinery. In 2020, the greenhouse gas emissions from road transport were 15.3 Mt CO_2-eq., 0.2 Mt CO_2-eq. from domestic aviation, 0.66 Mt CO_2-eq. from domestic shipping, 0.02 Mt CO_2-eq. from railways, and 0.36 Mt CO_2-eq. from non-road mobile machinery.

3.2.7 Waste

Greenhouse gas emissions from the waste sector amounted to 1.02 Mt CO_2-eq. in 2020, or 2 % of the national total of greenhouse gas emissions. Emissions from the waste sector have decreased by about 73% compared to 1990. From 2019 to 2020, emissions have been reduced by 6 % due to continued reduced emissions from landfills. Emissions from waste (CRF 5) include emissions from solid waste disposal (CRF 5A), wastewater treatment and discharge (CRF 5D), biological treatment of solid waste (CRF 5B) and incineration and open burning of waste (CRF 5C). The shares of the sub sectors of the total emissions of the sector are shown in Figure 3.10.

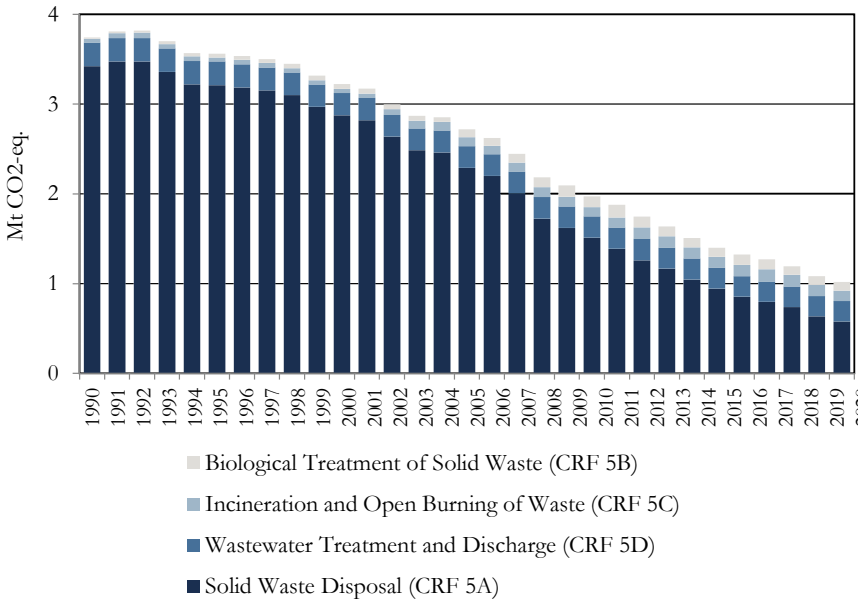


Figure 3.10 Greenhouse gas emissions 1990-2020 from the waste sector, per subsector

Emissions from the waste sector are dominated by methane gas from waste landfills. Methane emissions account for 58 % of emissions, while nitrous oxide emissions from wastewater treatment and biological treatment of solid waste account for 22 % and carbon dioxide emissions from waste incineration account for the rest. This decrease is mainly due to a ban, from 2002, on depositing combustible materials in landfills and a ban, from 2005, on depositing organic materials in landfill. A ban was introduced in 2002 on depositing organic materials in landfills and in 2005 a ban was introduced on deposition combustible materials in landfills. This created a shift towards incineration of waste for energy recovery. Emissions from the incineration of waste for electricity and heat production are allocated to the energy sector and not to the waste sector.

3.2.8 Agriculture

The total greenhouse gas emissions from Agriculture (CRF 3) amounted to about 6.9 Mt CO_2-eq in 2020, which equals to about 15 % of the total national greenhouse gas emissions. Emissions in 2020 were about 10 % lower compared with 1990 levels. The historical emission reduction was due to decline in numbers of livestock, especially dairy cattle as well as decreased emissions from agriculture soils, particularly from the use of mineral fertilizers.

In 2020, agriculture soils (3D) and enteric fermentation (3A) were the dominant sources of the greenhouse gas emission in the sector, accounted for about 47.3 % and 42.4 %, respectively. Manure management (3B) and liming (3G) accounted for about 8.6 % and 1.8 % of the sector's emission, respectively. Emission from urea application (3H) is insignificant (Figure 3.11).

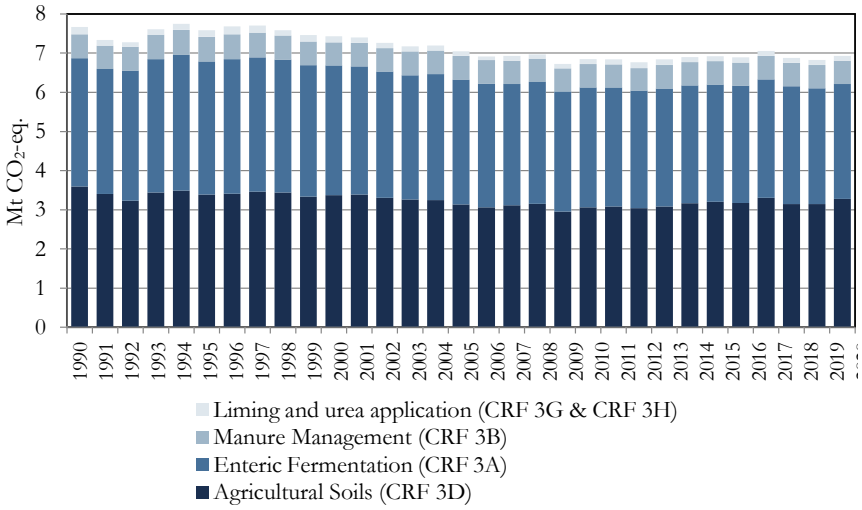


Figure 3.11 Greenhouse gas emissions from agriculture.

Greenhouse gas emissions related to agriculture originate from a range of sources and activities and are dominated by emissions from soil management, enteric fermentation, and manure management. In addition, there are emissions related to the energy use within the sector but reported in the energy sector. The main sources of CH_4 and N_2O emission in Sweden are animal husbandry and crop production. Emission from animal husbandry in Sweden is dominated by beef and dairy cattle but significant emissions also come from swine, sheep, and poultry. Other livestock farming species includes goats, horses, reindeer, and fur-bearing animals. Crop farming includes predominantly the production of cereals, sugar beet and oilseeds.

3.2.9 Land use, Land use change and Forestry

The LULUCF sector has generated annual net removals in Sweden during the whole period 1990-2020 (Figure 3.12). In 2020 total net removal from the sector was estimated to 40 Mt CO_2-eq. During the period total net

removals have varied between around 32 to 43 Mt of CO_2-eq. Between 2019 and 2020 the total net removals increased about 8 %.

The total size and variation of net removals in the LULUCF-sector is mainly affected by the carbon stock change in forest land, and changes in the carbon pool living biomass constitute the major part of these changes in net removals followed by carbon stock changes in mineral soils and dead organic matter. Net removals in this sector are heavily influenced by harvests and natural disturbances such as storms, drought and fires on forest land.

Most of the net removals are in the carbon pools living biomass and mineral soils and the dominating category is forest land. Forest land accounts for 63% of Sweden's land area. Within forest land, the total net removal has varied during the period from 1990 to 2020 and has been on averaged 38 million tonnes CO_2-equivalents. The lowest net removal in living biomass in forest land was 28 Mt of CO_2-eq in 2005 and the highest about 44 Mt of CO_2-eq. in 2012. Between 2019 and 2020 the total net removal on forest land increased slightly.

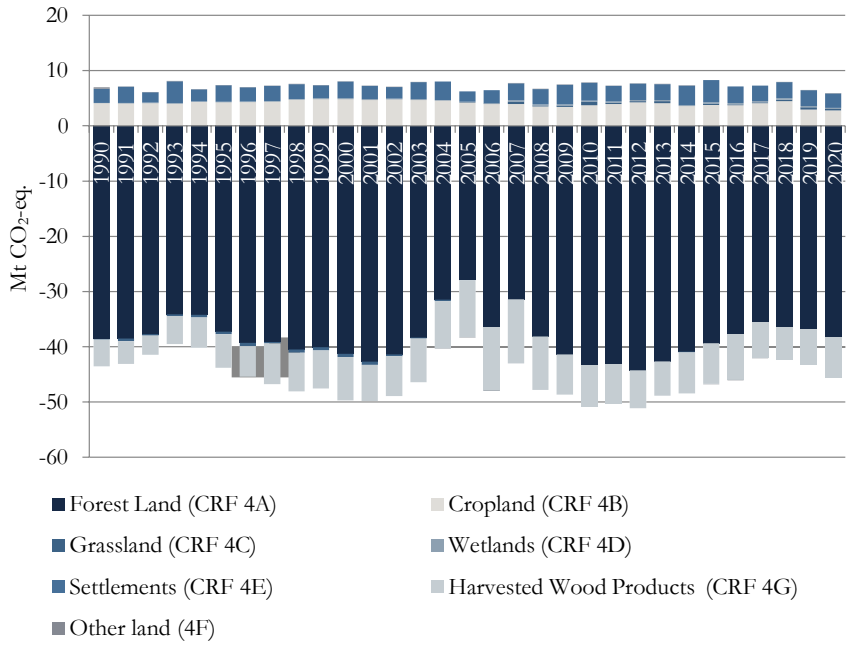


Figure 3.12 Greenhouse gas emissions and removals from land use.

The lowest net removal in living biomass in forest land was 28 Mt of CO_2-eq in 2005 and the highest about 44 Mt of CO_2-eq. in 2012. Between 2019 and

2020 the total net removal on forest land increased slightly. There are two dips in the trend, in 2005 and 2007, because of two severe storms. According to the Swedish National Board of Forestry, the felling, including wood felled by storms, was estimated at 122 Mm^3sk in 2005. However, the decrease in the living biomass in 2005, resulted in an increase in the HWP-pool in 2006. The HWP-pool increased slightly from 6.5 Mt of CO_2-eq in 2019 to 7.3 Mt of CO_2-eq in 2020. The increase was manly in the pulp and paper fraction caused by a higher demand.

3.2.10 International transport

Greenhouse gas emissions from international shipping and aviation, also known as international bunkers, are considerably larger than those from domestic shipping and aviation. In 2020, they amounted to 9.3 Mt of CO_2-eq, which is a decrease of 4 % since 2019 (Figure 3.13). The overall decrease in emissions from international bunkers is a result of the reduced air traffic during the COVID-19-pandemic. On the contrary, greenhouse gas emissions from international shipping increased during 2020.

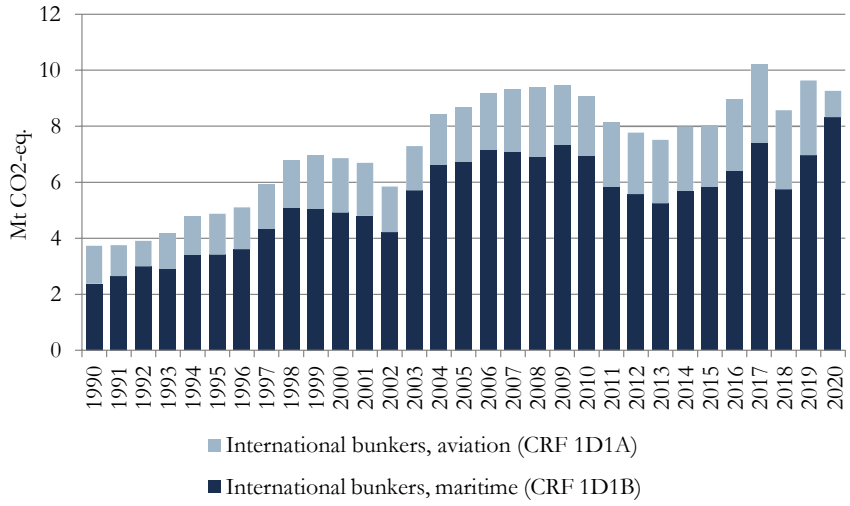


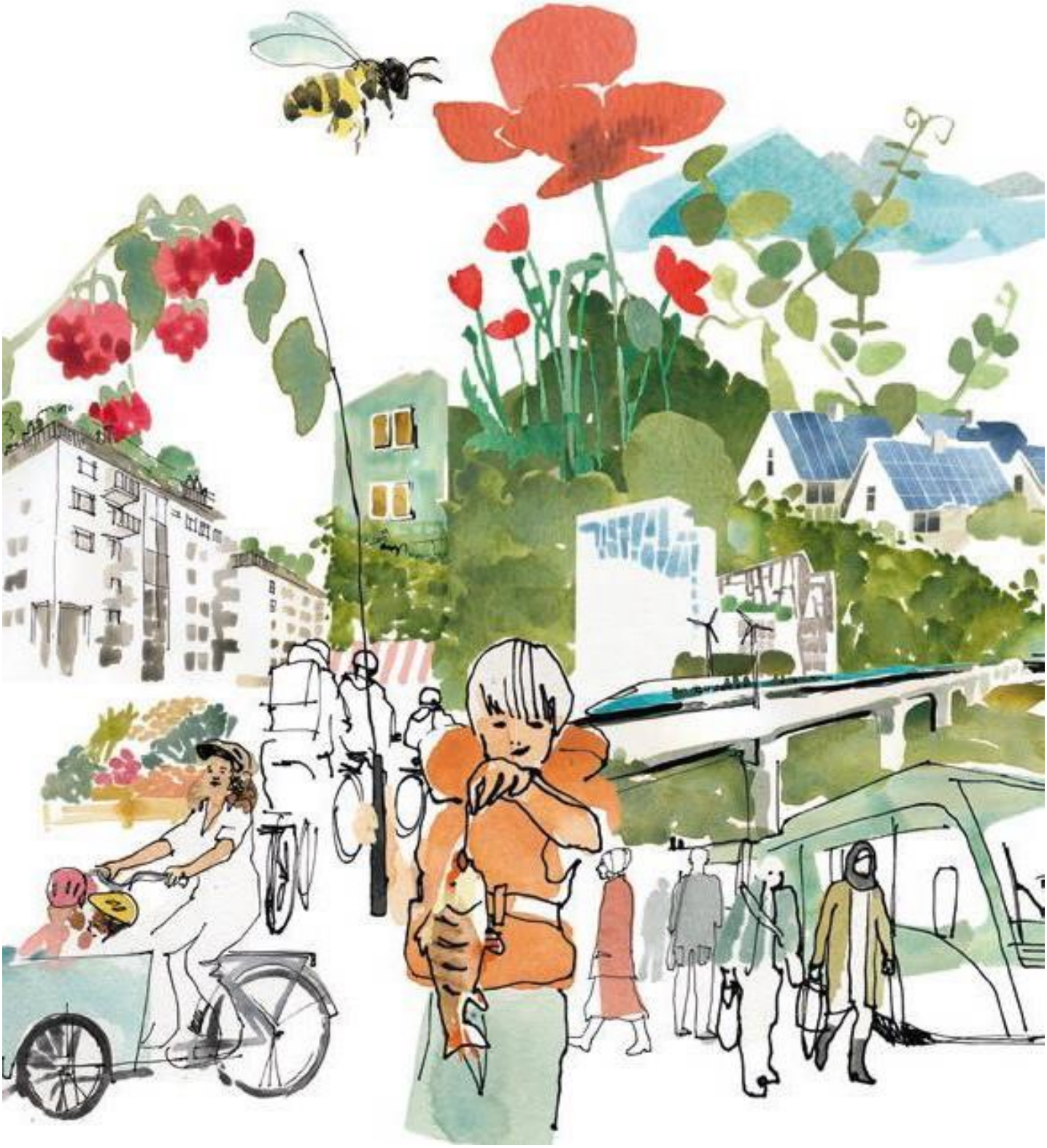
Figure 3.13 Greenhouse gas emissions 1990-2020 from international bunkers.

Emissions from international shipping reached a total of 8.3 Mt of CO_2-eq. in 2020. This is an increase of 20 % compared with 2019 and 251 % higher than in 1990. Greenhouse gas emissions from international aviation bunkers were 0.9 Mt of CO_2-eq. in 2020. This is a decrease of 65 % compared to 2019 and 30 % lower than in 1990. The large reduction in emissions from international aviation during 2020 is a result of the COVID-19-pandemic.

During the years before the pandemic, emissions were twice as high as in 1990. Emissions from international bunkering of aviation have varied over time, but the trend points to a rise in these emissions, owing to growth in travel abroad.

3.3 References

National Inventory Report Sweden 2022, Greenhouse gas emission Inventory 1990 – 2020, Submitted under UNFCCC and the Kyoto Protocol.



4. Policies and measures

4.1.1 Background

This chapter provides information on the Swedish climate strategy as well as key policies and measures implemented or decided in Sweden to reduce greenhouse gas emissions. The policies and measures are included in the projections on greenhouse gas emissions reviewed in chapter 5[11]. Further, the chapter includes information on the efforts to avoid adverse effects of policies and measures and work on project-based flexible mechanisms under the Kyoto Protocol. At the end of the chapter the policy instruments and their effects are summarized in a table.

4.1.2 Swedish climate strategy

Sweden's climate strategy has progressively developed since the late 1980s. It consists of objectives, policy instruments and measures, together with regular follow-up and evaluation. In 2017 a new National Climate Policy Framework, ensuring long term order and stability in climate policy, was adopted by the Riksdag (Swedish Parliament).

4.1.3 The Swedish Environmental quality objective-Reduced Climate impact

To provide a clear structure for environmental efforts in Sweden, the Riksdag has adopted 16 environmental quality objectives. One of these, *Reduced Climate Impact*, forms the basis for climate change action in the country. The interpretation of the objective is "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. Sweden will work internationally for global work to address this goal." (Govt. Bill 2016/17:146)

4.1.4 Sweden's national climate policy framework

In June 2017, the Riksdag adopted a proposal on a national climate policy framework for Sweden (Govt. Bill 2016/17:146). The climate policy framework consists of a Climate Act, national climate targets and a climate policy council. The climate policy framework is the most important climate reform in Sweden's history. It creates order and stability in climate policy and sets long-term conditions for the business sector and society at large.

[11] Some of the policy instruments are, due to recent date of decision, not included in the scenarios in chapter 5. Those are marked with a "*" in the summarizing table at the end of the chapter.

The climate act impose responsibility on the current Government, and on future governments, to pursue a climate policy that is based on the national climate targets and to provide clear feedback on the progress. As a result, Sweden now has long-term climate targets and a council that independently reviews climate policy. The reform is a key component of Sweden's efforts to live up to the Paris Agreement.

Targets

- By 2045, Sweden is to have no net emissions of greenhouse gases into the atmosphere and should thereafter achieve negative emissions. This means emissions from activities in Swedish territory are to be at least 85 % lower by 2045 compared with 1990. Supplementary measures may count towards achieving zero net emissions, such as increased uptake of carbon dioxide in forests and land, and investments in other countries. International accounting guidelines will be followed for this.
- Emissions in Sweden outside of the EU ETS should, by 2030, be at least 63 % lower than emissions in 1990, and by 2040 at least 75 % lower. To achieve these targets by 2030 and 2040, no more than 8 and 2 percentage points, respectively, of the emissions reductions may be realised through supplementary measures.
- Emissions from domestic transport are to be reduced by at least 70 % by 2030 compared with 2010. Domestic aviation[12] is not included in the goal since this subsector is included in the EU ETS.

[12] The emissions only includes CO_2.

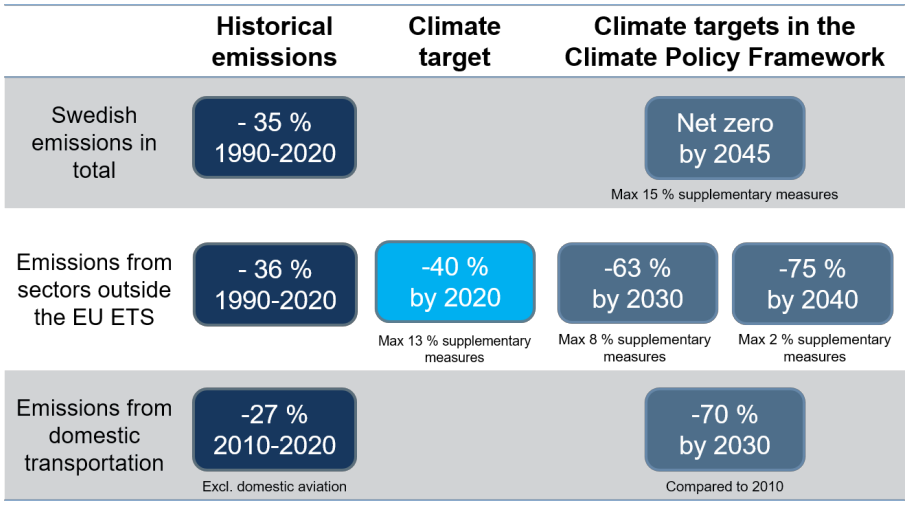


Figure 4.1 Sweden's national targets included in the climate policy framework.

Climate Act

- The Climate Act legislates that the Government's climate policy must be based on the national climate targets and specifies how the work should be carried out.
- In its Budget Bill, the Government must submit a climate review to the Riksdag every year. The climate review must contain:
    - A report on emissions development.
    - A report on the key political climate decisions taken during the year.
    - An assessment to identify the need for additional policies and measures, and when and how decisions about such policies and measures can be adopted.

- Every fourth year, the Government must develop a climate policy action plan which provides information on planned policies and measures to achieve emission reductions. The Swedish EPA supports the Government with data and analysis.
- The Climate Act entered into force on 1 January 2018.

Climate Policy Council

The climate policy council[13] provides independent assessments of how the overall policy presented by the Government is compatible with the national climate goals.

4.1.5 The Swedish target for 2020

Current climate policy is also set out in two Government Bills, entitled *An Integrated Climate and Energy Policy*, passed by the Riksdag in June 2009 (Govt. Bills 2008/09:162 and 163). The first of these Bills sets a national milestone target for climate, calling for a 40% reduction in emissions by 2020 compared with 1990. Emission statistics shows that the target was reached mainly through domestic emission reductions (36 percent reduction between 1990 and 2020) in combination with investments in flexible mechanisms. This target applies to activities not included in the EU Emissions Trading System and does not include the LULUCF sector. In addition, the Bills also set targets for energy efficiency and renewable energy.

Institutional arrangements

At the national level, the Swedish Environmental Protection Agency is responsible for the environmental quality objective *Reduced Climate Impact* and for Sweden's regular climate reporting to the UNFCCC and the EU. Its role thus includes ensuring that new statistics are produced annually on emission trends in the country, and that projections and reports on policies and measures forming part of Sweden's climate strategy are prepared every two years. This work is done in collaboration with the responsible sectoral authorities. The Swedish Energy Agency has a broad sectoral remit covering the supply and use of energy in society and is responsible, among other things, for the action plans being drawn up to achieve further improvements in energy efficiency and increase the use of renewable energy, as well as for Sweden's work on flexible mechanisms. The Swedish International Development Cooperation Agency (Sida), Swedish Transport Administration, Swedish Transport Agency, Swedish Forest Agency, Swedish Board of Agriculture and Swedish National Board of Housing, Building and Planning also have key roles in following up and developing the country's climate strategy. No specific legislation or special administrative procedures have been introduced to implement the Kyoto Protocol. The existing structure of central government administration and government

[13] www.klimatpolitiskaradet.se/en/

inquiries has proved effective also for the purposes of fulfilling Sweden's commitments under the Protocol.

4.1.6 Framework agreement on the Swedish energy policy

The Riksdag has decided on an overall goal for energy policy, which is based on the same three pillars as the energy cooperation in the EU and aims to unite security of supply, competitiveness, and ecological sustainability. The energy policy will thus create the conditions for an efficient and sustainable energy use and a cost-effective Swedish energy supply with a low negative impact on health, the environment, and the climate, and facilitate the transition to an ecologically sustainable society (Government Bill 2017/18:228, bet. 2017/18:NU22, rskr. 2018/19:411).

In addition, the Riksdag has decided on energy policy goals (Government Bill 2017/18:228, bet. 2017/18:NU22, rskr. 2018/19:411). The energy policy goals are:

- In 2020, the share of renewable energy shall be at least 50 percent of the total energy use, the share of renewable energy in the transport sector shall be at least 10 percent and the energy use shall be 20 percent more efficient.
- By 2030, Sweden will have 50 percent more efficient energy use compared to 2005.
- By 2040, the goal is 100 percent renewable electricity production. This is a target, not a deadline for banning nuclear power, nor does it mean closing nuclear power plants through political decisions. This goal is currently under review.

Box 4.1 Riksdag decisions of significance for Swedish climate policy

- In 1988, Sweden's first climate objective was adopted. It covered carbon dioxide only and called for emissions to be stabilised at 'present-day levels'.
- In 1991, the 1988 objective was extended to include all greenhouse gases and all sectors.
- In 1993 a national climate strategy was adopted in line with the UN Framework Convention on Climate Change (UNFCCC) objective of stabilising emissions in developed countries. The new national objective called for carbon dioxide emissions from fossil fuels to be stabilised at 1990 levels by 2000.
- The energy policy guidelines adopted by the Riksdag in 1997 included a strategy to reduce the climate impact of energy use and energy production.
- In 1998, as part of the transport policy framework, the Riksdag adopted the goal of stabilising carbon dioxide emissions from transport at 1990 levels by 2010.
- In 1999 the Riksdag decided to introduce a system of 15 environmental quality objectives, including one relating to the greenhouse effect: the environmental

objective *Reduced Climate Impact.*In 2005 the Riksdag decided on one additional environmental quality objective A Rich Diversity of Plant and Animal Life.
- In 2002 a Government Bill entitled *Sweden's Climate Strategy* was passed, including climate goals for 2010 and 2050.
- The same year, the Riksdag decided to further develop the system of environmental quality objectives, among other things regarding the responsibilities of different stakeholders for attaining the objectives.
- The 2002 energy policy decision included a climate strategy related to that area.
- A climate policy decision in 2006 evaluated and retained the national target for 2010.
- In 2009 Government Bills proposing *An Integrated Climate and Energy Policy* were passed. They included climate targets, targets for an increased share of renewable energy and improved energy efficiency by 2020, a vision for 2050, and a new interpretation of the overall wording of the climate objective.
- The Government Bills on *An Integrated Climate and Energy Policy* also set out policy for the areas of fossil energy, efficient energy markets, and research and development..
- The Government Bills proposing *An Integrated Climate and Energy Policy* also set out policy on nuclear power. The Riksdag subsequently passed Govt. Bill 2009/10:172, *Nuclear Power – Opening the Way to a Generation Change*, and Govt. Bill 2009/10:173, *Nuclear Power – Increased Liability*. These decisions repealed the Nuclear Phase-Out Act and made it possible to replace permanently closed reactors with new ones on the same site, as well as introducing unlimited liability for power producers for damage arising from nuclear accidents.
- The Government Bill 2016/17:179 *New target for renewable electricity and a check point review for the electricity certificate system 2017* includes a new target for the electricity certificate system by 2030 and a prolongation of the system to 2045.
- The Government Bill 2016/17:146 *A Climate Policy Framework for Sweden* consists of a climate act, new climate targets and a climate policy council. It creates order and stability in climate policy and sets long-term conditions for the business sector and society
- In the Climate Policy Action Plan (Govt. Bill 2019/20:65) the Government describes its plans to achieve the climate goals as decided by the Riksdag. The Climate Act requires the Government to draw up a Climate Policy Action Plan every forth year.
- The Electrification Strategy addresses the conditions in the energy sector for an efficient electrification. This would contribute to reach Sweden's climate objectives.

4.1.7 Regional and local action on climate change

Since 1998, Sweden's county administrative boards (CABs) have been tasked with applying the national environmental quality objectives at the regional level. All 21 CABs have adopted regional climate objectives. As of 2005, their role also included developing regional action programs to achieve the environmental quality objectives. Since 2008, they have also been entrusted with strategic coordination and leadership in regional efforts to implement government policies for a transition to renewable energy and reduced

climate impact. The CABs develop and implement regional action plans in collaboration with other stakeholders. They support efforts by the business sector, regions and municipalities in the area of climate and energy. Implementation of regional climate and energy strategies include a variety of measures, such as initiating cooperation and transferring knowledge between regional actors.

Regional energy offices also initiate and participate in a wide range of projects relating to energy efficiency and renewable energy sources, with funding from the Swedish Energy Agency, the EU, CABs, regional development councils and other organisations.

At the municipal level, a wide range of climate activities are being undertaken. Municipalities are obliged to have an energy plan, which is often combined with a climate strategy to reduce greenhouse gas emissions.

Energy and climate change advisory services, which are partly funded by the Swedish state and municipalities, have been provided since 1998. The Swedish Energy Agency is responsible for the advicory service, including providing support in other languages than Swedish.

The regions have the task of preparing and establishing a strategy for the county's development (regional development strategy) and coordinating efforts to implement the strategy. Economic, social and environmental sustainability is an integral part of analyzes, strategies, programs and initiatives in the regional development work. The region initiate, implements and participate in a wide range of projects relating to climate energy efficiency, renewable energy and reduced climate impact.

4.1.8 Other institutional set-ups to implement the climate targets

The Climate Board

The government's goal is for Sweden to become one of the world's first fossil free welfare nations. To achieve this, all policy areas must move in the same direction and the climate issue must be integrated into all relevant policy areas. For that reason, the government has established a climate board within the Government Offices[14].

[14] Klimatkollegiet

The purpose of the Climate Board is to strengthen the government's work to achieve the climate goals and to implement the climate policy action plan. The Climate Board has regular meetings chaired by the Prime Minister. In addition to the Prime Minister and the Minister for the Environment and Climate, six other ministers are included, whose areas are crucial for climate change.

The Electrification Commission

In 2020, the Government appointed a Commission for Electrification to speed up the electrification of the transport sector. The Commission for Electrification was an advisory body chaired by the Minister for Infrastructure and was composed of 16 members from business, the public sector and the research community. The Commission for Electrification's mandate was to work on the electrification of all modes of passenger and freight transport. Electrification here refers to electrification with all relevant technologies, including hydrogen technology.

4.2 Policies and measures in Sweden's climate strategy and their effects

4.2.1 Background

Sweden has introduced a range of policies and measures directly or indirectly affecting greenhouse gas emissions. The emphasis in the country's climate strategy is on the use of general economic instruments, but in many cases the general economic instruments are supplemented with targeted measures, for example to support the development and market introduction of technology and eliminate barrier effects. Many instruments which interact with carbon dioxide tax and emissions trading have also been adopted to achieve other policy goals than the climate objective, such as energy policy objectives.

Since the early 1990s, two key instruments in reducing Swedish emissions have been energy and carbon taxes. These taxes have been supplemented with other instruments, such as technology procurement, information, a CO_2-based annual vehicle tax and investment grants. Legislation, as those involving prohibitions, standards, and urban planning, also plays a part in curbing emissions. EU-wide policy instruments, in particular CO_2 emission performance standards for new vehicles and the Emissions Trading System (EU ETS), also have assumed growing importance in Sweden. At the same time, developments in recent decades have been defined by a framework for spatial planning and other long-established instruments in Sweden. Of

particular importance are earlier decades' investments in an expansion of district heating networks, public transport systems and carbon-free production of electricity.

Given the large number of policies and measures, many of them introduced with other primary objectives than climate mitigation, it can be difficult to evaluate the progress made towards the objective. As several instruments interact, it is also hard to distinguish the effect of a single instrument. Furthermore, picking out the effects of policy instruments from the impact of other, external changes, such as energy prices, is often complicated.

Yet another difficulty in evaluating policies and measures in Sweden is that instruments which reduce electricity consumption or increase the production of carbon-free electricity have only a limited impact on carbon dioxide emissions inside Sweden's borders, because the electricity production in Sweden is largely fossil free albeit integrated with Nordic/north European market.

It should also be noted that, even before 1990, there were instruments in the Swedish energy sector with a similar steering effect to those used after 1990, and through those instruments incentives were created early on for the introduction of bioenergy and an expansion of district heating. For the energy supply sector and the residential and commercial/institutional sector it may, therefore, be difficult to disentangle the additional effects of policy instruments introduced in Sweden after 1990 from the effects that might otherwise have arisen if instruments had not been subsequently strengthened.

Figure 4.2 illustrates an overall assessment of the impact of economic instruments affecting Sweden's stationary energy system. Forming the basis for the results is the TIMES-NORDIC energy system model, in which a scenario based on policy instruments in place in 1990 has been compared with a scenario reflecting the actual development of instruments (see box 4.2. Economic instruments introduced after 1990 have been important for the reduction of carbon dioxide emissions. This is most evident for the electricity and district heating sector, see Figure 4.2. Not all policy instruments are included in the analysis why the total effect is underestimated (Profu 2021). The different sectors are described in more detail in the relevant sections of this chapter.

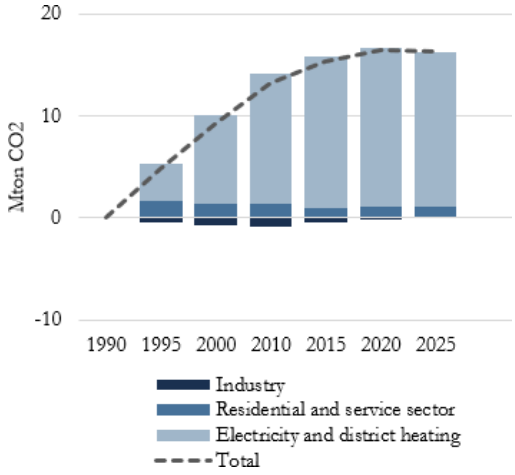


Figure 4.2 Difference in carbon dioxide emissions between a scenario based on 1990 policy instruments and actual development of policy instruments. The importance of policy instruments introduced after 1990 has increased over time, most notable for the eclectricity and district heating sector (Profu 2021).

Box 4.2 TIMES-NORDIC modelling
To assess the effects of economic instruments on Sweden's stationary energy system, results of estimates made with the TIMES-NORDIC energy system model (Profu 2021). The 'stationary energy system' comprises production of electricity, district heating and process steam, together with final energy consumption in the residential sector, services and industry. The estimates covered two cases:
1. Actual development of policy instruments from 1990 to 2020. Current instruments are subsequently assumed to remain in use up to and including 2030.
2. A '1990 scenario', using the policy instruments in place in 1990 throughout the period studied (1990–2050). In other respects, this case is identical to (1).

Modeling attempts to capture the most important variables that could conceivably influence the outcome we are interested in studying; all modeling therefore necessarily involves a simplification of reality and hence some uncertainty.

4.2.2 Cross-sectoral instruments

EU Emissions Trading System Directive 2003/87/EC

The EU Emissions Trading System (EU ETS) is the EU's most important tool to combat climate change. It was introduced in 2005 and has since been expanded to cover more sectors and greenhouse gases. The rules for monitoring and reporting and for free allocation of allowances have subsequently been improved and harmonized between the EU member states.

The amount of emissions allowed within the system is limited by a cap, which is decreased every year. Almost half of the allowances are allocated for free to installations covered by the system, the rest are auctioned.

Free allocation is used to avoid risks of carbon leakage in specific industrial sectors such as steel and cement. As a rule, there is no free allocation for emissions from electricity production. Free allocation to sectors not exposed to carbon leakage will cease in 2030. However, free allocation to district heating and district cooling will continue on a low level.

At the outset, EU ETS covered emissions of carbon dioxide from combustion installations and energy-intensive industries (mineral oil refineries, coke ovens, iron and steel industry, pulp and paper industry, and mineral industry). The scope was extended in 2013 with new greenhouse gases (nitrous oxide and perfluorocarbons) and with some new industrial activities. At present, about 750 Swedish installations are included in the system. At the EU level in total, approximately 13,000 installations are covered, which corresponds approximately to 45 percent of the total EU GHG emissions.

To strengthen EU ETS, the EU has decided on a reform of the system. From 2021 onwards, the annual reduction of the cap will increase from 1.74 % to 2.2 %. A market stability reserve has been introduced to reduce the surplus of emission allowances on the market. From 2023 onwards, allowances held in the market stability reserve above the number of allowances auctioned the previous year will be cancelled. Finally, the auction share has been set to 57 % and free allocation will be focused on sectors highly at risk of carbon leakage.

Emissions from aviation were included in the system in 2012. Because of extensive protests from some countries outside the EU the EU decided on a temporary exemption for flights outside the EEA.

As the ICAO in September 2016 decided to implement a global measure, the Carbon Offsetting and Reduction Scheme for International Aviation (Corsia), the EU has decided to maintain the geographic scope of the EU ETS limited to intra-EEA flights from 2017 onwards. Corsia is implemented in EU law through a revision of the EU ETS legislation. Sweden is the administering Member State for approximately 90 aircraft operators, however only a few were subject to report their emissions in CORSIA in 2020.

In 2021, the European Commission released proposed amendments to the EU ETS as part of the "Fit for 55" package. Key proposed amendments involve tightening the emissions cap. For the sectors covered a -61% emissions reduction target is planned (by 2030 compared to 2005 levels). The linear reduction factor would be increased from 2.2% to 4.2%. Moreover, the European Commission is proposing to extend the EU ETS to maritime transport, particularly for large ships (above 5000 gross tonnage) from 2023.

Energy tax and carbon tax

The Swedish system of energy taxation is based on a combination of a carbon tax, an energy tax on fuels, and an energy tax on electricity. The key taxes influencing greenhouse gas emissions in Sweden are the carbon tax and the energy tax on fuels, which are described below in general and more in detail for each sector.

Carbon tax

A carbon tax, based on the fossil carbon content in the fuel, was introduced in 1991 and aims at reducing the emissions of carbon dioxide in sectors outside the EU ETS. The tax has been raised in several steps since it was first implemented. In total, the tax has increased from SEK 0.25/kg (1991) carbon dioxide to SEK 1.20/kg (2021). In addition to specific tax increases stipulated in government bills, a yearly indexation of the tax level is applied to adjust for changes in the consumer price index and to take account of the development of the gross domestic product (GDP). The GDP-indexation is added to the energy tax. In 2021-2022 the GDP-indexation is put on hold (Gov. Bill 2020/21:196).

The tax level is proportionate to the calculated amount of carbon dioxide emissions based on the fuel's fossil carbon content. This means that biofuels currently are not subject to carbon taxation, if not used within the reduction obligation scheme for motor fuels. Regarding motor fuels, changes to carbon taxation of biofuels were implemented on 1st July 2018 (see separate section on carbon and energy taxation in the transport sector). A reduced carbon tax and energy tax is applied for diesel used in, for example, agriculture, forestry and aquaculture.

Energy tax

Taxes on energy have been used in Sweden for a long time.[15] An energy tax on petrol and diesel was introduced in 1924 and 1937, respectively. Fuel used for heating and electricity became subject to an energy tax in the 1950s.

The aim of the energy tax is mainly fiscal. It does also have the effect to steer energy usage towards Sweden's energy efficiency, renewability, and climate targets[16]. The energy tax on motor fuels used in road vehicles and off-road machinery also internalises external costs from the traffic, such as road wear, noise, etc (National Institute of Economic Research, 2013). The energy tax on fuel varies depending on whether it is used as motor fuel or for heating purposes. The tax level on heating fuels also varies between households, industry and the energy conversion sector. A reduced energy tax is applied in some sectors.

Carbon tax and energy tax on motor fuels used for road vehicles and off-road machinery

Petrol and diesel are covered by both an energy tax and a carbon tax on fuels used in road vehicles, off-road machinery and private ships and boats. Since 1994, the energy tax on fuels and electricity as well as the carbon tax on fuels are adjusted to changes in the consumer price index (CPI), to take account of inflation. As of 2017, tax rates on petrol and diesel are also adjusted to take account of the development of the gross domestic product (GDP).[17] The Parliament has decided (Govt. Bill 2020/21:196) to put the GDP adjustment on hold during 2022 to compensate for increased prices due to the reduction obligation scheme, see below.

In December 2021, the energy tax on diesel (environmental class 1) was SEK 2.478 per liter and the carbon tax was 2.262 per liter, while the energy tax on petrol was SEK 4.13 per liter and the carbon tax was 2.61 per liter. In May 2022 the energy tax on both diesel and petrol was lowered by SEK 0.4 per litre (SEK 0.5 per litre including VAT). At the same time a temporary decrease of the tax rates by 1.05 SEK per litre was implemented (Govt. Bill 2021/22:84 and 2021/22:221)

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[15] Tax on energy is a collective term for excise taxes for fuel and electrical power and is governed by the Act of Excise Duties on Energy (1994:1776).

[16] The energy efficiency target and the renewable target for 2020 are part of Govt. Bills 2008/09:162 and 163.

[17] This is achieved through a flat-rate increase of 2 percent per year. The combined change in the carbon and energy tax rates is, however, added exclusively to the energy tax rate (i.e. the carbon tax rate is only directly affected by the indexation to CPI).

Swedish Parliament decided to introduce an emission reduction obligation scheme in 2018. In 2021 the reduction levels within the reduction obligation scheme were decided until 2030. The scheme was accompanied by several tax rule changes for petrol and diesel. In particular, low-blended biofuels that are covered by the reduction obligation scheme are subject to carbon tax and energy tax rates that correspond to the rates of their fossil equivalents. At the same time, the carbon tax rates for petrol and diesel were adjusted downwards to take account of the share of low-blended biofuel per liter full blend, as a result of the emission reduction obligation scheme. The energy tax on petrol and diesel was also lowered. High-blended and pure biofuels are not covered by the reduction obligation scheme and such sustainable biofuels are still exempted from both the carbon tax and the energy tax. If the biofuel is classified as petrol or diesel it needs to consist of more than 98 volume percent biomass to be covered by the tax exemption. As the exemption of the carbon and energy tax for these biofuels are not considered compatible with the EU state aid rule, Sweden has sought a prolongation of an exemption which was approved by the European Commission in the autumn 2021. The prolongation of the tax exemption is for one year.[18] Moreover the European Commission approved in the autumn 2020, under EU state aid rule, a 10-year prolongation of the tax exemption (2021-2030) for non food-based biogas and bio propane used for heating or as motor fuel in Sweden. The objective of the tax exemption is to increase the use of biogas and biopropane and to reduce the use of fossil fuels and their greenhouse gas emissions, while facilitating the transition towards advanced biofuels.

Carbon tax and energy tax for heat production

Fuels used for heat production are subject to energy tax as well as carbon tax. Fuels used for heat production in combined heat and power plants (CHPs) and in other heating plants within the EU ETS were subject to 11 % of the carbon tax and 30 % of the energy tax until 31 July 2019. Between 1 august 2019 and 31 December 2022 the tax levels were increased to 91 % of the regular carbon tax and 100 % energy tax. The Carbon tax for heat production within the EU ETS was abolished as of 1 January 2023 since carbon emissions are already priced through the EU ETS. The energy tax for fuels used to produce heat in CHPs outside the EU ETS was raised on the

[18] https://www.regeringen.se/pressmeddelanden/2021/09/klart-med-fortsatt-skattebefrielse-for-flytande-biodrivmedel/ 3 September 2021

1st of August 2019 and is now subject to 100 % of the energy tax. These fuels are also subject to 100 % carbon tax.

Carbon tax and energy tax for electricity production

Fuel used for electricity production is exempted from both energy and carbon taxes. However, the use of electricity is generally subject to the energy tax on electricity.

Carbon tax and energy tax in the manufacturing industry sector

The manufacturing industry sector is subject to some exemptions and reductions in energy and carbon taxes, primarily because most of the manufacturing industry is already covered by the EU ETS. One of the main reasons behind the tax reductions is to avoid the application of more than one policy instrument for the same purpose for cost-efficiency reasons.

The manufacturing industry, both covered and not covered by the EU ETS, used to pay 30% of the general energy tax. As of 1 January 2022, fuels used for heat production in manufacturing processes in industries are subject to 100 % of the energy tax no matter if the industrial activity is part of the EU ETS or not (Govt. Bill 2020/21:97). No carbon tax is charged for fuels used for heat production in manufacturing processes in industries if the industrial plant is part of the EU ETS.

Previously, industries not covered by the ETS had significant reductions in the carbon tax, but in recent years the tax has been raised. The carbon tax reduction was then totally rescinded from 2018. For so-called mining diesel (diesel that is used in working machinery in manufacturing processes in mining industrial activity), energy taxes and carbon taxes were levied with 11 % and 60 % respectively of the general levels of taxation until 31 July 2019. This reduction of energy and carbon tax has now been rescinded since August 2019, meaning that the full energy and carbon tax rates are applied.

Carbon tax and energy tax in agriculture, forestry and aquaculture sectors

Up until 2014 the agriculture, forestry and aquaculture sectors paid 30% of the general energy and carbon tax rates for fossil fuel used for heating purposes. Since then, the carbon tax reduction in the sectors has been reduced in steps and was totally rescinded by 1 January 2018. The energy tax was 30 % of the general energy tax rate for heating fuels in these sectors until 1 July 2021. Since then, the reduction has been reduced. It was totally rescinded 1 January 2022 (Govt. Bill 2020/21:97). Diesel for machinery in

agricultural, forestry and aquaculture activities are subject to carbon and energy taxation. A special reimbursement has fluctuated over the years. The current level of reimbursement is for carbon tax SEK 2.292 per litre and for energy tax 2.111 SEK per litre.

National and international commercial shipping

Fuels for national and international commercial shipping are not targeted with any energy tax or carbon tax.

Local Climate Investment Program – The Climate Leap

To further stimulate the reduction of greenhouse gas emissions, a program for local investments was introduced in 2015, the Climate Leap. In total, SEK 7.7 billion has been granted for investments within the program (as of November 2021). The Swedish Environmental Protection Agency (Swedish EPA) administers grants for local and regional investments to cut greenhouse gas emissions. Investments in all sectors, except those included in the EU ETS, and all types of organisations are eligible to apply for grants. Some investments in sectors included in the EU ETS are also eligible for grants if these result in an increased utilisation of waste heat. Applicants compete based on the estimated greenhouse gas reduction of each investment.

Examples of investments that can be granted support are charging infrastructure for electric vehicles, biogas plants, infrastructure for biofuel and changes from fossil oil to biofuel or district heating. In 2022 the budget for the program amounts to SEK 2.8 billion. The budget is estimated to SEK 2.7 billion for 2023 and SEK 3.7 billion for 2024 (Govt. Bill 2021/22:1).

Effects of the Local Climate Investment Program

In total, the investments granted are expected to generate a reduction of approximately 1.5 Mt CO_2-eq. per year during the technical lifespan of the investments[19] (Govt. Bill 2021/22:1). Measures in the transport sector represents around 60 % of the total emission reductions while around 35 % of the reductions can be attributed to measures in the residential and service sector along with the industry. It should, however, be noted that the measures in the investment program are of different character, including enabling activities for vehicle shifts such as infrastructure investments,

[19] The technical lifespan of the investments is in average 16 years.

including charging infrastructure, and supply of biofuels with an indirect effect on emission reductions. Further, all emission reductions cannot not be attributed to this policy instrument alone, as other instruments will also affect the emissions. E.g. the electric vehicles need the infrastructure but are also affected by other national and EU policy instruments.

A national center for carbon dioxide capture and storage

In order to achieve net zero emissions by 2045, and enable negative emissions thereafter, the Swedish Energy Agency has been appointed as national centre for CCS-related issues. Tasks include to promote the appropriate implementation of CCS in Sweden, for example by following the latest development, providing the government with necessary analysis, and identifying legal barriers for CCS in Sweden. The Agency has also been appointed auctioneer for the support system, through reversed auctions, for BECCS.

National strategy for electrification

The government has decided on a national strategy for electrification. The strategy will contribute to a fast, smart and economically efficient electrification. In the strategy, the government takes a holistic approach to the conditions in the energy sector to enable increased electrification. Means has been allocated to enable the implementation of the strategy to meet society's needs and expectations. Among other things, the Government intends to set up an electrification council to support the implementation of the electrification strategy. A plan to deal with any obstacles to increased electrification will also be included. To implement the electrification strategy the Government has budgeted SEK 20 million for 2022, SEK 35 million for 2023 and SEK 25 million for 2024 (Govt. Bill 2021/22:1).

The Environmental Code and planning legislation

General legislation in the area of the environment has been collected in the Environmental Code since January 1999. Among other aspects, the Environmental Code contains general rules for consideration to be observed in all activities and measures that are not of negligible significance in individual cases and that can affect the environment. Environmentally hazardous activities, as defined in the 9th chapter, require obtaining a permit. The permit application must include an environmental impact assessment as described in the 6th chapter. In 2018 changes were made in the 6th chapter in order to clarify that direct, indirect and cumulative impacts should be included in the environmental impact assessment. Greenhouse gas emissions

form part of the permit assessment procedure and the Code also includes requirements to use the best available technology. However, effective 2005, issuing emissions limit values for carbon dioxide or limiting the use of fossil fuels for installations covered by the EU Emissions Trading Scheme is no longer permitted.

Measures in the area of public planning chiefly impact emission trends in the longer term and may have significance from this point of view. Measures in public planning are principally governed by the Planning and Building Act (PBL)(SFS 2010:900), but many measures are also covered by the Environmental Code. Since May 2011, the PBL introduced new requirements on considering the environmental and climate aspects of planning. The longer term significance of the development of the built environment for energy and transport needs has been increasingly highlighted, and the PBL also made it mandatory to consider inter-municipal and regional circumstances in planning. To enhance the implementation of the requirements in the PBL, the National Board of Housing, Building and Planning published new guidelines in 2017 for municipal structure planning, aimed at reducing greenhouse gas emissions.

In 2016 changes to annual report legislation came into force. Large corporations must now comply with new regulations for sustainability reporting. Sustainability reports must include information needed to understand a company's development, position, earnings and the consequences of their operations that concern the environment.

From 1 January 2022, the requirement for a climate declaration applies to the construction of new buildings. This means that builders must report the impact on the climate of a new building. The purpose of the law on climate declaration for new buildings (SFS 2021:78) is to help reduce the climate impact from the construction phase.

Fossil Free Sweden

The Swedish Government has adopted the objective to make Sweden one of the world's first fossil-free welfare states. This ambition requires a mobilisation of the entire society, not least municipalities, cities and business. The governmental initiative 'Fossil Free Sweden', launched in 2015, aims to strengthen the dialogue between the state and the business sector, municipalities and civil society. A national coordinator, appointed by the government, is the link between the actors and the government in efforts to

remove obstacles and create conditions to speed up the reduction of greenhouse gas emissions. Fossil Free Sweden is open to all actors who support the declaration drawn up for the initiative. The declaration stipulates that actors participating in the initiative share the view that the world must become fossil free. It also stipulates that actors who participate must be able to present concrete measures to reduce emissions. So far, more than 500 actors have signed the declaration and 22 roadmaps from different sectors have been submitted to the government (Fossilfritt Sverige, 2021).

Climate change communication

Swedish governmental authorities have a long experience of using communication of knowledge as policy instruments for the public and business sectors and for citizens. Some examples:

The Swedish Environmental Protection Agency is a driving force and provides support in climate work in Sweden. The website www.naturvardsverket.se is a hub for statistics and facts on emissions and knowledge on effective mitigation activities. It is widely used by policymakers, media, business, organizations and researchers.

The Swedish Meteorological and Hydrological Institute (SMHI) develops and distributes information about the weather, water and climate change adaptation. The National Knowledge Centre for Climate Change Adaptation, set up at SMHI, launched *the Swedish Portal for Climate Change Adaptation*, with facts and guidance on adaptation to a warmer climate.

The Swedish Energy Agency is responsible for giving both citizens and businesses information and advice on more efficient energy use. On-line energy tests; the websites where you find energy tests of white goods for consumers, are the most visited on the Swedish Energy Agency's web. Energy and climate advisers in Sweden's municipalities reply free of charge to questions about heating, energy costs and efficiency, transport, climate and government grants relating to energy.

The Swedish Forest Agency and *the Swedish Board of Agriculture* focus on e-services and digital information to land and forest owners, forest officers and farmers on how to reduce the climate impact of forestry, agriculture as well as on climate adaptation.

The Swedish Civil Contingencies Agency are in charge of prevention and mitigation of the effects of natural accidents and support measures to adapt the work of social protection and preparedness to a changing climate.

Public awareness

Public awareness on climate change is generally high in Sweden. The Swedish Environmental Protection Agency regularly conducts surveys of Swedes' attitudes on climate issues. The purpose is to measure the public preparedness on cutting emissions based on their own lifestyle and consumption, and the general attitudes on public climate change instruments. The survey conducted in 2021 (SEPA/Gullers 2021) shows that there is a great commitment among the public in Sweden to solve the climate issue. Swedes are keen to contribute and very positive about societal climate initiatives and corporate climate work.

Education and training

In cooperation with the Swedish Environmental Protection Agency, The National Swedish Agency for Education has clarified the connection between curriculum and syllabus and the national environmental goal Reduced Climate Impact. In-depth teaching on climate issues is common in upper secondary level. The National Swedish Agency for Education is currently working towards goal 4 in the Agenda 2030: Ensure inclusive and quality education for all and promote lifelong learning. The work is carried out together with relevant stakeholders.

Higher education institutions offer courses on the scientific basics of the climate and/or climate-related subjects like energy and forestry. There are various networks and centers of competence, for example, the Centre for Climate and Safety at Karlstad University and the Centre for Climate and Environmental Research at Lund University.

Increased competence for climate transition

To meet future needs in the labour market as a result of the climate transition, there is a need for educational initiatives. Government-funded education aimed at key competences in the labour market can facilitate the transition of industry and society to a circular economy and help reduce unemployment. The Government proposes that SEK 100 million be allocated for 2022. For 2023 and 2024 the allocation is estimated at SEK 100 million per year.

Research and development

Public investment in climate-related research and development are aimed at creating better prerequisites for achieving the substantial longer term emissions reduction required. Swedish climate-related research covers a broad spectrum, from natural sciences to humanities, but with an emphasis on technical and scientific research and development. Three important research areas are energy, transport and industry, for which the Government has decided to grant extensive funding.

Energy and climate issues are closely linked, and the solutions to the challenge of climate change are largely energy-related. The overall objective of energy research and innovation in Sweden is to contribute to fulfilling the national energy and climate objectives, the long-term energy and climate policy, and energy-related environmental objectives.

In the budget bill for 2022 (Govt. Bill 2021/22:1) the Government allocates SEK 1.43 billion for energy research in 2022. Estimated amounts for 2023 and 2024 are SEK 1.37 billion and SEK 1.38 billion respectively.

Alongside the contribution to energy research, climate-related research is also being financed by other national research funding programs. In Government Bill 2020/21:60 (Research, freedom, future – knowledge and innovation for Sweden) climate is listed as one of several societal challenges that require special contributions.

A national ten-year research program for climate was established in 2017 with an annual budget (from 2021) of SEK 230 million (Formas.se, 2021.11.13).

In order to reduce greenhouse gas emissions from working machineries and strengthen the competitiveness of the Swedish automotive industry, the Government has decided on targeted support for research, development and market introduction for working machineries in 2021 and 2022 (Government Bill 2020/21:1).

Swedens strategy for a circular economy

Transforming production and consumption towards a circular economy has a large potential to reduce the use of materials and thus the negative impact on the climate. This requires a shift from virgin materials to circular material flows. This, in turn, requires toxic chemical to be removed (see section

4.2.7). To enable a circular economy the Swedish Government has presented a strategy[20] as well as two more hands-on action[21] plans for the transformation, the second focusing on plastics[22].

4.2.3 Energy – production of electricity and district heating and residential and service sector

Energy Efficiency Directive 2012/27/EU

The Energy Efficiency Directive came into force in December 2012, replacing the Energy Services Directive and the Cogeneration Directive 2004/8/EC. The Directive establishes a set of binding measures to help the EU reach its 20% energy efficiency target for 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages in the energy chain from production to final consumption.

To adapt Swedish regulations to the Directive, the following changes were implemented: i) Large enterprises must conduct an energy audit every fourth year; ii) electricity suppliers must invoice customers for the measured consumption of electricity, if the supplier has access to measurements; iii) new requirements are established on the measurement of energy consumption in apartments; and iv) requirements are tightened on authorities to use energy more efficiently. The main part of the new legislation came into force 1 June 2014 (Govt. Bill 2013/14:174). Moreover, changes were made in the Electricity Law (SFS 2014:1064) requiring network operators to adjust tariffs and other practices to promote energy efficiency.

On 30 November 2016, the European Commission presented a package of legislative proposals containing measures in the EU's energy policy, the so-called Clean-energy-for-all package. Putting energy efficiency first is an important goal in the package. The package included a proposal to amend the EED. The European Parliament and Council Directive (EU) 2018/2002 of 11 December 2018 amending Directive 2012/27 / EU on energy efficiency (amending directive) entered into force on 24 December 2018.

The amending directive includes a headline target of at least 32.5% improved energy efficiency by 2030. The target can be reviewed and sharpened. The directive requires Member States to achieve cumulative energy savings

[20] Sverige_strategi_cirkulär_ekonomi.pdf

[21] cirkular-ekonomi-handlingsplan-for-omstallning-av-sverige.pdf

[22] Sveriges_handlingsplan_för_plast_-_en_del_av_den_cirkulära_ekonomin_-_Regeringen.se

obligations for the period 2021-2030. The directive also includes revised requirements regarding metering and billing of energy. In 2021, as part of the "Fit for 55", the European Commission proposed amendments to the directive, introducing a higher target for reducing primary (39%) and final (36%) energy consumption by 2030 now binding at EU level, in line with the Climate Target Plan, up from the current target of 32.5% (for both primary and final consumption) (Commission proposes new Energy Efficiency Directive | European Commission (europa.eu)).

Renewable Energy Directive 2009/28/EC

The EU has adopted a binding target requiring an increase in the percentage of renewable energy, currently at 8.5%, to 20% of total energy use over the period 2005–2020. Responsibility for attaining this target has been shared among the Member States. According to this burden sharing, Sweden had to increase its share from just under 44% (2007) to 49% in 2020. Sweden reached the EU commitment (49%) and the national target (50%) back in 2012. Since then, the use of renewable energy has increased to a level of 56% in 2019.

The EU has adopted a revised Renewable Energy Directive that sets a new binding renewable energy target for the EU for 2030 of at least 32 %, including a review clause by 2023 for an upward revision of the EU level target. In 2021, as part of the "Fit for 55" package, the European Commission proposed amendments to the directive, increasing the current EU-level target to at least 40% by 2030, which represents doubling the current renewables share of 19.7% in a decade (Commission presents Renewable Energy Directive revision | European Commission (europa.eu)).

EU has also set a specific target for the share of renewable energy in the transport sector to increase to 10% in 2020 (Renewable Energy Directive 2009/28/EC). In 2019 the share of renewable energy in the transport sector in Sweden according to the renewable directive's calculation methodology was already 30,3%.

Production of electricity and district heating

The production of district heating has risen approximately 50% since 1990. At the same time, emissions from this source have been significantly reduced, as the expansion largely has been achieved by the increased use of biofuels. The carbon tax is one of the main factors behind this trend, but the electricity certificate system has also been important in phasing out fossil

fuels in the sector. The low emissions from electricity generation are explained by the fact that nuclear power and hydropower account for a dominant share of production, while additional production of electricity in recent years chiefly comes from biomass-fired combined heat and power plants (CHPs) and wind power.

Tax on waste incineration

Between 2020–2022 incineration of waste was taxed (SFS 2019:1274). The tax was gradually increased and in 2022 it was SEK 125 per ton. The tax excludes for example hazardous waste and bio energy. The tax was abolished as of 1 January 2023.

Electricity certificate system

An electricity certificate system aiming to support electricity based on renewable energy was introduced in 2003. Conceptually, the system works as follows. Electricity suppliers are obliged by law to submit electricity certificates corresponding to a certain share, or quota, of their electricity deliveries. The quota is gradually being increased yearly up to 2020. Electricity producers are allocated a certificate from the central government for every megawatt-hour (MWh) of renewable electricity produced. The producers are allowed to sell the certificates in an open market where the price is set by the seller and buyer. The certificates thereby provide extra profit for the producers of renewable electricity (SFS 2011:1200).

The electricity certificate system was earlier prolonged up until 2045 (Govt. Bill 2016/17:179) but the rapid development with regard to the expansion of renewable electricity production has led to the electricity certificate system now fulfills a limited function. Therefore, the government proposed, and the Parliament decided, that new electricity generation facilities may not be eligible for the electricity certificate system after the end of 2021 and the electricity certificate system will be terminated by the end of 2035 (Government Bill 2020/21:16; Näringsutskottets betänkande 2020/21:NU6).

Initiatives for wind power

Research programs

Different programs have promoted the dissemination of knowledge and information about wind power. An example is the research program Vindval, which aims to collect and provide scientific knowledge about wind power's impacts on humans and on nature (Swedish EPA 2021, naturvardsverket.se/vindval).

Designation of areas of national interest for wind power

Since 2004, certain land and water areas in Sweden have been designated as areas of national interest for wind power. There are 313 such areas in Sweden, of which 284 are located onshore and 29 offshore. The most recent update was carried out in 2013 and four areas were added in 2015. The total area of these national interests for wind power is roughly 7,6000 km^2, representing about 1.5% of the country's land area, including Swedish waters (Swedish Energy Agency 2021).

A national strategy for sustainable wind power expansion

The Swedish Energy Agency and the Swedish Environmental Protection Agency have jointly developed a national strategy for sustainable wind power expansion, which was presented in January 2021. The strategy, which only covers land-based wind power, contains a regional distribution of a national development need and a national planning basis (Swedish Energy Agency, 2021)[23]

Support for solar power

A subsidy for installations of solar power systems was initiated in 2009. The budget for this support was around SEK 4 billion for the period 2016–2020. All types of actors could obtain financial support for installing grid-connected solar electricity and solar hybrid systems. The investment support contributed to an increased electricity production from solar power systems and to business development of solar energy technology. The support ended 31 December 2020 and has for private individuals been replaced by a tax reduction for green investments (see below). Municipalities and companies will be eligible to continued support in 2021 for the installation of solar cells and energy storage. The subsidy is lowered to 10 percent with the aim to end

[23] Swedish Energy Agency, 2021. *Nationell strategi för en hållbar vindkraft*. ER 2021:02, ISBN 978-91-89184-88-6

after 2021, as the Government's assessment is that there is no longer a long-term need for support.

Support for storage of self-produced electricity

During 2016-2020 support was available for private individuals for installation of systems for storage of self-produced electricity. Grants were awarded with a maximum of 60 percent of the eligible costs, however, with a maximum of SEK 50,000 (SFS 2016:899). In 2021 the support system was replaced by tax reduction for green investments.

Tax reduction for installation of green technology

With the aim to reduce greenhouse gas emissions private individuals are, since 1 January 2021, eligible to a tax reduction for installation of green technology including solar cells, systems for storage of self-produced electricity and at home charging stations. The tax reduction is given on the cost of labour and materials. For installation of mains-connected solar cell systems the tax reduction is 20 %, for installation of a system for storage of electricity and for installation of at home charging stations for electric vehicles the deduction is 50 %. The tax reduction cannot be more than SEK 50,000 per person and year (Govt. Bill 2022/23:15).[24]

Tax reduction for micro-production of renewable electricity

A tax reduction for households and businesses was introduced in 2015 to stimulate investment in the micro-production of renewable electricity. The income tax reduction is SEK 0.60/kWh renewable electricity fed into the grid in a connection point with a fuse size of up to 100 Amps but limited to the amount of electricity received from the grid in the same connection point. The tax reduction is capped at SEK 18,000 per year.

Effects of policy instruments in the electricity and district heating sector

Estimates using the TIMES-NORDIC modelling tool (see Box 4.2) show that emissions from the electricity and district heating sector (including back-pressure power) could have been 9-15 Mt CO_2 higher per year in the time period 2005-2020 if policy instruments had remained at their 1990 levels (see Table 4.1). The difference in modelled emissions is due above all to significantly greater use of coal in the scenario based on 1990 instruments

[24] Energimyndigheten.se, Så kan du få skattereduktion för grön teknik, 2021.01.22

than in the one based on current levels of instruments, in which fossil fuels have been replaced by renewables.

In summary, the influence of policy instruments in the sector has led to increased costs for fossil fuels at the same time as the conditions for biofuels and wind power for electricity production have improved. After 2005 the impact of the policy instruments on the fossil fuels for CHP has been the same as, or even less than, in 1990. Low prices, until recently, in the EU ETS strengthen this picture. However, thanks to the electricity certificate system, which is bringing in incentives for renewable fuels, the fossil fuels are kept away. Even if the steering effect of electricity certificate system is reduced in recent years the total effect for the period 1990-2050 is a strong drive away from fossil fuels (Profu 2021).

Table 4.1 Estimated aggregate effects of policy instruments introduced since 1990 on emissions from electricity and district heating production in Sweden, compared with a scenario based on 1990 instruments (Mt CO_2 eq per year) (Profu 2021)

1995	2000	2010	2015	2020	2025	2030	2035	2040	2045	2050
3.6	8.7	13	15	15	15	6.2	3.2	4.1	6.0	6.2

Residential and commercial/institutional

Greenhouse gas emissions from heating individual homes, and commercial and institutional premises (heating other than district heating), have fallen dramatically since 1990. The energy and carbon taxes are seen as the instruments contributing most to reducing the use of fossil fuels in this sector in recent decades. The aggregate level of taxes on fossil fuel use for heating in the sector has risen steadily since 1990, even though the increase in recent years is modest. This has made it considerably more expensive to use these fuels than if energy taxation was kept at its 1990 level (Profu 2021). Oil prices and the available technologies for fossil-fuel substitutes have also had significant impact on trends in the sector.

Alongside carbon and energy taxes, there are several instruments targeting energy use in homes, and commercial and institutional premises. Some of the most important ones include building regulations, energy performance certificates, and the Ecodesign, Energy Labelling and Energy Efficiency Directives. In addition, there are instruments such as technology procurement, network initiatives and information campaigns at the local, regional and national levels.

Ecodesign Directive (2009/125/EC), Energy Labelling Directive 2010/30/EU and the Ecodesign Act

Energy labelling is mandatory for the product groups that are regulated by the Energy Labelling Directive (2010/30/EU) and applies to all EU member states. Energy labeling makes the product's energy use visible and facilitates for consumers who want to make energy smart choices.

The Ecodesign Directive (2009/125/EC) aims to improve the products' environmental performance during their full life cycle. The requirements act as a floor to prohibit and remove the very worst products on the market, seen from an energy perspective. In principle, these rules can be applied to all energy-related products (except transport) and cover all energy sources. Sweden is particularly active in market surveillance activities, involving laboratory tests of products as well as supervision of distributors. The directive has been implemented in Sweden through the Ecodesign Act (SFS 2008:112).

Energy Performance of Buildings Directive 2010/31/EC

The Energy Performance of Buildings Directive is a framework within which EU Member States have decided on requirements for setting minimum energy performance standards, building energy certificates and inspections or advice on boilers and air conditioning systems. The aim of the directive is to reduce greenhouse gas emissions from the EU Member States and secure the energy supply in the medium and long-term.

Law on energy performance certificates for buildings

Based on the Energy Performance of Buildings Directive, Sweden has implemented a law on energy performance certificates for buildings (SFS 2006:985). The law includes an obligation for owners of single-family and multi-dwelling buildings and of commercial premises to declare the energy use of buildings and certain parameters regarding the indoor environment. The aim is to promote efficient energy use and a healthy indoor environment by requiring property owners to learn more about which measures are cost-effective to implement for improving building energy performance.

Building regulations

Building regulations have been used since the 1960s to set minimum requirements for energy use in new buildings in Sweden. Since 2009, building regulations for new production have included stricter requirements for electrically heated buildings. Stricter requirements for energy use in new

buildings with other heating systems took effect in 2012. Regulations include requirements for specific energy use (kWh/m² and year) and average thermal transmittance (W/m²K).

Training programs in building for low energy consumption

Since 2016, the Swedish Energy Agency in cooperation with other actors has been responsible for a set of capacity building programs in the area of building for low energy consumption. The programs target different construction stakeholders, such as architects, engineers, clients, technicians, installers, site managers and teachers in building programs at upper secondary schools (National Board of Housing, Building and Planning and the Swedish Energy Agency 2016).

Support for market introduction, technology procurement and networks

Technology procurement is an instrument designed to initiate a market transition and disseminate new, more efficient technology, such as new products, systems and processes. Network-based procurement of technology is an approach that encompasses the entire decision-making process, from feasibility study and purchaser group to requirements specification and dissemination and further development of more energy-efficient technology. It is being used in areas like heating and control, ventilation and lighting. The Swedish Energy Agency coordinates procurement networks for housing (BeBo), commercial and institutional premises (BeLok), small houses (BeSmå), food distribution (ReLivs, and new construction of, and conversion to, energy-efficient buildings (LÅGAN).

Effects of policy instruments in the residential and service sector

Between the early 1990s and the present day, carbon and energy taxes have helped to phase out oil-based and electric heating. The aggregate level of taxes on fossil fuel use for heating in the residential and service sector has risen steadily since 1990, even though the increase in recent years has slowed down, making it considerably more expensive to burn these fuels than it would have been if energy taxation had been kept at its 1990 level (Profu 2021). This is shown in figure 4.3.

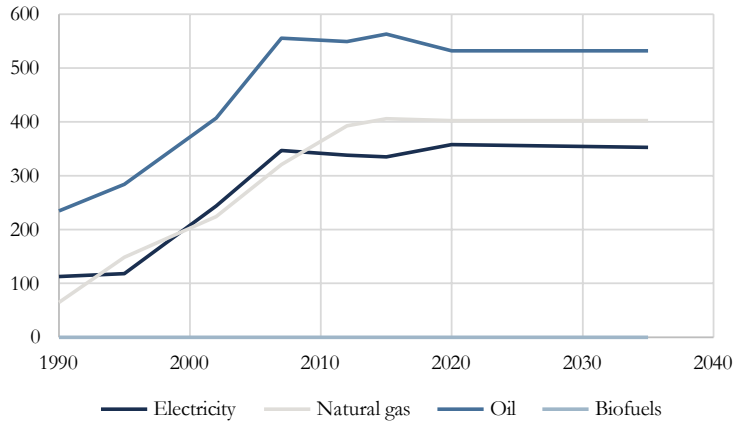

Figure 4.3 Policy instruments affecting light fuel oil, biofuels, natural gas and electricity in the residential and service sector: development between 1990 and 202015, and model assumptions for 20325 (constant 2015 2020 prices) (Profu 202117a).

Given a political will to phase out fossil fuels, relatively substantial policy instruments can be motivated. Analysis of model estimates based on TIMES-NORDIC shows that drivers for a switch to other heating options exist in both the scenario retaining 1990 policy instruments and the one based on current levels of instruments, but that the incentive to replace existing oil-fired heating is greater in the scenario in which taxes have been developed and raised to today's levels. By 2025, according to the model's scenarios, fossil based heating will be phased out altogether in the residential sector with current instruments, whereas there would still have been a certain proportion of fossil fuels left if instruments had remained at 1990 levels (Profu 2021).

4.2.4 Industrial emissions from combustion and processes (including emissions of fluorinated green house gases)

Industrial emissions from combustion and processes

Total greenhouse gas emissions from combustion in manufacturing industries have decreased since 1997. The instruments affecting combustion emissions from the industrial sector are the EU ETS, energy and carbon taxes, the electricity certificate system and the Environmental Code, the Energy Step, Energy Audits, Energy and climate coaches, and Energy efficiency networks.

Greenhouse gas emissions from industrial processes show an overall decreasing trend since 2006. The instruments primarily affecting process

related emissions are the EU ETS, the Environmental Code, the Industrial Leap, the Energy Step and Energy Audits.

Industrial Leap

The Industrial Leap is a long-term reform which began in 2018 and continues until 2040. It consists of a government scheme that aims to support development of technology and processes to reduce the process-related greenhouse gas emissions in Swedish industry. Financial support, administered by the Swedish Energy Agency, may be provided for research, feasibility studies, pilot and demonstration projects as well as full-scale investments. Projects related to mitigation, as well as to negative emissions, are eligible for funding. The target group for support is industries with process-related emissions, along with universities and research institutes.

One example of a project funded is the initiative "Hydrogen Breakthrough Ironmaking Technology", HYBRIT, which aims at ending the use of coal, traditionally needed for ore-based steel-making, and substitute it with hydrogen. The production of hydrogen is moreover planned to be produced from fossil-free electricity. The result would be fossil-free steel-making technology, which has potential to cut Swedish emissions by 10 percent.

In 2018, the government budgeted SEK 300 million for the program. The budget for the Industiral Leap increased the following years (Govt. Bill 2020/21:1). In the budget for 2022 the Government proposes allocations of SEK 909 million for 2022, SEK 754 million for 2023, and SEK 757 million for 2024 (Govt. Bill 2021/22:1).

Support scheme for BECCS

Following the budget for 2022 the Government proposes a support system for BECCS designed as a reversed auction where the winning company (the company offering the most cost-efficient solution) will receive support for capture, transport and storage of biogen carbon dioxide. The Swedish Energy Agency is authorized up to SEK 36 billion for this purpose for the period 2026-2046. A first such auction is planned to be launched late 2022. The Swedish Energy Agency is also allocated SEK 15 million annually (from 2022) for administrative support of the system.

Energy audits and the Energy Step for large enterprises

The law on energy audit in large enterprises aims at promoting improved energy efficiency (SFS 2014:266)[25]. The law requires large enterprises to conduct energy audits, including information of total energy use, as well as proposals of cost-efficient measures to improve energy efficiency. The audit must be conducted at least every fourth year.

Enterprises that are subject to the law, and have conducted an energy audit, have had the possibility to apply for support in terms of an in-depth projection of arrangements and additional costs in investment decisions to increase energy efficiency through the Energy Step Program. The program had a budget of totally SEK 125 million during the period 2018–2020. There is a need for further efforts to achieve the Swedish Parliament's goal of 50 percent more efficient energy use by 2030.

A government green credit guarantee

In 2021 a state green credit guarantee was introduced with a limit of SEK 10 bn (Govt. Bill 2021/22:1). It was introduced to facilitate major industrial investments that contribute to achieving the goals in the Environmental quality objectives system and the Climate Policy Framework. In the budget bill for 2022 the Government proposes a limit of SEK 50 bn for 2022, SEK 65 bn for 2023 and SEK 80 bn for 2024 for the credit guarantee (Govt. Bill 2021/22:1, ch. 9.4, Table 9.8).

Effects of The Industry Leap combined with other instruments

The projects that have received support through the Industry Leap until 13 January 2021 is estimated to have a total potential to contribute to the reduction of greenhouse gas emissions by a further 11 million tonnes of carbon dioxide equivalents per year compared to the most recent reference scenario. Of these, just under 8 million tonnes refer to a further reduction in industrial emissions and 1-2 million tonnes refers to negative emissions through capture and storage of biogenic carbon dioxide emissions (BECCS). When industrial projects are also included in the reference scenario, the potential for reduced industrial emissions rises to 9 million tonnes of carbon dioxide equivalents per year (Govt. Bill 2021/22:1).

The overall reduction potential mentioned above cannot be attributed as a potential future effect of the Industry Leap alone. The instrument operates

[25] The law is part of fulfilling the EU Energy Efficiency Directive, EED (Directive 2012/27/EU)

in interaction with several others, that in combination may contribute to an overall emission reduction of the volume mentioned.

4.2.5 Regulations governing emissions of fluorinated greenhouse gases

EU Regulation (No 517/2014) on fluorinated greenhouse gases and BREF

The EU Regulation (No 517/2014) on fluorinated greenhouse gases (f-gases) entered into force on 1 January 2015. The regulation strengthens measures from former EU Regulation No 842/2006 on f-gases, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). The regulation aims to cut emissions by two-thirds from current levels by 2030, and includes provisions for the use, reuse and destruction of f-gases. Most importantly, the regulation includes a mechanism for quantified emission reductions of substances containing HFCs, with a gradual decreasing cap for the total HFC emissions.

The EU adopted a Best Available Techniques reference document (BREF) for the non-ferrous metal industry in June 2016. These could significantly reduce emissions from aluminium production.

Swedish Regulation 2016:1128 on fluorinated gases

Swedish Regulation 2016:1128 on fluorinated greenhouse gases complements the EU regulation. Provisions in Sweden for cooling and air conditioning and heat pump equipment include:

- Requirements on leak checks in conjunction with installation, reconstruction and other interventions.
- Requirements on leakage checks and certified competence, also applying to mobile equipment containing f-gases.
- The results of periodic inspections must be reported to the supervisory authority.
- The supervisory authority must be informed before the installation of equipment containing more than ten kilograms of refrigerants.
- It is prohibited to sell f-gases as refrigerants to recipients other than those stated in the regulation.
- Upon disposal, importers and those who transfer refrigerants are required to take back any refrigerants that they delivered, free of charge, and to provide containers for this purpose.

- Equipment manufactured, imported or brought into Sweden shall be provided with accurate and easy-to-understand operating and maintenance instructions.

4.2.6 Domestic transport

Emissions from domestic transport, where road transport dominates, increased after 1990, reaching a peak in 2007. Since then, emissions have been declining.

The decrease in emissions since 2007 can be attributed to policy instruments introduced both nationally and at the EU level. The most significant ones include carbon dioxide emission performance standards for new vehicles, vehicle taxes and vehicle fuel taxes, and more recently, the greenhouse gas emission reduction obligation. These have resulted in more energy-efficient vehicles and a greater use of renewable fuels. Reducing transport-related emissions is essential to meet the 2030 climate targets set by the Swedish Parliament. Consequently, the Government has implemented several policies and measures aimed at the transport sector in the last years.

Aviation

Tax on air travel

A tax on air travel was introduced in 2018. The tax aims to reduce the climate impact of aviation. For domestic flights the tax is SEK 64 for a one-way ticket and SEK 128 for a round trip. The tax is described further in section 4.2.10.

Reduction obligation scheme for aviation

In 2021 a reduction obligation scheme for aviation was introduced for renewable fuels. The level is 0,8 percent in 2021 and will increase to 27 percent[26] in 2030 (prop. 2020/21:135, bet. 2020/21:MJU20, rskr. 2020/21:303).

Differentiated take-off and landing fees for aviation

In 2021 a decision was taken to introduce differentiated take-off and landing fees. The fees are differentiated according to environmental performance of

[26] 1% and 30% respectively in volume.

the aircrafts. Initially, the differentiated fees are introduced at the two largest airports, Landvetter and Arlanda.

Aviation in the EU Emissions Trading System

Aviation is included in the EU Emissions Trading System as of 2012 in accordance with EU Regulation No 421/2014 of the European Parliament and of the Council of 16 April 2014 amending Directive 2003/87/EC. As part of the Fit for 55 legislative package the European Commission is now proposing to revise the ETS aviation rules. This includes a reduced number of free allowances allocated to aircraft operators to reach full auctioning by 2027.

Road transport

Emission reduction obligation (Fuel change)*

In July 2018, a greenhouse gas emission reduction obligation for petrol and diesel in conjunction with fuel tax reforms, called the Fuel Change, was implemented. The emission reduction obligation establishes an obligation on petrol and diesel suppliers to reduce life-cycle carbon dioxide emissions. The obligation replaced the former tax exemption for low-blended biofuels, i.e. biofuels covered by the scheme is subject to the same tax rate per liter as fossil equivalents. At the same time, both the carbon dioxide and energy tax rates for fuels covered by the Reduction obligation scheme have been reduced.

When implementing the scheme, the adjustment of the carbon tax rate was implemented to reflect the reduced greenhouse gas emissions that the blend-in of sustainable biofuels entails. The energy tax rate was reduced to maintain a stable price-level for fuels, so that consumers would be largely unaffected by the reform. High-blended biofuels are not covered by the scheme and are, if sustainable, completely exempt from both carbon dioxide and energy tax.

Bonus–malus system for new light-duty vehicles*

A bonus–malus system for new light-duty (max 3,5 tonnes) vehicles has been in place between July 2018 and November 2022. Vehicles with low carbon dioxide emissions qualified for a bonus at purchase, while vehicles with high carbon dioxide emissions are subject to an increased vehicle tax (malus) during the first three years from the date when the car first becomes taxable. The system covered purchases of new passenger cars, including

campers, and vans. Cars adapted for alternative fuels such as ethanol and gas, except LPG, are exempted from the increased tax. The aim of the system has been to increase the proportion of environmentally friendly vehicles sold.

From 2021 a maximum bonus has been given to new vehicles with zero emissions from the exhaust pipe - SEK 70,000. At 60 grams of carbon dioxide per kilometer, the bonus ends. The maximum bonus for vehicles with emissions above zero amounts to SEK 45,000. Gas-powered cars received a bonus amount of SEK 10,000 regardless of their level of carbon dioxide emissions.

Vehicles with emission in the range of 60-90 grams of carbon dioxide per kilometer neither qualified for any bonus, nor have they been subject to malus. Vehicles with emissions exceeding 90 grams per kilometer are subject to malus. In the range of 90–130 grams per kilometer the increased annual vehicle tax is SEK 107 per gram. For emissions exceeding 130 grams per kilometer the increased annual vehicle tax is SEK 132 per gram.

As of 1 June 2022, vehicles with emissions exceeding 75 grams carbon dioxide per kilometer are subject to malus and emissions exceeding 125 grams per kilometer are taxed at SEK 132 per gram. The system was abolished in November 2022.

Requirements for renewable fuels at filling stations

The availability of renewable fuels has been subject to legislation requiring that filling stations with annual sales of petrol and diesel above a specified level must supply at least one kind of renewable fuel. The law (SFS 2005:1248) became effective 1 January 2006. This requirement has resulted in an increased number of mainly E85 pumps. As of 2015, the legal requirements were loosened so that filling stations selling more than 1,500 m^3 of petrol or diesel must supply at least one kind of renewable fuel.

EC Fuel Quality Directive

In 2009, Directive 2009/30/EC was adopted to revise the Fuel Quality Directive (98/70/EC). It introduces requirements for fuel suppliers to reduce the greenhouse gas intensity of energy supplied for road transport (low carbon fuel standard) by 6 percent until 2020. The emission reduction obligation in Sweden is far more ambitious than this, see Table 4.3 above. In addition, the Renewable Energy Directive (2009/28/EC) establishes

sustainability criteria that must be met by biofuels if they are to count towards the obligation to reduce greenhouse gas intensity.

Emission performance standards for new vehicles

Manufacturers selling vehicles in the EU are subject to EU regulations (Nos 443/2009 and 510/2011) that set emission performance standards for new passenger cars and vans as part of the Community's integrated approach to reducing CO_2 emissions from light-duty vehicles. Under these regulations, new passenger cars should not emit an average of more than 95 g CO_2/km by 2021. New vans should not emit an average of more than 147 g CO_2/km by 2020. New standards for 2025 and 2030 were adopted by the EU during 2019. Accordingly, CO_2-emissions from new passenger cars and new vansare to be reduced by 37.5 percent and 31 percent respectively by 2030 compared to average emissions 2021. Following the Fit for 55 package, the European Commission is preparing a revision of the standards. Proposed reduction levels, 2030 compared to 2021, are 55 percent for new passenger cars and 50 percent for vans. By 2035 the reduction target is 100 percent for both categories (European Commission 2021.07.14). In 2019 the EU also adopted CO_2-emissions standards for heavy-duty vehicles. Emissions from new heavy-duty vehicles in 2025 are to be 15 percent below the average for 2019, and 30 percent lower compared to 2019 by 2030.

CO_2-based vehicle tax

In 2006 Sweden implemented a CO_2-based vehicle tax system for passenger cars. For older vehicles the tax is weight-based. All vehicles in the system are subject to a basic charge of SEK 360 per year. In addition, vehicles are subject to a CO_2 component depending on their level of carbon dioxide emissions per kilometer in mixed driving. The CO_2 component is SEK 22 per gram carbon dioxide per kilometer exceeding 111 grams. For diesel cars that first become taxable on 1 July 2018 or later, a fuel surcharge is added, together with an environmental surcharge. For other diesel cars in the CO_2-based system, the CO_2 component is multiplied by a fuel factor of 2.37 and an environmental surcharge is added. For cars adapted for alternative fuels such as ethanol and gas, except LPG, the CO_2 component is SEK 11 per gram carbon dioxide per kilometer exceeding 111 grams. Vans and campers are also included in the CO_2-based vehicle tax system since 2011. The main purpose of the CO_2-based differentiation is to reduce carbon dioxide emissions by making car buyers choose fuel efficient cars.

The CO_2-based vehicle tax system applied to cars that first became taxable before the bonus–malus system was introduced in July 2018, and also to any car "leaving" the bonus–malus system three years after it first became taxable.

Climate premiums for electric buses, heavy-duty vehicles and working machinery

Since January 2020 regional public transport agencies, public transport companies, municipalities and limited companies[27] are eligible to apply for climate premiums for electric buses. Companies and municipalities are also eligible to apply for climate premiums, for Electric and other renewable-fueled heavy-duty vehicles as well as for electric tractors and working machinery. The total budget for these premiums is SEK 1 430 million for 2022, SEK 330 million for 2023, and SEK 300 for 2024 (Govt. Bill 2021/22:1). The bulk (SEK 1100 million) of the premium for 2022 is earmarked for electric buses.

Local Climate Investment Program (Climate leap)

The Climate Leap is a comprehensive investment support scheme. Municipalities, companies, organisations and others can apply for investment support for measures to reduce climate impact. A large number of these investments relate to the transport sector, such as investments in biogas plants or the installation of charging points for electric vehicles. The program is prolonged until 2026 with a total budget for the period 2015-2026 of SEK 12.2 billion (Govt. Bill 2021/22:1). More about the Climate leap in section 4.2.2 Cross-sectoral instruments.

Tax reduction for installation of green technology*

With the aim to reduce greenhouse gas emissions private individuals are, since 2021, eligible to a tax reduction for installation of green technology including solar cells, systems for storage of self-produced electricity and at home charging stations (Govt. Bill 2021/22:1). The tax reduction is given on the cost of labor and materials. For installation of home charging stations for electric vehicles the reduction is 50 % (Govt. Bill 2020/21:1).

Urban environment agreements

Urban environment agreements is a scheme for investments in public transport, cycling infrastructure or sustainable freight transport at the

[27] Which by the regional public transport authorities have been given the authority to enter into public transport contracts.

regional and local level in Sweden. The scheme commenced in 2015. In the national plan for the transport infrastructure 2022-2033, SEK 6 billion for the period 2022-2027 is allocated to the urban environmental agreements.

Municipalities are eligible to apply for grants to cover part of the investment costs for public transport infrastructure. The investment should be coupled with other actions aiming at increasing the long-term sustainability of urban areas, including increased housing construction, and the transport system. The scheme is administered by the Swedish Transport Administration.

Research and demonstration

Swedish agencies are financing several large research programmes covering the entire chain from cultivation of raw materials for bio-based motor fuels to the use of new fuels. These include:

- FFI – Strategic vehicle research and innovation
- F3 – Collaboration program for renewable fuels and systems
- SFC – Research on biomass gasification
- Battery funding program
- Vinnova – Innovations for a sustainable society
- Triple F (Fossil Free Freight) focusing on three major challenges: A more transport efficient society; energy efficient and fossil-free vehicles and ships; increased share of renewable fuels.

Sweden is also involved in the EU Refuel project, which aims to develop strategies for introducing cost-effective alternative vehicle fuels. The project is also investigating potential effects on stationary installations using biofuels.

Consideration of climate in long-term infrastructure planning

In 2021, the Riksdag decided on an economic framework for a new twelve-year national infrastructure plan. In 2022 the government then adopted a new national plan for transport infrastructure for 2022-2033, to be implemented by The Swedish Transport Administration with other relevant actors. The Swedish Transport Administration is responsible for long-term planning of all modes of infrastructure for transport. Planning is undertaken in dialogue with local and regional planning bodies. Under the applicable legislation there is a clear requirement to take environmental consideration in the planning process.

Eco-bonus system to stimulate transfer from road to shipping*

In 2018, the government launched a temporary eco-bonus support aimed at stimulating the transfer of goods from road to shipping to reduce greenhouse gas emissions from heavy transport. The annual budget of the eco-bonus system for heavy transports is SEK 50 million for 2020-2022. The eco-bonus system for heavy transports is prolonged for the period 2022-2024. This period the scope is broader, althogh not yet decided, and the annual budgdet is SEK 100 million (Govt. Bill 2020/21:1; 2021/22:1).

Environmental compensation for railway transport of goods

In 2018 an environmental compensation scheme was introduced to stimulate railway transports of goods. SEK 550 million is budgeted per year between 2021-2025 (Govt. Bill 2021/22:1). An extra SEK 697 million was budgeted for 2022.

Congestion tax

Congestion tax is levied in the cities of Stockholm and Gothenburg since 2007 and 2013, respectively. The tax is levied during such hours and on such places where there is considered to be congestion. Various levels of tax are levied throughout the day (in Stockholm for 2022: SEK 11–45, in Gothenburg for 2022: SEK 9–22) with a maximum amount per day of SEK 135 in Stockholm and SEK 60 in Gothenburg.

Low emission zone

Eight municipalities in Sweden have already set up low emission zones, restricting access to lorries and buses that don't meet specific requirements. From 2020 and onwards municipalities also have the possibility to set restrictions on cars, based on two new environmental categories of low emissions zones.

State co-financing for certain regional public transport facilities

Government co-financing for certain regional public transport facilities is an investment support for infrastructure for regional public transport. Investment support may also be provided for vessels in regional public transport as well as for improved environment and traffic safety on municipal roads and streets. Co-financing amounts to a maximum of 50 % of the costs (SFS 2009:237).

Support for electric charging infrastructure for heavy vehicles

The Government decided in its Budget Bill for 2021 on a support scheme for regional electrification pilots with charging infrastructure for heavy vehicles. The aim is to enable electrification of heavy road transport in the busiest areas. Tank infrastructure for hydrogen is also included in the support scheme (Government Bill 2020/21:1). SEK 400 million is allocated for 2021, SEK 550 million for 2022 and SEK 1 billion for 2023 (Govt. Bill 2021/22:1).

Support for electric fast charging infrastructure

In July 2020 the Government decided on a new support for public fast charging infrastructure in connection with major roads in areas where fast charging is missing. The support aims at ensuring basic access to charging infrastructure for fast charging of electric vehicles throughout the country. The support adds up to SEK 150 million for the period 2020-2022 and is administrated by Swedish Transport Administration (Govt. Bill 2021/22:1, UO 21; Trafikverket 2021).[28]

National ticket system for public transport

The Government proposes additional funds for the introduction of a national ticket system for all public transport throughout Sweden. The system will make it easier for travelers to choose to travel by public transport, which is judged to have positive effects for both leisure travelers and work commuting and benefit local and regional labor market regions. SEK 105 million is allocated for 2022 and 2023 respectively. SEK 1 million is allocated for 2024 (Govt. Bill 2021/22:1).

Night train traffic in Sweden and abroad

To bind Sweden together, and at the same time contribute to sustainable travel, opportunities are needed to continue night trains to and from upper Norrland and Jämtland in the future. New carriages and locomotives are also needed for traffic.

In July 2020, the Swedish Transport Administration was commissioned to carry out a procurement of night train traffic through Sweden and Denmark, which contributes to the establishment of international night train connections with daily departures from Sweden to other European

[28] https://www.trafikverket.se/tjanster/ansok-om/ansok-om-bidrag/ansok-om-bidrag-till-snabbladdningsstationer-for-elfordon/, February 2021

countries. Traffic between Stockholm and Hamburg started in September 2022.

The effort contributes to meeting, and contributes to, a growing demand for travel by night train abroad so that the conditions are improved for continued night train traffic on commercial grounds. If train travel replaces travel by air and car, a great climate benefit can be achieved (Govt. Bill 2021/22:1).

Conversion premium

To reduce emissions from the existing vehicle fleet the Government proposed in its budget bill for 2021 that a conversion premium for cars from fossil fuels to biofuels or biogas should be introduced in 2022 (Govt. Bill 2020/21:1).

Effects of selected policy instruments in the transport sector

Emissions from domestic transport account for about one third of Sweden's total greenhouse gas emissions and about half of greenhouse gas emissions in the non-trading sector. The transport sector has a sector-specific intermediate target by 2030, which means that emissions from domestic transport (excluding domestic flights) will be reduced by at least 70% by 2030 compared to 2010. Greenhouse gas emissions from domestic transport (excluding domestic flights) amounted to 15 million tonnes of CO_2 equivalent in 2020, which is a decrease of 10% compared to 2019.

Road traffic accounts for by far the largest share (about 95%) of emissions from transport in the country, of which passenger cars account for about 63% and heavy and light trucks account for about 30%. Compared to 1990, emissions from domestic transport (excluding domestic flights) have decreased by 21%%. The reduction in emissions is mainly a result of an increase in the share of biofuels while at the same time making vehicles more energy efficient.

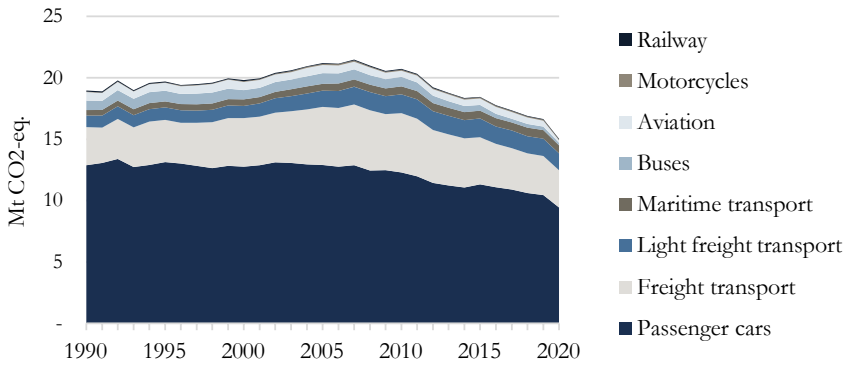

Figure 4.4 Greenhouse gas emissions from domestic traffic, excluding domestic aviation, 1990 -2020 (SEPA 2021).

The combined effects of the emission reduction obligation (Fuel change)* and policies affecting fuel efficiency and the introduction of electric vehicles

The final reduction effect and the total volumes of sustainable biofuels needed to meet the emission reduction obligation in 2030, depends on the development of the demand for petrol and diesel, which in turn depends on the level of traffic and the level of fuel efficiency in the vehicle fleet, including the amount of battery electric and plug-in hybrid electric vehicles.

The potential emission reduction effect that may be attributed to the reduction obligation depends therefore to a large degree on the assumptions made regarding other factors also influencing the fuel demand.

Compared to the projection scenario, see chapter 5, where the assumed level of electric vehicles in 2030 is low compared to more recent estimates and the actual introduction shares in recent years, the Swedish EPA estimate an effect of approximately 5–6 million tonnes of carbon dioxide per year in 2030 resulting from the reduction obligation. The volumes of biofuels increase substantially in this assessment. The corresponding effect of the reduction obligation in mobile machinery was estimated to 1,5-1,8 million tonnes.

However, there are challenges linked to the volumes of biofuels needed and the possibility of achieving targets for air quality regarding nitrogen oxides. There is also uncertainty about how large volumes of biofuels can be available nationally and internationally in different time perspectives, depending on how demand develops in other countries and sectors, for

example in aviation. Constraints in the supply of sustainable biofuels globally can also lead to higher costs.

In a sensitivity analysis the rate of electrification in the vehicle fleet is assumed to be higher, more in line with the market development in recent years in Sweden ("elektrifieringsscenario" ER 2021:06). In this scenario the emissions decrease with approximately 2,7 million tonnes of carbon dioxide per year in 2030 compared to the projection in chapter 5, due to the increased energy efficiency in the vehicle fleet.

This effect may be attributed to national and EU-instruments in combination that affects the choice and the performance of new cars introduced to the market, see next section. National instruments and EU standards contribute and interact with policies enabling vehicle charging. The fuel price development is also of importance for the overall development.

The increase in demand for biofuels is lowered quite substantially in the scenario with a higher electrification rate and the overall effect of the reduction obligation is, accordingly, reduced to 3-4 million tonnes of carbon dioxide per year in 2030. When the estimated effect in mobile machinery is added this sensitivity analys result in total in 4-6 million tonnes reduction of carbon dioxide per year in 2030 due to the reduction obligation.

When it comes to the rate of electrification of cars in Sweden it could be noted that the latest statistics show a significant increase in sales of rechargeable cars in Sweden. In 2020, the share of electric cars and plug-in electric hybrids sold in Sweden was about 31 percent of sales of passenger cars. In 2021, the share had risen to 45 percent of new car sales. At the same time, the proportion of electric cars is increasing in relation to plug-in hybrids. The proportion is among the highest in EU member states in terms of the share of chargeable cars in new car sales (IEA 2021).

National and EU instruments for energy efficiency

New cars are becoming more and more energy efficient, and CO_2 emissions from the average car have steadily declined since the mid 1990's with an acceleration around 2005. In recent years an increasing share of chargeable cars in new cars sales contributes the most to the decrease in average CO_2-emissions from new cars.

There are several policy instruments that have interacted to promote the energy efficiency of new cars sold in Sweden. First, several national instruments[29] have been introduced since 2005. Second, the EU has introduced carbon dioxide emission standards for new cars. In the previous national communication, NC7, The Swedish Transport Administration assessed the effect on national emissions of the EU CO_2 standards for new cars and the national instruments introduced since 2005 that affect car choices. This assessment has been updated and revised by the SwEPA for this communication, since both the EU performance standards and the national instruments has been amended to stricter levels in recent years.

The updated assessment shows a greater effect of the EU CO_2 standards compared to the previous estimate. The increased effect can be explained by the amendment of the EU CO_2 standards on light duty vehicles, with stricter requirements in 2025 and 2030 in combination with the introduction of EU CO_2 standards also on heavy duty vehicles. The assessment also indicates that the national instruments has an additional effect on the emissions in 2030 when combined with EU CO_2 standards. The scenario "with EU CO_2 standards and national incentives", builds on the development in "the electrification scenario" mentioned in the previous section.

The emission effect increases over time as the share of the fleet replaced by vehicles meeting stricter standards grows. In 2030, the total effect compared to the the scenario without EU-standards and national incentives is estimated to approximately 8 million tonnes CO_2/year.

[29] CO2-based vehicle tax, green-car insurance premium, super-green car rebate, tax exemption for environmental friendly vehicles, reduced taxable values for some company cars with environmentally friendly technology, bonus–malus system, grants for charging infrastructure etc.

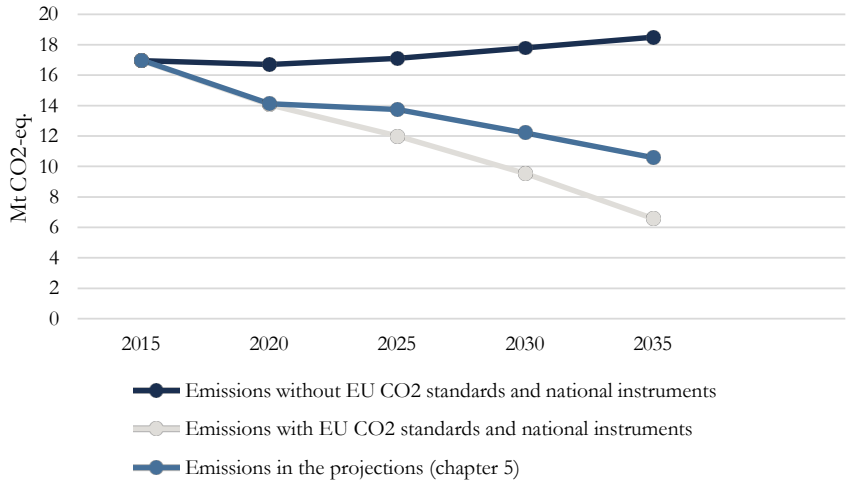

Figure 4.5 Historic and future CO2 emissions from passenger cars, light duty and heavy duty vehicles in total, with and without implemented policy instruments for energy efficiency.

4.2.7 Waste

Emissions from waste have declined. There has been a series of policy instruments at both national and EU levels. Demand for waste as a fuel for district heating has also strongly encouraged diversion from landfill to incineration.

Landfill Directive (1999/31/EC)

The Landfill Directive requires landfilling of biodegradable waste to be reduced and for methane to be collected from landfills, preferably with energy recovery. Sweden has, however, introduced more far-reaching national instruments resulting in earlier attained emissions reductions.

Landfill tax

In 2000 a tax of 250 SEK per tonne landfilled waste was imposed on waste disposal to landfill (SFS 1999:673). The landfill tax has been increased gradually and is today 555 SEK per tonne landfilled waste (Swedish Tax Agency 2021).[30]

Ban on landfilling combustible and organic materials and methane collection

Under the Swedish Ordinance on the Landfill of Waste (SFS 2001:512), a ban on landfilling combustible materials was introduced in 2002 and a

30
https://skatteverket.se/foretagochorganisationer/skatter/punktskatter/avfallsskatt.4.18e1b10334ebe8bc80002886.html

similar ban was imposed for organic material in 2005. The ordinance also regulates the collection and disposal of methane gas from landfills. The ordinance is intended to prevent and reduce adverse effects on human health and the environment from landfilling.

Extended producer responsibility

A set of ordinances mandates extended producer responsibility for producers of eight product groups. Producer responsibility promotes sorting, collection, and recycling of certain waste flows[31]. Producer responsibility aims to incentivise producers to develop more resource-efficient products that are easier to recycle and do not contain environmentally hazardous substances. It also aims to reduce the amount of waste. The legislation on extended producer responsibility contains national targets for recycling and has resulted in increased separated collection of waste fractions and increased recycling (apart from pharmaceuticals and radioactive products, where there are no specific targets).

The municipal waste planning requirement

Since 1991, there has been a requirement that all the municipalities in Sweden must have their own municipal waste plan. A Swedish EPA regulation (NFS 2006:6) sets out the minimum requirements of what each municipality must include in its waste plan, such as a description of the current situation, recycling plants and landfills, environmental assessment, measures and monitoring. Both the national waste plan (Swedish EPA 2012) and the national prevention program (Swedish EPA 2015) act as guidance for the municipalities in developing their local plans and deciding on prioritised actions.

The Waste Directive, Regulation on shipment of waste and REACH

Several EU regulations and directives are crucial for facilitating the Swedish strategy for a circular economy (see above). These include the Directive on waste (2008/98/EC), the regulation on shipment of waste ((EC) No 1013/2006) and Regulation ((EC) No 1907/2006) concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Transforming production and consumption towards a circular economy has a large potential to reduce the use of materials and thus the

[31] Extended producer responsibility has been developed for packaging, waste paper, end of life vehicles, tyres, electrical and electronic equipment, batteries, pharmaceuticals and radioactive products.

negative impact on the climate. This requires a shift from virgin materials to circular material flows. This, in turn, requires toxic chemical to be removed.

Effects of policy instruments in the waste sector

An analysis of the combined effect of policy instruments influencing methane emissions from landfill sites showed that, in a scenario based on instruments decided on at the time of the analysis, emissions would end up around 1.7 Mt CO_2 eq lower in 2015 than in a scenario based on 1990 instruments. By 2020, the difference was assessed to be 1.9 Mt CO_2 eq.

According to preliminary statistics from the Swedish Environmental Protection Agency, emissions from waste have decreased by 4.6 per cent in 2020 compared to the previous year. Behind this development are the landfill bans and taxation of landfilling of waste, which were introduced in the early 2000s.

4.2.8 Agriculture

Greenhouse gas emissions from Swedish agriculture have decreased compared to 1990. As yet, there are relatively few economic policy instruments directly targeting greenhouse gas emissions in this sector. However, the Government has taken several initiatives to increase awareness and encourage the use of measures to curb emissions of greenhouse gases from manure and fertiliser management and from land use. An Official Report of the Swedish Government (SOU 2021:67 Vägen mot fossiloberoende jordbruk) was published in 2021 with proposals on how to reduce the agriculture sector's dependence on fossil fuels. Apart from using CAP[32]-funding, investments in the agricultural sector have been granted funds from the Local Climate Investment Program (described in section 4.2.2).

Common Agricultural Policy

In 2021 the European Parliament the Council ot the EU and and the European Commission agreed on the reform of the CAP. The new CAP for the period 2023-2027 aims to support the transition towards sustainable agriculture and forestry in the EU and to contribite to the goals of the European Green Deal. 40% of the CAP budget will have to be climate

[32] Common Agricultural Policy

relevant (European Commission 2021).[33] The current CAP of 2013 is extended until 2023.

In 2013, the Council of EU Agriculture Ministers formally adopted the four Basic Regulations for a reformed CAP. Based on certain requirements, farmers can receive support for measures aimed at producing non-profitable services delivered to the wider public, such as landscapes, farmland biodiversity and climate change mitigation. Through the CAP's second pillar for rural development member states have access to a wide range of measures to encourage higher environmental performance including climate mitigation and adaptation. The policy also requires member states to allocate a minimum share of the second pillar funds to such measures. According to the *Strategic plan for the implementation of the common agricultural policy in Sweden 2023-2027* "[c]limate-impacting emissions from the agricultural sector can be reduced but not completely removed". Measures, mentioned in the Strategic plan, where agriculture can contribute to reduced climate impact include becoming more resource efficient per unit produced, increasing carbon storage in soil and contributing to increased production of renewable energy.

Rural Development Program (pillar 2 of the CAP)

The Swedish Government decided on a Rural Development Program in June 2014. The program for 2014–2020, extended until 2022, includes investment grants for young entrepreneurs, capacity building, cooperation and innovation, support to areas with natural constraints, animal welfare subsidies, ecological farming, and environmental and climate actions. Measures specifically contributing to climate change mitigation include those aimed at: increasing energy efficiency; production and use of renewable energy (including biogas production and establishment of perennial energy crops); conversion from fossil to renewable energy sources; improved manure handling; more efficient use of nitrogen; climate and energy advice; measures to prevent the risk of nitrogen leakage; restoration and establishment of wetlands; promotion of grass ley and catch crop production in intensive cropping areas; conservation of semi-natural pastures; and other separate projects relating to climate and energy. The program budget for 2014-2020 totalled SEK 36 billion, of which 59% is financed by Sweden and

[33] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/new-cap-2023-27_en

the remaining 41% by the EU. For the extention period 2021-2022 the program budget is SEK 10.5 billion.[34]

The rural network

The rural network complements the Swedish Rural Development Program, the Ocean and Fishery Program, and the program for local leadership development in the Social fund and Regional fund. The network brings together actors at the local, regional and central levels for exchanging information and experiences. The network is intended to reinforce implementation of these programs.

'Focus on Nutrients' advisory service

Financed by the Swedish Rural Development Program, the Swedish Board of Agriculture offers an advisory service called 'Focus on Nutrients' together with the Federation of Swedish Farmers and the County Administrative Boards of Sweden. The service started in 2001, with an initial focus on advice for higher nutrient efficiency in order to reduce nutrient leaching. Today, it also provides advice specifically targeting GHG emission reductions and energy efficiency as reducing GHG emissions has become one of the main objectives of the service.

Support for biogas production

In 2015, the Government introduced a support scheme for biogas production through anaerobic digestion of manure. The support program ends in 2023. It aims to increase biogas production from manure and thereby gain two-fold environmental and climate benefits through reduced methane emissions from manure and the substitution of fossil energy.[35] The increased digestion of manure offers several environmental benefits. It reduces both emissions of greenhouse gases and eutrophication of fresh and marine waters as well as produces biogas for energy. The biogas generated can be used to generate electricity or heat, or as vehicle fuel. The subsidy amounts to a maximum of 0.40 SEK/kWh of biogas produced. The support amounts to SEK 30 million for 2021 and SEK 22.5 million per year for 2022-2023. Support for investments in new biogas plants can also be granted through the Rural Development Program.

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[34] Landsbygdsprogrammet - Jordbruksverket.se

[35] Jordbruksverket.se/stod/fornybar-energi/godselgasstod

4.2.9 Land use, land-use change and forestry (LULUCF)

Forest Policy and the Forest Act

The Swedish Forest Policy has two overarching, equal objectives: the production objective and the environment objective.

The production objective means that forests and forest lands should be used effectively and responsibly so they produce sustainable yields. The direction of forest production should be given flexibility in the use of what the forests produce.

The environment objective means that the natural productive capacity of forest land should be preserved. Biodiversity and genetic variation in forests should be secured. Forests should be managed in a manner that enables naturally occurring plant and animal species to survive in natural conditions and in viable populations. Threatened species and habitats should be protected. Cultural heritage assets of forests and their aesthetic and social values should be safeguarded.

Under the Forest Policy, there are no production subsidies, and forest owners have considerable freedom and responsibility to independently conduct long-term sustainable forest management. The regulations in the Forestry Act (as of 1993) concerning timber production cover the notification of felling, the lowest age for felling, requirements for reforestation, guidelines for thinning and measures to limit damage. Special regulations apply to certain types of forests, such as subalpine forests and deciduous forests. Examples of regulations concerning nature conservation and cultural heritage include not disturbing important biotopes, buffer zones and arable land, and leaving older trees, high stumps and dead wood in situ. Sustainable forest management influences carbon dioxide removals and emissions in various ways, through the production of renewable raw materials that can replace fossil fuels and materials that generate emissions of greenhouse gases while maintaining or increasing carbon stocks in biomass, soils and harvested wood products.

Regulation on land drainage in the Environmental Code

The Swedish Environmental Code is a coordinated and broad environmental legislation aimed at promoting sustainable development so that present and future generations can live in a good, healthy environment. For example, chapter 11 of the Code contains regulations on land drainage, which can be

used to reduce emissions from peat soils with large carbon stocks. Land drainage measures are actions taken to remove water from soil or protect against water. In order for the measure to be a land drainage measure according to the Environmental Code, the purpose of the measure is to permanently increase the soil's suitability for a specific purpose, such as cultivation, development, peat cover, road construction, garden plant or golf courses.

In central parts of the southern Swedish highlands and north of the *limes norrlandicus* (the biogeographical boundary of northern Sweden), drainage may only be undertaken with a permit. In the rest of the country, and on sites specially protected under the RAMSAR Convention, such schemes are prohibited. Land drainage has decreased since the beginning of the 1990s and is now occurring only to a very limited extent.

Provisions on nature reserves and habitat protection in the Environmental Code and nature conservation agreements

In Sweden, forests and land are allocated for the conservation of biodiversity, nurture and preserve valuable natural environments, protect, restore or create valuable natural environments and for outdoor recreation. These measures, for example in the form of nature reserves, nature conservation agreements and voluntary disposal of land, are also positive for carbon stocks in forest biomass and soil coal by allowing them to be maintained or continue to increase.

Nature reserves

In Sweden, nature reserves[36] are one of the most common ways of protecting valuable nature in the long term. At present, there are close to 5000 nature reserves in Sweden. The seventh chapter of the Environmental Code contains the regulations for the establishment of nature reserves. The work of establishing nature reserves is led by the Swedish Environmental Protection Agency.

Nature conservation agreements

Nature conservation agreement is a civil law agreement (Swedish Environmental Protection Agency 2019c). The property owner and the state or a municipality agree on a certain financial compensation for the property owner, for example, to refrain from, for example, forestry. The Swedish

[36] http://www.naturvardsverket.se/Var-natur/Skyddad-natur/Naturreservat/

Forest Agency and the Swedish Environmental Protection Agency together guide how to go about it. For the landowner it should not matter what authority you agree with.

The Swedish National Forest Program

In 2015 the Government initiated a comprehensive dialogue with stakeholders within the Swedish National Forest Program.

In 2018, the Government adopted a strategy for Sweden's National Forest Program, followed by an action plan with specific measures. The action plan will be updated in dialogue with interested parties. The core of the National Forest Programme is the broad dialogue on the role forests play to ensure a sustainable society and a growing bioeconomy.

The strategy for the National Forest Programme focuses on objectives in five main areas:

- Sustainable forest management with greater climate benefits
- Multiple uses of forest resources for more jobs and sustainable growth throughout the country
- World-class innovation and processed forest products
- Sustainable use and conservation of forests as a profile issue in Sweden's international cooperation
- A knowledge leap to ensure the sustainable use and conservation of forests

Methods for increased carbon sinks

The Swedish Forest Agency receives SEK 1.5 million per year in 2021 and 2022 to develop methods for increased carbon sinks. In addition, the Agency receives an additional SEK 30 million for efforts to monitor, prevent and combat forest damage. Combating forest damage can contribute to reduced climate impacts by promoting forest growth and reducing natural emissions (Govt. Bill 2021/22:1).

Support for re-wetting of wetlands

Since 1990, the Swedish state has funded the rewetting of more than 3500 ha of drained wetlands on organic soils for purposes such as nutrient retention and biodiversity. Data of rewetting efforts from the period 1990 to 2019 vary in quality, and the total area of forest land (150 ha) is likely underestimated. Rewetting of much larger areas on forest land have been

funded and reported, but they have not been registered into the utilized database.

In 2020 the Government decided on a new support scheme for re-wetting previously drained wetlands, which aims at providing climate benefits while also strengthening biodiversity, balance water flows, increase the addition to ground water and reduce eutrophication. The re-wetting of wetlands on peat soils are expected to reduce the CO_2 emissions caused by the drainage. The initiative is implemented primarily by raising funds within the local nature conservation initiative (LONA). The initiative is based on voluntary participation by landowners (Government Bill 2020/21:1). SEK 350 million is allocated for the support in 2021. For 2022 and 2023 SEK 325 million and 100 million is proposed respectively (Govt. Bill 2021/22:1).

The Swedish Forest Agency has also received SEK 5 million in funding for the advice to forest owners regarding re-wetting previously ditched or drained wetlands.

Effects on LULUCF (re-wetting)

The investment in re-wetting measures is estimated to contribute to an emission reduction of a total of 1.5-3.6 million tonnes of CO_2-equivalents over a twenty-year period. For 2030, the emission reduction is estimated at 0.08-0.18 million tonnes of CO_2-equivalents depending on the land you choose to re-wet. The same emission reduction is expected for 2040 (Govt. Bill 2021/22:1).

Implementation of Articles 3.3 and 3.4 of the Kyoto Protocol

For the second commitment period of the Kyoto Protocol (2013–2020), Sweden has decided to account for changes in removals and emissions from mandatory activities: afforestation, reforestation, deforestation and forest management (Swedish EPA 2016). Sweden has not elected additional voluntary activities under Article 3(4) for the second commitment period of the Kyoto Protocol.

Sweden established the definition of forest back for the first commitment period under the Kyoto Protocol. The definition follows the criteria for forest land as derived from the FAO definition and the IPCC's good practice guidance. Sweden intends to apply the provisions to exclude emissions from natural disturbances for the accounting of afforestation and

reforestation under Article 3(3) and forest management under Article 3(4) during the second commitment period of the Kyoto Protocol.

The forest management reference level for Sweden is -41.3 million tonnes of CO_2-equivalents per year, applying a first-order decay function for harvested wood products. The forest management reference level was based on averages of the projected emissions/removals for carbon pools and included sources for forest management data series for the period 2013–2020, taking into account policies implemented before mid 2009. Sweden is allowed to claim a maximum credit of 2.5 million tonnes of CO_2 per year in the second commitment period of the Protocol. For the years 2013-2019 Sweden has reported a net sink from forest management that is significantly larger than the cap of credits from forest management of 2.5 million tonnes of CO_2 per year. The full description of the forest management reference level calculations can be found in Sweden's submission of information on forest management reference levels (Swedish Govt. 2011).

Under the Kyoto Protocol, the National Communication is to include information on national legislative or administrative procedures to ensure that implementation of Articles 3.3 and 3.4 also contributes to the conservation of biodiversity and sustainable use of natural resources. Sweden's current forest policy puts great emphasis on using forests sustainably as a natural resource and on conserving biodiversity. Under the Forestry Act, forests are to be managed and harvested in such a way as to contribute to sustainable forestry. The provisions of environmental legislation on nature reserves and habitat protection areas provide long-term formal protection for forest areas of high biological value, and the Forestry Act stipulates that forests must be managed using measures that meet good environmental standards. There has therefore been no need for supplementary legislation to conserve biodiversity and ensure sustainable use of natural resources as a consequence of implementation of Articles 3.3 and 3.4.

4.2.10 Shipping water-borne navigation and aviation, including international bunkers in Sweden

Tax on air travel*

A tax on air travel was introduced in 2018. The tax aims to reduce the climate impact of aviation. The tax is regulated in the Swedish act SFS 2017:1200 regarding tax on air travel. It is designed as a tax on commercial

flights and is paid for passengers travelling from a Swedish airport. The airline that carries out the flight is liable to tax. Various levels of tax are levied based on the final destination (for 2021: SEK 63, 262 or 418), with a yearly indexation.

ICAO

Within the ICAO, Sweden and the EU have been pressing for action to limit greenhouse gas emissions from international aviation, using a unified global measure. ICAO decided in 2016 to develop a market-based mechanism, Carbon Offsetting and Reduction Scheme for International Aviation, CORSIA, to compensate for some of the CO_2 emissions from international aviation. The ICAO Council adopted this mechanism in 2018. Sweden is among the nations that have voluntarily participated in the scheme from its outset. Sweden is a long-standing member of the Committee on Aviation Environment Protection (CAEP) and relevant subgroups that have been working on the technical parts of the proposal.

CAEP is also working with analyses and policy measures for sustainable aviation fuels, metrics and possible measures for reducing emissions through operative procedures and studies of non-CO_2 effects from particles and nitrogen oxides.

International Maritime Organization (IMO)

Sweden has been working actively in the International Maritime Organization (IMO) for many years, pushing for the adoption of ambitious reduction measures.

The Energy Efficiency Design Index (EEDI), which is a standardized way to describe ships' energy efficiency, was made mandatory from 2013 for most (some 85 %) newly built vessels. All ships, to which the regulation applies, have to comply with the required EEDI level, which is set relative to a reference line, depending on ship type and size and year of building. The mandatory Ship Energy Efficiency Management Plan (SEEMP) was also introduced in 2013. The SEEMP is to be used in ships' management systems to improve energy efficiency in both existing and new ships. Both the EEDI end SEEMP applies to ships in international traffic with a gross tonnage of more than 400. Since 2019 the IMO data collection system for fuel oil consumption of ships (DCS) mandates all ships in international traffic with a gross tonnage of more than 5000 to collect and report data related to fuel

consumption. The system is similar to the monitoring, reporting and verficiation system (MRV) of EU that entered into force in 2018.

In 2018 the IMO adopted an initial strategy on the reduction of greenhouse gas emissions from ships, setting out a vision to reduce GHG emissions from international shipping and phase them out, as soon as possible during this century. IMO is now focusing on developing measures to meet the ambitions in the initial strategy. A first measure, aiming to complement and strengthen the EEDI and SEEMP was approved in 2020 and, provided formal adoption in 2021, is expected to enter into force in 2022/2023.

Sweden actively promotes the use of batteries and alternative fuels as well as related infrastructure. In 2015, the IMO adopted the IGF Code, which is a regulatory framework for ships using gases or other low-flashpoint fuels. Guidelines for using methanol as marine fuel (MSC.1/Circ.1621) were approved in 2020, and will be included in the IGF code after a test period of 3 to 5 years. Work on guidelines for fuel cells is also under way, which will allow for the use of hydrogen propulsion.

Many Swedish ports have invested in infrastructure allowing ships to use shore-side electricity, considerably reducing their emissions. The Port of Stockholm has introduced attractive incentives for ships using this infrastructure. All these measures form part of a national policy framework for development of alternative fuels and related infrastructure, implementing directive 2014/94/EU.

Part from greenhouse gases, emissions of black carbon from ships is also having considerable impact, not least in the Arctic. Black carbon emissions from shipping are now under review by the IMO, with a particular focus on the potential impacts of future Arctic shipping. Sweden was one of the countries that proposed to raise this issue on IMO's agenda.

4.2.11 Efforts to avoid adverse effects of policies and measures introduced as part of the country's climate strategy

Parties under the UN Framework Convention of Climate Change should strive to implement policies and measures in such a way as to minimise adverse effects. These include the adverse effects of climate change, effects on international trade, and the social, environmental and economic impact on other parties, especially developing countries.

Sweden has not made any changes since the seventh National Communication on climate change in the work to avoid adverse effects of policies and measures introduced as part of the country's climate strategy.

Under Sweden's policy for global development (PGD), all policy areas should interact in a coherent way so the country can make an effective contribution to equitable and sustainable global development. When decisions in a given policy area are judged to affect this goal of equitable and sustainable global development, an impact assessment must be carried out. The policy's two perspectives – a rights perspective and the perspective of poor people on development – should serve as a guide. In the framework of the PGD, for example, coordination and collaboration take place through a reference group on trade policy at the Ministry for Foreign Affairs. Regular meetings of this group, which includes representatives of business, the Swedish International Development Cooperation Agency (Sida) and civil society organisations have created a basis for broad consultation on trade policy.

In connection with decision making on policies and measures in Sweden and at the EU level, impact assessments are carried out, including environmental impact assessments. To the extent possible, such assessments include an appraisal of the risk of adverse effects on other countries. Both beneficial and adverse effects need to be taken into account. Sweden is helping to implement a range of measures that could improve the ability of developing countries to adapt to climate change and take action of their own to reduce their greenhouse gas emissions. Finally, Sweden has designed a broad-ranging climate strategy that encompasses many different types of measures and most sectors, both inside and outside the country. This, combined with all the greenhouse gases regulated by the Kyoto Protocol, represents a fundamental effort to minimise the risk of adverse effects.

4.3 Work on project-based flexible mechanisms under the Kyoto protocol

The core mission of the Swedish Program for International Climate Initiatives is to support the development of international climate cooperation, to achieve cost-effective greenhouse gas reductions and to contribute to sustainable development in developing countries. Initially, the program consisted solely of projects and multilateral funds generating emission reductions under the Kyoto Protocol. In 2018, the program was

expanded to include the development of new types of cooperation under the Paris Agreement, in particular its Article 6.

4.3.1 Project-based flexible mechanisms under the Kyoto Protocol

The Swedish Program for International Climate Initiatives supports the development of effective climate policy instruments through the implementation of market-based mechanisms which contribute to cost-effective greenhouse gas reductions, and also promotes sustainable development in host countries. The program has involved participation in individual projects for Clean Development Mechanism (CDM) and Joint Implementation (JI) as well as multilateral carbon funds and collaborations. The projects and the emissions reductions they generate are scrutinized and verified by the UNFCCC, ensuring the projects' additionality, cost effectiveness and promotion of sustainable development.

Throughout the program, Sweden has supported over 90 bilateral projects through CDM and JI and has participated in 11 multilateral carbon funds[37]. By the end of 2020, SEK 1,8 billion had been granted, corresponding to approximately 31 Mt CO2 -eq. The program has a total commitment of approximately SEK 1,9 billion[38] and is expected to generate emission reductions equivalent to a total of 35 Mt CO2 -eq. The program is expected to close in 2025, with final payments in 2022.

All projects are carried out in developing countries, and priority has been given to projects in least developed countries (LDCs), small island developing states (SIDS) and in Sub-Saharan Africa. Overall, the program supports climate projects in more than 50 developing countries. A majority of the projects are in renewable energy, energy efficiency and waste management.

Sweden's participation in multilateral funds offers an opportunity to support a larger number of projects across several regions and project categories. Collaboration in multilateral funds has also provided a valuable knowledge

[37] Future Carbon Fund (FCF), Asia Pacific Carbon Fund (APCF), Transformative Carbon Asset Facility (TCAF), Carbon Initiative for Development (Ci-Dev), Carbon Partnership Facility (CPF), Pilot Auction Facility for Methane and Climate Change Mitigation (PAF), Umbrella Carbon Facility Tranche 2 (UCF T2), Prototype Carbon Fund (PCF), Multilateral Carbon Credit Fund (MCCF), Testing Ground Facility (TGF) and Partnership for Market Readiness (PMR).

[38] Calculated with currency rates from October 2021.

exchange, network development and many insights into carbon pricing and implementation.

Sweden has decided to cancel all emission reductions received up until the end of 2019. The cancelled international credits have not been used to fulfil commitments under the Kyoto Protocol. Instead, the financial support related to cancelled international credits has been reported as climate finance (see section 7.4.3.)

4.3.2 New market mechanisms under the Paris Agreement

Since 2018, the Swedish Energy Agency (SEA) has received funding aimed at supporting the development of new international forms of cooperation under the Paris Agreement, namely Article 6. The aim is to contribute to increased climate ambition and to provide results-based climate finance or, alongside other supplementary measures, contribute to the fulfilment of Sweden's national climate targets.

In 2018, the SEA commissioned nine virtual pilots to be developed in seven different countries. Each pilot resulted in a report, presenting a blueprint of a mitigation activity in a real-world Article 6 setting. In late 2019, efforts moved closer toward developing concrete, bilateral collaborations under Article 6 as the SEA launched a global call for proposals on international climate collaborations within the Article 6 framework. Over 60 proposals were received, out of which six activities were selected for further development of detailed mitigation activity design documents, focusing on compliance with the Article 6 framework. These project documents formed a foundation for future decisions on financing and implementation.

In parallel to the progress of these Article 6 activities, there are ongoing dialogues with the respective host countries to find agreement on the conditions and rules for the collaboration. In 2019, the SEA entered into an agreement with the Global Green Growth Institute (GGGI) for a tailor-made Article 6-program. The objective of the agreement is to develop ideas for feasible Article 6-activites and build the competence and institutional infrastructure necessary for host countries to trade with emission outcomes. In 2020, the program with GGGI resulted in four proposals for mitigation activities in three different countries, as well as blueprints for host country agreements and institutional infrastructure.

The work is also focused on methodological development with a special focus on monitoring, reporting and verification (MRV) and sustainable development. Representing Sweden in the negotiations of the rulebook for Article 6, the SEA is actively working for robust rules on sustainable development and environmental integrity. The SEA also participates in several capacity building initiatives aimed at supporting countries in entering collaborations under Article 6, such as the Article 6 Support Facility hosted by the Asian Development Bank and the Climate Market Club hosted by the World Bank.

4.4 Cost-effectiveness of policies and measures in Sweden's climate strategy

4.4.1 Cost-effectiveness of policy instruments

The concept of cost-effectiveness refers in this context to achieving a given objective at the lowest possible cost. To be able to assess the cost-effectiveness of different policies and measures, there thus needs to be an objective and an estimate of the costs of the instruments concerned. In the case of a national target for greenhouse gas emissions, the relevant costs are the economic costs, i.e. the change in current and future households' scope for consumption (in a wide sense) due to the instruments.

A given instrument may be intended to achieve a number of objectives, and it may therefore be difficult to correctly allocate the costs stemming from it. An instrument may for example – as is commonly the case in Sweden's climate strategy – be designed to be of significance for several environmental objectives at once, but also to help meet broader energy, waste and employment policy goals.

By and large, general, cross-sectoral policy instruments, such as a carbon dioxide tax or an emissions trading system, which impose the same marginal cost on emissions, have potential to be cost-effective. This is due to the flexibility they offer in the choice of measures to reduce emissions, resulting in low-cost actions being implemented.

It can be argued that there are two main reasons for supplementing general instruments with more targeted ones. The first has to do with the existence of other market failures than the actual emission of greenhouse gases. These include, for example, knowledge leakage from R&D investments, other

obstacles to new technology and infrastructure, and various information failures. (Swedish EPA 2012)

The second reason is that there are sometimes factors restricting the implementation of the, in theory, most cost-effective policy. This may mean that, instead of introducing the first choice of instrument, the second-best solution may be applied, such as a less cost-effective instrument or several blunter ones. This may be because the first choice of instrument is not judged feasible to implement due to factors such as political feasibility or EU regulations such as the state aid rules and the energy tax regulation. Following Sterner (2018): "In an ideal world, there would never be a need for anything other than carbon pricing. But according to the theory of "second-best", sometimes, in the presence of several external effects and/or obstacles to decision-making, it can be optimal with completely different policy combinations – which would not be optimal in an ideal situation."

Moreover, there is a risk that, because of conflicts with other goals, general policy instruments cannot be designed in a theoretically desirable way. Targeted instruments can then help to increase awareness of the options for action available. This means that, in certain cases, it may be cost-effective to combine general and targeted instruments. In the words of Meckling et al. (2018): "As countries move toward deeper emissions cuts, combining and sequencing policies will prove critical to avoid environmental, economic, and political dead-ends in decarbonizing energy systems."

4.5 Summary of policies and measures[39]

Cross-sectoral

Name of policy/measure	Sectors primarily affected	GHG(s) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing agency	Estimate of mitigation impact in Mt CO_2 eq per year compared with 1990 instruments[40]					
									2010	2015	2020	2030	2040	2050
Local climate investment program (Climate leap)	All sectors	All	Enhance and speed reduction of greenhouse gas emissions	Economic	Implemented	Grants for local and regional investments, in all sectors, except those included in the EU ETS to cut greenhouse gas emissions,	2015	Swedish Environmental Protection Agency	1.5 Mt CO_2-eq. per year during the technical lifespan of the investments[41]					
Environmental Code	All sectors	All	Ecologically sustainable development	Legislation	Implemented	General rules for consideration to be observed in all activities and measures that are not of negligible significance and that can affect the environment	1999	Swedish Environmental Protection Agency	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
Planning and Building Act (PBL)	All sectors	All	Promote sustainable development of society	Legislation	Implemented	In 2011, the PBL introduced new requirements on considering the environmental and	2011	Swedish National Board of Housing, Building and Planning	N.E.	N.E.	N.E .	N.E.	N.E.	N.E.

[39] Some of the policy instruments are, due to recent date of decision, not included in the scenarios in chapter 5. Those are marked with a "*" in the table.

[40] For quite a few policies/measures thers is no reliable estimate of mitigation impact. This is indicated with "N.E." in the table.

[41] The technical lifespan of the investments is in average 16 years. Note that all emission reductions can not be attributed to this policy instrument alone. The figure can thus be an overstatement.

						climate aspects of planning.								
Fossil-Free Sweden initiative	All sectors	Carbon dioxide	Mobilize efforts from actors to reduce the use of fossil fuels.	Information	Implemented	Strengthen the dialogue between the state and the business sector, municipalities and civil society	2015	Fossil free Sweden	N.E.	N.E.	N.E .	N.E.	N.E.	N.E.
Climate and energy advice	All sectors	All	Greater awareness of possible measures	Information	Implemented	Energy and climate advisers in municipalities reply free of charge to questions about heating, energy costs and efficiency, transport, climate and government grants relating to energy	1998	Swedish Energy Agency	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
Research and development	All sectors	All	Development of technology with very low climate impact	Economic	Implemented	Climate-related research and development aimed at achieving emissions reduction	1990	Swedish Energy Agency (mainly)	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
A national center for carbon dioxide capture and storage*	All sectors	Carbon dioxide	Enable negative emissions	Information	Adopted	Promote the appropriate application of CCS in Sweden, enable the export of CO2 from Swedish operations for long term geological storage, ensures that transport and storage is safe	2021	Swedish Energy Agency	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
National strategy for electrification*	All sectors	Carbon dioxide	Contribute to a fast, smart and	Legal, information	Planned (2022-2024)	Contribute to a fast, smart and economically	2022	Government Offices	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.

			economically efficient electrification			efficient electrification								
Increased competence for climate transition*	All sectors	All	To meet future needs in the labour market as a result of the climate transition	Education	Planned	To meet future needs in the labour market as a result of the climate transition	2022	The Legal, Financial and Administrative Services Agency	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
Education and training	All sectors	All	Education on climate related issues	Education	Adopted	Clarify the connection between curriculum and syllabus and the national environmental goal Reduced Climate Impact	N.d.	The National Swedish Agency for Education, Swedish Environmental Protection Agency	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.

Production of electricity and district heating

Name of policy/measure	Sectors primarily affected	GHG(s) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing agency	Estimate of mitigation impact in Mt CO_2 eq per year compared with 1990 instruments					
									2010	2015	2020	2030	2040	2050
Energy tax	Energy	Carbon dioxide	Fiscal, and to improve efficiency of energy use	Economic	Implemented	The aim is mainly fiscal. It also steer energy usage towards Sweden's energy efficiency, renewability and climate targets	1957	Swedish Tax Agency	13	15	15	6	4	6
Carbon dioxide tax	Energy	Carbon dioxide	Reduce use of fossil fuels	Economic	Implemented	Based on the fossil carbon content in the fuel	1991	Swedish Tax Agency						
Electricity certificate system	Energy	Carbon dioxide	Increase supply of electricity from renewable energy sources	Economic	Implemented	Electricity suppliers are obliged by law to submit electricity certificates corresponding to a certain share of their electricity deliveries.	2003	Swedish Energy Agency						
EU Emissions Trading System (EU ETS)	Energy	Carbon dioxide	Reduce use of fossil fuels in trading sector	Economic	Implemented	The amount of emissions allowed within the system is limited by a cap, which is decreased every year. Almost half of the allowances are allocated for free,	2005	Swedish Environmental Protection Agency and Swedish Energy Agency						

						the rest are auctioned.							
Initiatives for wind power	Energy	Carbon dioxide	Increase supply of electricity from renewable energy sources	Simplifying rules and information	Implemented	This includes research programs, designation of areas of national interest for wind power	2004	Swedish Energy Agency	N.E	N.E	N.E	N.E	N.E	N.E
Support for solar power	Energy	Carbon dioxide	Increase supply of electricity from renewable energy sources	Economic	Implemented	A subsidy for installations of solar power systems	2009	Swedish Energy Agency	N.E	N.E	N.E	N.E	N.E	N.E
Income tax reduction for micro production of renewable energy	Energy	Carbon dioxide	Increase micro production of renewable energy	Economic	Implemented	Tax reduction for households and businesses to stimulate investment in the micro-production of renewable electricity	2015	Swedish Tax Agency	N.E	N.E	N.E	N.E	N.E	N.E
Tax on waste incineration	Energy	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	Incineration of waste is taxed. The tax has gradually been increased and is from 2022 SEK 125 per ton. The tax excludes for example hazardous waste and bio energy.	2020	Swedish Tax Agency	N.E	N.E	N.E	N.E	N.E	N.E
Tax reduction for green investments*	Energy	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	Individuals are eligible to a tax reduction for installation of green technology including solar cells, systems for storage of self-produced electricity and at home charging stations	2021	Swedish Tax Agency	N.E	N.E	N.E	N.E	N.E	N.E

Residential and commercial/institutional sector

Name of policy/measure	Sectors primarily affected	Greenhouse gas(es) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Status of instrument	Implementing agency	Estimate of mitigation impact in Mt CO_2 eq per year compared with 1990 instruments[42]					
									2010	2015	2020	2030	2040	2050
Energy tax	Energy	Carbon dioxide	Fiscal, and to improve efficiency of energy use	Economic	Implemented	The aim is mainly fiscal. It also steer energy usage towards Sweden's energy efficiency, renewability and climate targets	1957	Swedish Tax Agency	1.3	1.0	1.1	1.0	1.0	1.0
Carbon dioxide tax	Energy	Carbon dioxide	Reduce use of fossil fuels	Economic	Implemented	Based on the fossil carbon content in the fuel	1991	Swedish Tax Agency						
Building regulations	Energy	Carbon dioxide	More efficient energy use	Legislation	Implemented	Requirements for energy use in new buildings	2009 (1960s)	Swedish National Board of Housing, Building and Planning						
Energy declarations (Law on energy performance certificates for buildings)	Energy	Carbon dioxide	More efficient energy use	Legislation and information	Implemented	Obligation for owners to declare the energy use of buildings	2006	Swedish National Board of Housing, Building and Planning						

[42] For aggregated effects for the sector, see Table 4.2

Ecodesign Directive	Energy	Carbon dioxide	More efficient energy use	Legislation	Implemented	Aims to improve the products' environmental performance during their full life cycle	2008	Swedish Energy Agency						
Mandatory energy labelling	Energy	Carbon dioxide	More efficient energy use	Information	Implemented	Makes the product's energy use visible and facilitates for consumers who want to make energy smart choices	1995	Swedish Energy Agency						
Training programs in building for low energy consumption	Energy	Carbon dioxide	More efficient energy use	Information	Implemented	Target different construction stakeholders, such as architects, engineers, clients, technicians, installers, site managers and teachers in building programs	2016	Swedish Energy Agency	N.E	N.E	N.E	N.E	N.E	N.E
Technology procurement	Energy	Carbon dioxide	More efficient energy use and increased use of renewable energy	Economic	Implemented	An instrument designed to initiate a market transition and disseminate new, more efficient technology, such as new products, systems and processes	N.d.	Swedish Energy Agency	N.E	N.E	N.E	N.E	N.E	N.E
Energy Performance of Buildings Directive 2010/31/EC	Energy	Carbon dioxide	More efficient energy use and reduce emissions	Legislation	Implemented	A framework within which EU Member States have decided on minimum energy performance standards, building energy certificates etc	2010	Swedish National Board of Housing, Building and Planning	N.E	N.E	N.E	N.E	N.E	N.E

Industrial emissions from combustion and processes

Name of policy/measure	Sectors primarily affected	Greenhouse gas(es) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing agency	Estimate of mitigation impacct in Mt CO_2 eq per year compared with 1990 instruments					
									2010	2015	2020	2030	2040	2050
Energy tax	Industrial sector	Carbon dioxide	Fiscal, and to improve efficiency of energy use	Economic	Implemented	The aim is mainly fiscal. It also steer energy usage towards Sweden's energy efficiency, renewability and climate targets	1957	Swedish Tax Agency	-0.9	-0.5	-0.1	0.5	0.8	3.3
Carbon dioxide tax, incl. stepwise reduced carbon dioxide tax relief for industry outside EU ETS	Industrial sector	Carbon dioxide	Reduce use of fossil fuels	Economic	Implemented	Based on the fossil carbon content in the fuel	1991-	Swedish Tax Agency						
Electricity certificate system	Industrial sector	Carbon dioxide	Increase supply of electricity from renewable energy sources	Economic	Implemented	Electricity suppliers are obliged by law to submit electricity certificates corresponding to a certain share of their electricity deliveries.	2003	Swedish Energy Agency						
EU Emissions Trading System (EU ETS)	Industrial sector	Carbon dioxide	Reduce use of fossil fuels in trading sector	Economic	Implemented	The amount of emissions allowed within the system is limited by a cap, which is decreased every year. Almost half of the allowances are allocated for free,	2005	Swedish Environmental Protection Agency and Swedish Energy Agency						

						the rest are auctioned								
Energy audit for large enterprises	Industrial sector	Carbon dioxide	More efficient energy use	Legislation and information	Implemented	Requires large enterprises to conduct energy audits, including information of total energy use	2014	Swedish Energy Agency	N.E	N.E	N.E	N.E	N.E	N.E
Environmental Code	Industrial sector	All	Ecologically sustainable development	Legislation	Implemented	General rules for consideration to be observed in all activities and measures that are not of negligible significance and that can affect the environment	1999	Swedish Environmental Protection Agency	N.E	N.E	N.E	N.E	N.E	N.E
Industrial Leap, in combination with several other policy instruments enabling the investmens in low coal technologises	Industrial sector	All	Reduce greenhouse gas emissions	Research and market introduction	Implemented	A government scheme that supports development of technology and processes to reduce the process-related greenhouse gas emissions in Swedish industry	2018	Swedish Energy Agency	N.E.	N.E	N.E.	N.E.	N.E.	N.E.
Operating aid for BECCS*	Industrial sector	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Planned	A reversed auction where the company offering the most cost efficient solution will receive operating aid to operate a BECCS facility.	2022	Swedish Energy Agency	N.E.	N.E	N.E.	1-2	1-2	1-2

Product use

Name of policy/measure	Sectors primarily affected	Greenhouse gas(es) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing agency	Estimate of mitigation impacct in Mt CO_2 eq per year compared with 1990 instruments					
									2010	2015	2020	2030	2040	2050
EU regulation on Fluorinated greenhouse gases and BREF	Non-ferrous metal industry	HFCs	Reduce use of HFCs	Legislation	Implemented	Includes a mechanism for quantified emission reductions of substances containing HFCs	2015	Swedish Environmental Protection Agency	0.2	0.5	0.7	N.E	N.E	N.E
EU regulation on mobile air conditioning units in cars	Automotive industry	HFCs	Reduce use of HFCs	Legislation	Implemented	Requirements for vehicles as regards emissions from, and the safe functioning of, air-conditioning systems fitted to vehicles.	2006	Swedish Environmental Protection Agency						
Swedish regulation on fluorinated gases and ozone depleting substances	Cooling and air conditioning	HFCs	Reduce use of HFCs and ozone depleting substances	Legislation	Implemented	Prohibition to sell f-gases as refrigerants to recipients other than those stated in the regulation etc	2016	Swedish Environmental Protection Agency						

Transport

Name of policy/measure	Sectors primarily affected	Greenhouse gas(es) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing agency	Estimate of mitigation impacct in Mt CO_2 eq per year compared with 1990 instruments					
									2010	2015	2020	2030	2040	2050
Energy tax, including stepwise increase of tax on diesel and petrol	Transport	Carbon dioxide	Fiscal, and to improve efficiency of energy use	Economic	Implemented	The aim is mainly fiscal. It also steers energy usage towards Sweden's energy efficiency, renewability and climate targets	1924	Swedish Tax Agency	2	2	2.3	N.E	N.E.	N.E.
Carbon dioxide tax	Transport	Carbon dioxide	Reduce use of fossil fuels	Economic	Implemented	Based on the fossil carbon content in the fuel	1991	Swedish Tax Agency						
Emission performance standards for new vehicles	Transport	Carbon dioxide	Reduce carbon dioxide emissions	Legislation	Implemented	Manufacturers selling vehicles in the EU are subject to EU regulations that set emission performance standards	2015 (2017 and 2020)	Swedish Transport Administration	N.E	N.E	N.E	8	N.E	N.E.
CO_2-based vehicle tax	Transport	Carbon dioxide	Reduce carbon dioxide emissions	Economic	Implemented	All vehicles in the system are subject to a basic charge of SEK 360 per year. In addition, vehicles are subject to a CO_2 component depending on their level of CO_2	2006	Swedish Tax Agency						

						emissions per kilometer in mixed driving.								
Super-green car rebate (replaced by the bonus-malus system in 2018)	Transport	Carbon dioxide	Reduce carbon dioxide emissions	Economic	Implemented	A subsidy aimed to contribute to technology development and to lower barriers for a large-scale introduction of environmental friendly cars	2012	Swedish Transport Agency	N.E	N.E	N.E	N.E	N.E	N.E
Tax exemption for environmental friendly vehicles	Transport	Carbon dioxide	Reduce carbon dioxide emissions	Economic	Implemented	Lower tax for vehicles with environmental friendly technology	2010	Swedish Tax Agency						
Reduced taxable values for some company cars with environmentally friendly technology	Transport	Carbon dioxide	Reduce carbon dioxide emissions	Economic	Implemented	To increase the incentive to purchase company cars that use environmental technologies, those who use green cars receive relatively favorable tax treatment	2000	Swedish Tax Agency						
Support for charging infrastructure	Transport	Carbon dioxide	Reduce carbon dioxide emissions	Economic	Implemented	Ensuring basic access to charging infrastructure for charging of electric vehicles	2020	Swedish Transport Administration						

Local climate investment program (Climate leap)	Transport	All	Enhance and speed reduction of greenhouse gas emissions	Economic	Implemented	Municipalities, companies, organisations and others can apply for investment support for measures to reduce climate impact	2015	Swedish Environmental Protection Agency	N.E.	N.E.	N.E.	0.9	0.9	0.9[43]
Support for research and demonstration	Transport	Carbon dioxide	Develop technology for sustainable growth and reduced fossil fuel dependence	Economic	Implemented	Swedish agencies are financing several large research projects covering the entire chain from cultivation of raw materials for bio-based motor fuels to the use of new fuels	N.d.	Vinnova and Swedish Energy Agency (mainly)	N.E	N.E	N.E	N.E	N.E	N.E
Consideration of climate in long-term infrastructure planning	Transport	Carbon dioxide	Take environmental and climate issues into account in planning all modes of transport	Legal	Implemented	Planning is undertaken in dialogue with local and regional planning bodies with a requirement to take environmental and climate issues into account	2018	The Swedish Transport Administration	N.E	N.E	N.E	N.E	N.E	N.E
Tax on air travel	Transport	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	A tax on commercial flights paid for passengers	2018	Swedish Tax Energy	N.E	N.E	N.E	N.E	N.E	N.E

[43] The program is expected to generate total reductions of 1.5 Mt CO_2-eq. per year during the technical lifespan of the investments. 60% of these, i.e. 0.9 Mt CO_2-eq. per year, are from the transport sector. The technical lifespan of the investments is in average 16 years.

						travelling from a Swedish airport								
Reduction obligation scheme for aviation*	Transport	Carbon dioxide	Reduce greenhouse gas emissions	Legal	Implemented	The level of renewable fuels was 0,8 percent in 2021 and will increase to 27 percent in 2030	2021	Swedish Energy Agency	N.E	N.E	0.2 (2025)	1[44]	1[45]	1.1[46] (2045)
Differentiated take-off and landing fees for aviation*	Transport	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	The fees are differented according to environmental performance of the aircrafts	2021	Swedish Energy Agency	N.E	N.E	N.E	N.E	N.E	N.E
Aviation in the EU ETS	Transport	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	Aviation is included in the EU Emissions Trading System	2012	Swedish Environmental Protection Agency	N.E	N.E	N.E	N.E	N.E	N.E
Emission reduction obligation*[47]		Carbon dioxide	Reduce greenhouse gas emissions	Legislation	Implemented	An obligation on petrol and diesel suppliers to reduce life-cycle carbon dioxide emissions, by gradually increasing blending with sustainable biofuels,	2018	Swedish Energy Agency	N.E	N.E	N.E	4-6[48]	N.E	4 (2045)

[44] Domestic 0.1

[45] Domestic 0.1

[46] Domestic 0.1

[47] The reduction obligation is today more ambitious then assumed in the projections in chapter 5.

[48] Including the effect from mobile machinery.

Climate premiums for electrical buses, heavy-duty vehicles and working machinery	Transport	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	Regional public transport agencies, public transport companies, municipalities and limited companies are eligible to apply for climate premiums	2020	Swedish Energy Agency	N.E	N.E	N.E	N.E	N.E	N.E
Tax reduction for installation of green technology	Transport	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	Private individuals are eligible to a tax reduction for installation of green technology	2021	Swedish Tax Agency	N.E	N.E	N.E	N.E	N.E	N.E
Eco-bonus system for heavy transport	Transport	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	Support aimed at stimulating the transfer of goods from road to shipping to reduce greenhouse gas emissions from heavy transport	2018	Swedish Transport Administration	N.E	N.E	N.E	N.E	N.E	N.E
Environmental compensation for railway transport of goods	Transport	Carbon dioxide	Reduce greenhouse gas emissions	Economic	Implemented	Suport to stimulate railway transports of goods	2018	Swedish Transport Administration	N.E	N.E	N.E	N.E	N.E	N.E
Congestion tax	Transport	Carbon dioxide	Reduce congestion	Economic	Implemented	The tax is levied during such hours and on such places where there is considered to be congestion	2007	Swedish Transport Agency	N.E	N.E	N.E	N.E	N.E	N.E

Low emission zone	Transport	Carbon dioxide	Restrict traffic	Legal	Implemented	Restricting access to vehicles that don't meet specific requirements	2013 (2020 for cars)	Swedish Transport Agency	N.E	N.E	N.E	N.E	N.E	N.E
State co-financing for certain regional public transport facilities	Transport	Carbon dioxide	Support for infrastructure for public transport	Economic	Implemented	An investment support for infrastructure for regional public transport.	2009	Swedish Transport Administration	N.E	N.E	N.E	N.E	N.E	N.E
Urban environmental agreements	Transport	Carbon dioxide	Reduce carbon dioxide emissions and incentivise building of public transport	Economic	Implemented	A scheme for investments in public transport, cycling infrastructure or sustainable freight transport at the regional and local level	2015)	Swedish Transport Administration	N.E	N.E	N.E	N.E	N.E	N.E
National ticket system for public transport*	Transport	Carbon dioxide	Facilitate travel by public transport	Economic	Planned	The system will make it easier for travelers to choose to travel by public transport	2022	Swedish Transport Administration	N.E	N.E	N.E	N.E	N.E	N.E
Night train traffic in Sweden and abroad*	Transport	Carbon dioxide	Replace travel by air and car	Economic	Adopted	Procurement of night train traffic through Sweden and Denmark	2022	Swedish Transport Administration	N.E	N.E	N.E	N.E	N.E	N.E
Conversion premium*	Transport	Carbon dioxide	Reduce emissions from cars	Economic	Planned	A conversion premium for cars from fossil fuels to biofuels or biogas	2022	Swedish Tax Energy	N.E	N.E	N.E	0.006	≈0	≈0

Continued tax exemption for clean and highly mixed biofuels*	Transport	Carbon dioxide	Compensate for increased costs	Economic	Implemented	An exemption of the carbon and energy tax for biofuels are not considered compatible with the EU state aid rule why Sweden has sought a prolongation of an exemption	2020 (2021 for biogas)	Swedish Tax Energy	N.E	N.E	N.E	1[49]	0.8	0.8 **(2045)**

[49] If the exemption continues after 2021. Otherwise no effect from 2030 and onwards.

Agriculture

Name of policy/measure	Sectors primarily affected	Greenhouse gas(es) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing agency	Estimate of mitigation impacct in Mt CO_2 eq per year compared with 1990 instruments					
									2010	2015	2020	2030	2040	2050
Common Agricultural Policy	Agriculture	Nitrous oxide, methane and carbon dioxide	Sustainable agriculture	Economic	Implemented	Common Agricultural Policy of the EU	2021 (for the period 2023-2027)	Swedish Board of Agriculture	N.E	N.E	N.E	N.E	N.E	N.E
Measures under the Rural Development Program	Agriculture	Nitrous oxide, methane and carbon dioxide	Reduced Climate Impact, a varied agricultural landscape and zero eutrophication	Economic	Implemented	Support to areas with natural constraints, animal welfare subsidies, ecological farming, and environmental and climate actions, etc.	2014	Swedish Board of Agriculture	N.E	N.E	N.E	N.E	N.E	N.E
Support for biogas production	Agriculture	Methane	Reducing emissions of greenhouse gases and production of biogas for energy purposes	Economic	Implemented	Increase biogas production from manure and thereby gain two-fold benefits through reduced methane emissions from manure and the substitution of fossil energy	2015	Swedish Board of Agriculture	N.E	N.E	N.E	N.E	N.E	N.E
The rural network	Agriculture	Nitrous oxide, methane and carbon dioxide	Reinforce implementation of the Rural Development Program	Information	Implemented	Brings together actors at the local, regional and central levels for	2007	Swedish Board of Agriculture	N.E	N.E	N.E	N.E	N.E	N.E

						exchanging information and experiences								
Focus on nutrients advisory service	Agriculture	Nitrous oxide, methane and carbon dioxide	GHG emission reductions and energy efficiency	Information	Implemented	Initial focus on reduced nutrient leaching. Today, it also provides advice targeting GHG emission	2001	Swedish Board of Agriculture	N.E	N.E	N.E	N.E	N.E	N.E

Waste

Name of policy/measure	Sectors primarily affected	Greenhouse gas(es) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing agency	Estimate of mitigation impacct in Mt CO_2 eq per year compared with 1990 instruments					
									2010	2015	2020	2030	2040	2050
Landfill tax	Waste sector	Methane	Increase recycling and reduce total quantities of waste	Economic	Implemented	The tax has been increased gradually, and is today 555 SEK per tonne landfilled waste	2000	Swedish Tax Agency	1.4	1.7	1.9	N.E.	N.E.	N.E.
Bans on landfill of combustible waste (2002) and of organic waste (2005)	Waste sector	Methane	Improved landfill management, enhanced recycling, improved wastewater management systems	Legislation	Implemented	Intended to prevent and reduce adverse effects on human health and the environment from landfilling.	2002	Swedish Environmental Protection Agency						
Extended producer responsibility	Waste sector	Carbon dioxide	Increase resource efficiency	Legislation	Implemented	Producer responsibility promotes sorting, collection and recycling of certain waste flows	1994	Swedish Environmental Protection Agency						
Rules on municipal waste planning	Waste sector	Methane, Carbon dioxide	Increase resource efficiency	Legislation	Implemented	A requirement that all the municipalities in Sweden must have their own municipal waste plan	1991	Swedish Environmental Protection Agency						

Land use, Land use change and forestry (LULUCF)

Name of policy/measure	Sectors primarily affected	Greenhouse gas(es) primarily affected	Primary objective	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing agency	Estimate of mitigation impacct in Mt CO_2 eq per year compared with 1990 instruments					
									2010	2015	2020	2030	2040	2050
Provisions of Forestry Act	Forestry	Carbon dioxide	Achieve environmental and production objectives for sustainable forest management	Legislation	Implemented	Regulations concerning nature conservation and cultural heritage include not disturbing important biotopes, buffer zones and arable land, and leaving older trees, high stumps and dead wood in situ.	1993	Swedish Forest Agency	N.E	N.E	N.E	N.E	N.E	N.E
Provisions of Envionmental Code including land drainage	Forestry	Carbon dioxide and methane	Biodiversity	Legislation	Implemented	A coordinated, broad and strict piece of environmental legislation aimed at promoting sustainable development so that present and future generations can live in a good, healthy environment	1999	County administrative boards	N.E.	N.E	N.E	N.E	N.E	N.E
Provisions on nature reserves and habitat protection areas in Environmental Code,	Forestry		Biodiversity		Implemented	The property owner and the state or a		Swedish Environmental Protection Agency and county						

and nature conservation agreements		Carbon dioxide		Legislation		municipality agree on a certain financial compensation for the property owner, for example, to refrain from, for example, forestry	N.d.	administrative boards	N.E.	N.E	N.E	N.E	N.E	N.E
Swedish National Forest Program	Forestry	Carbon dioxide	Increase the national supply of bio-based materials and energy	Information	Implemented	A broad dialogue on the role forests play to ensure a sustainable society and a growing bioeconomy	2018	Swedish Forest Agency	N.E.	N.E	N.E	N.E	N.E	N.E
Methods for increased carbon sinks*	Forestry	Carbon dioxide	Promote forest growth and prevente damage	Information	Implemented	Develop methods for increased carbon sinks	2021	Swedish Forest Agency	N.E.	N.E	N.E	N.E	N.E	N.E
Support for re-wetting of wetlands	Forestry	Carbon dioxie	Provide climate benefits and strengthen biodiversity	Economic, information	Implemented	Rewetting of drained wetlands on organic soils for purposes such as nutrient retention and biodiversity.	1990	Swedish Forest Agency	N.E.	N.E.	N.E.	0.08-0.18	0.08-0.18	N.E.

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5. Projections of greenhouse gas emissions and removals and total effect of policies and measures

This chapter presents projections of greenhouse gas emissions and removals for various sectors and in total[50][51]. The information is based on Sweden's report on projections submitted to the EU[52] in accordance with the requirements of the EU Regulation on Governance of the Energy Union and Climate Action[53]. The projections with existing measures are based on the policies and measures adopted by the EU and the Swedish Parliament up to June 2020. The base-year for the projections is 2018[54].

Model-based calculations and, to some extent, expert evaluations were used to produce the projections. The projections are based on a number of assumptions, all of which are characterised by uncertainty. This should be taken into account when interpreting the results. The projections can be mainly regarded as a consequential analysis of the assumptions made. The method for estimating the projections was mainly developed for medium-term or long-term projections, so the projections do not take into account shorter-term variations. However, the effects of the Covid-19 pandemic have partly been taken into account in the short term. The key parameters, assumptions and methodology used in the projections are presented in Annex 5.

In addition to the projections with existing measures, sensitivity projections have been calculated for emissions in the energy sector, for the road transportation sector and for the LULUCF sector. Projections with additional measures are not provided since there were no planned measures in Sweden when producing the projections. However, policies and measures are continuously developed, and new measures have been adopted and planned since the projections were produced, see chapter 4.

[50] All emissions and removals of greenhouse gases use global warming potentials from IPCC Fourth Assessment Report (AR4)

[51] Sweden's Common Tabular Format (CTF) for projections with measures can be found in Sweden's fifth Biennial Report under the convention.

[52] Ministry of the Environment. 2021.

[53] Regulation (EU) No 2018/1999.

[54] National Inventory Report Submission 2021 were used when producing the projections. For this Eighth National Communication the historical emissions and removals of greenhouse gases presented are based on National Inventory Report Submission 2022.

5.1 Greenhouse gas emission projections

Total greenhouse gas emissions in Sweden in 2020[55] were 46.3 Mt CO_2-eq. (excluding The Land Use, Land Use Change and Forestry sector). Total emissions decreased by 25.2 million tonnes, or 35 %, between 1990 and 2020. The projection results point to a gradual decline in total emissions of greenhouse gases (excl. LULUCF) over the projection period. Projected emissions for 2030 are 39 % below 1990 levels, and by 2040 total emissions are projected to be 45 % below 1990 levels. See Table 5.1 and Figure 5.1.

The LULUCF sector contributed to an annual net removal of carbon dioxide in Sweden during the period 1990–2020 and is expected to continue to do so during the projection period.

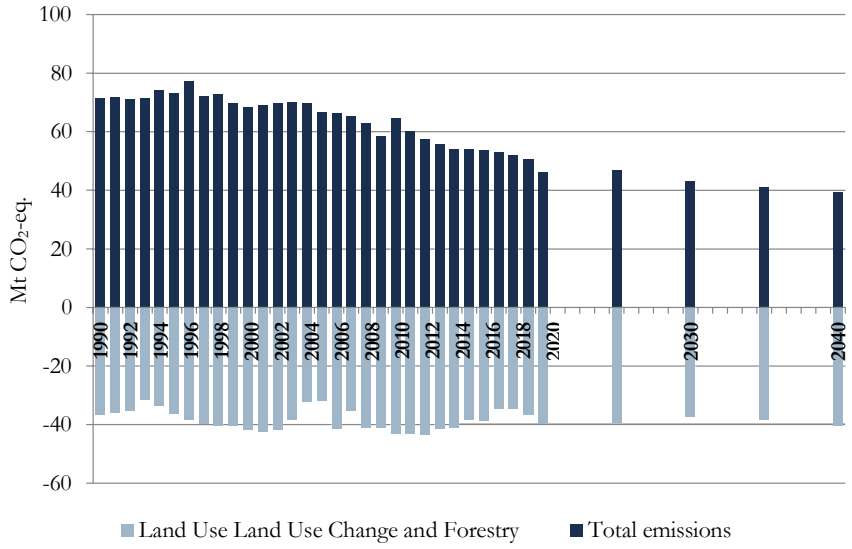

Figure 5.1 Historical and projected emissions and removals of greenhouse gases with existing measures (WEM).

Table 5.1 Historical and projected emissions and removals of greenhouse gases by sector (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Energy excl. transport	32.3	16.4	17.4	16.6	16.3	16.2	-49%	-50%
Transport	20.0	15.4	15.2	13.6	12.0	10.7	-31%	-46%

[55] National Inventory Report Sweden, Submission 2022

Industrial processes and product use	7.7	6.6	7.2	6.1	6.0	6.0	-20%	-22%
Agriculture	7.7	6.9	6.3	6.1	6.0	5.9	-20%	-22%
Waste	3.7	1.0	0.9	0.8	0.7	0.6	-79%	-83%
Total emissions	**71.4**	**46.3**	**47.0**	**43.2**	**41.0**	**39.4**	**-39%**	**-45%**
LULUCF	-36.6	-39.8	-39.3	-37.4	-38.4	-40.4	2%	10%

5.2 Projections by gas

In 2020, carbon dioxide emissions accounted for around 79 % of greenhouse gas emissions, while methane emissions accounted for around 9 %, nitrous oxide for around 10 % and fluorinated greenhouse gases for just over 2 %. During the projection period, emissions of all gases are projected to decrease except HFCs. See Table 5.2.

Table 5.2 Historical and projected emissions of greenhouse gases per gas (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	57.6	36.5	38.1	35.0	33.1	31.7	-39%	-45%
Methane	7.4	4.1	3.6	3.4	3.2	3.1	-55%	-58%
Nitrous oxide	5.8	4.6	4.5	4.4	4.3	4.3	-24%	-26%
HFC	0.006	0.9	0.7	0.5	0.3	0.3	7011%	4282%
PFC	0.6	0.07	0.04	0.04	0.04	0.04	-92%	-92%
SF_6	0.1	0.04	0.03	0.03	0.03	0.02	-71%	-76%
Total emissions (excl. LULUCF)	**71.4**	**46.3**	**47.0**	**43.2**	**41.0**	**39.4**	**-39%**	**-45%**

5.3 Projections by sector

In the projections, the emissions from all sectors are decreasing until 2040. The largest reduction is projected for the energy and transport sectors, see Figure 5.2.

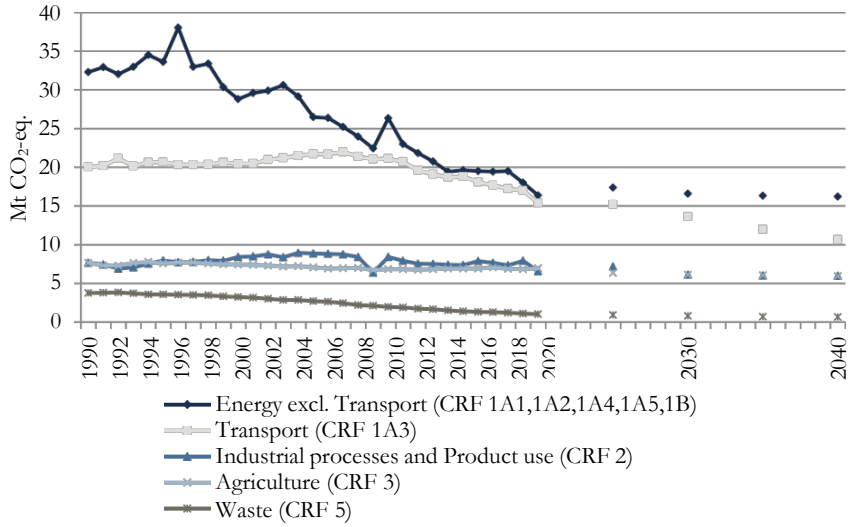

Figure 5.2 Historical and projected emissions of greenhouse gases by sector.

5.3.1 Energy industries (Electricity- and heat production, Refineries, Manufacturing of solid fuels)

Emissions from energy industries, i.e. production of electricity and district heating, refineries and the manufacturing of solid fuels, are projected to decrease slightly to 2040. However, projections for subsectors show differing trends.

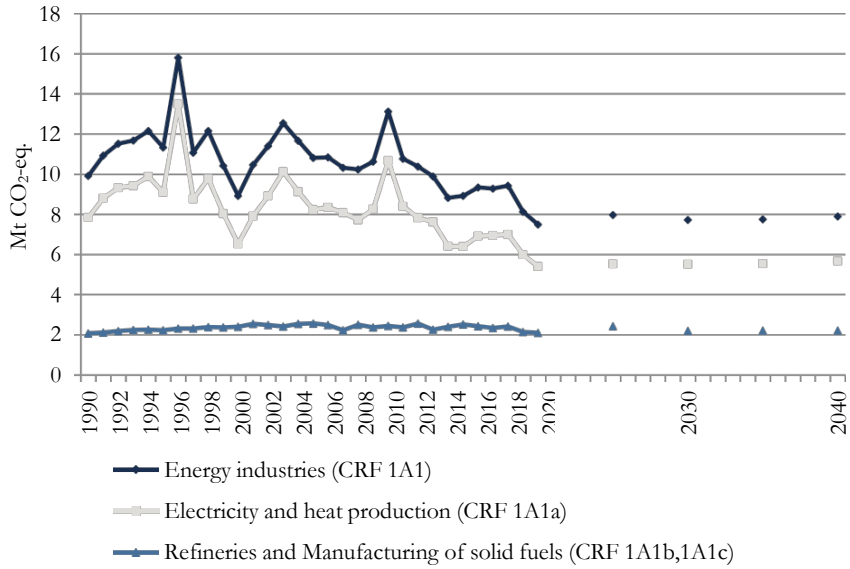

Figure 5.3 Historical and projected emissions of greenhouse gases from energy industries.

Emissions of greenhouse gases from electricity and heat production have varied since 1990, mainly due to temperature variations and precipitation. The production of electricity is expected to increase during the projection period while the productions of district heating is expected to remain stable. However, emissions do not increase to the same extent as production, mainly due to biofuels and incineration of waste and increased use of wind and solar power. Emissions are projected to decrease and then stabilize, see Table 5.3 and Figure 5.3. An increased use of waste contributes to the increase in emissions, but this increase is partly offset by increased use of biomass and wind and solar power, as well as decreased use of oil and coal. Production of electricity is assumed to grow more than consumption, resulting in a projected export of about 40 TWh by 2040.

Table 5.3 Historical and projected emissions of greenhouse gases from electricity and heat production (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	7.7	5.2	5.3	5.3	5.3	5.4	-31%	-29%
Methane	0.02	0.05	0.05	0.04	0.04	0.04	159%	173%
Nitrous oxide	0.1	0.2	0.2	0.2	0.2	0.2	59%	68%
Total emissions	**7.8**	**5.4**	**5.5**	**5.5**	**5.6**	**5.7**	**-30%**	**-28%**

Emissions from refineries and manufacturing of solid fuels are projected to increase slightly during the projection period, see Table 5.4 and Figure 5.3. The emissions from refineries are expected to continue to increase slightly until 2040, compared to the 1990 level. The emissions from refineries are also accounted for in the sector of fugitive emissions. The emissions from manufacturing of solid fuels are estimated to remain stable until 2025 and then decrease due to an assumed shift to fossil free technology.

Table 5.4 Historical and projected emissions of greenhouse gases from refineries and manufacturing of solid fuels (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	2.1	2.1	2.4	2.2	2.2	2.2	6%	7%
Methane	0.001	0.001	0.001	0.001	0.001	0.001	-8%	-8%
Nitrous oxide	0.001	0.001	0.001	0.001	0.001	0.001	-25%	-24%
Total emissions	**2.1**	**2.1**	**2.4**	**2.2**	**2.2**	**2.2**	**6%**	**7%**

5.3.2 Residential and commercial/institutional

Emissions from households and premises and from combustion in the agricultural, forestry and fishing sectors are projected to continue to decrease, see Table 5.5 and Figure 5.4. This decline is mainly due to a continuing replacement of individual oil-fuelled boilers for heating and hot water purposes in households and premises with district heating, electric heating, heat pumps and biomass. The shift to electric and district heating results in decreased emissions in this sector. However, since the increased production of electricity and heat is mainly based on wind power, biomass and waste, and with district heating being a more efficient way of heating, emissions on the whole still decrease.

Total emissions from combustion in the agricultural, forestry and fishing sectors are projected to decrease during the projection period. Emissions from energy consumption in the agricultural sector are expected to decrease to some extent during the projection period, due to a reduction in the use of diesel fuel for working machinery and a reduction in oil consumption for buildings. Emissions from working machinery in the forestry sector and from fishing are assumed to remain at about the same level during the entire projection period.

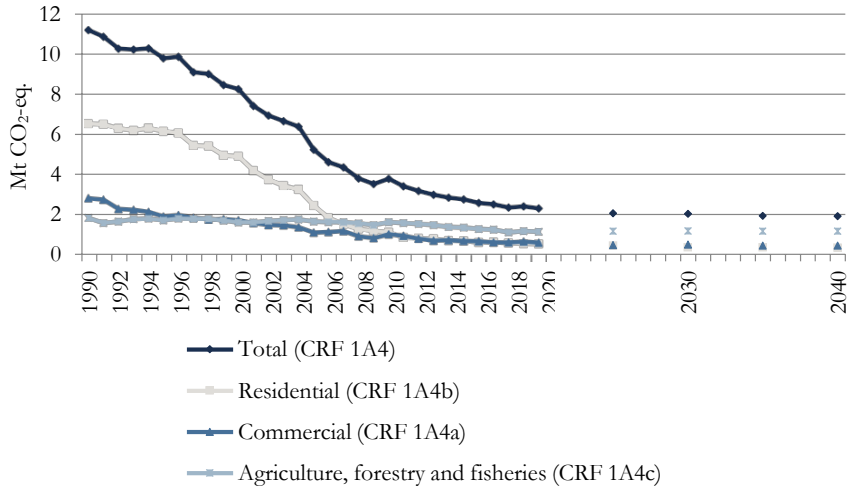

Figure 5.4 Historical and projected emissions of greenhouse gases from combustion in households, premises, agriculture, forestry and fisheries.

Table 5.5 Historical and projected emissions of greenhouse gases from residential and commercial sectors (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	10.9	2.2	1.9	1.9	1.8	1.8	-83%	-83%
Methane	0.1	0.06	0.05	0.05	0.04	0.04	-57%	-69%
Nitrous oxide	0.2	0.1	0.1	0.1	0.1	0.1	-51%	-57%
Total emissions	**11.2**	**2.3**	**2.1**	**2.0**	**1.9**	**1.9**	**-82%**	**-83%**

5.3.3 Industrial combustion

To cover all industry-related emissions, it is necessary to take account of process emissions, emissions from combustion, part of energy industries and fugitive emissions, which according to UNFCCC guidelines are to be reported under separate CRF (Common Reporting Format) categories.

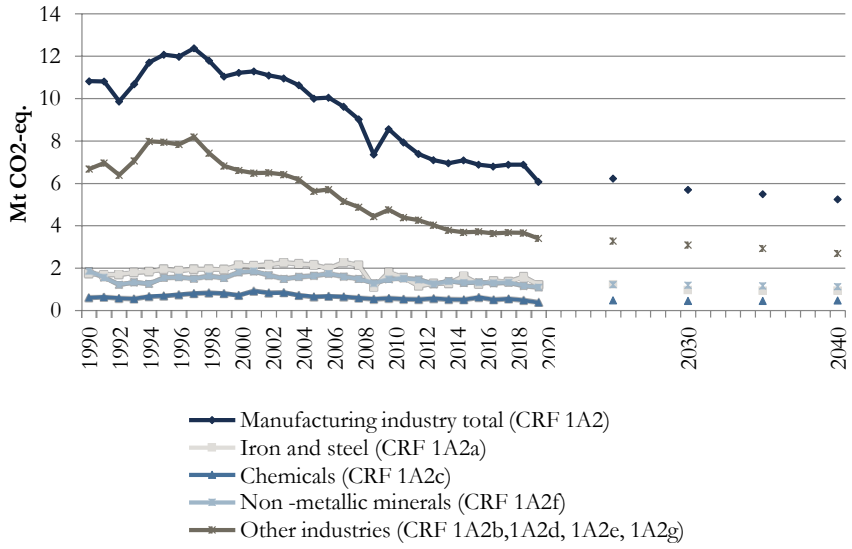

Figure 5.5 Historical and projected emissions of greenhouse gases from combustion in manufacturing industries.

Emissions from combustion in manufacturing industries are projected to decrease to 2040, because the use of biofuel and electricity is expected to increase more than the use of fossil fuels, see Table 5.6 and Figure 5.5. This decrease in emissions is mainly due to a shift in the pulp and paper industry from using fossil fuels to using biofuels. Emissions from the mineral industry are also expected to decrease, while emissions from the chemical

industry and the iron and steel industry remain relatively stable in the projection.

Table 5.6 Historical and projected emissions of greenhouse gases from combustion in manufacturing industries (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	10.7	5.9	6.0	5.5	5.3	5.1	-48%	-52%
Methane	0.02	0.02	0.03	0.03	0.03	0.03	13%	16%
Nitrous oxide	0.1	0.1	0.1	0.1	0.2	0.2	8%	10%
Total emissions	**10.8**	**6.1**	**6.2**	**5.7**	**5.5**	**5.2**	**-47%**	**-52%**

5.3.4 Fugitive emissions

The majority of fugitive emissions originate from refineries. The emissions were 0.9 million tonnes of carbon dioxide equivalents in 2018 and have increased compared to 1990 due to new installations with the capacity to manufacture hydrogen gas. Emissions were lower in 2020 due to effects of the pandemic. Emissions are assumed to increase slightly until 2040 compared to 2018, see Table 5.7.

Table 5.7 Historical and projected emissions of greenhouse gases from fugitive emissions (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	0.3	0.4	0.9	1.0	1.0	1.0	165%	170%
Methane	0.1	0.04	0.06	0.06	0.06	0.06	-25%	-25%
Nitrous oxide	0.001	0.001	0.001	0.001	0.001	0.001	4%	4%
Total emissions	**0.4**	**0.5**	**0.9**	**1.0**	**1.0**	**1.0**	**128%**	**133%**

5.3.5 Industrial processes and product use

The industrial processes and product use sector contributes with greenhouse gas emissions from the materials used in industrial processes and the use of solvents and other products, including the use of fluorinated greenhouse gases.

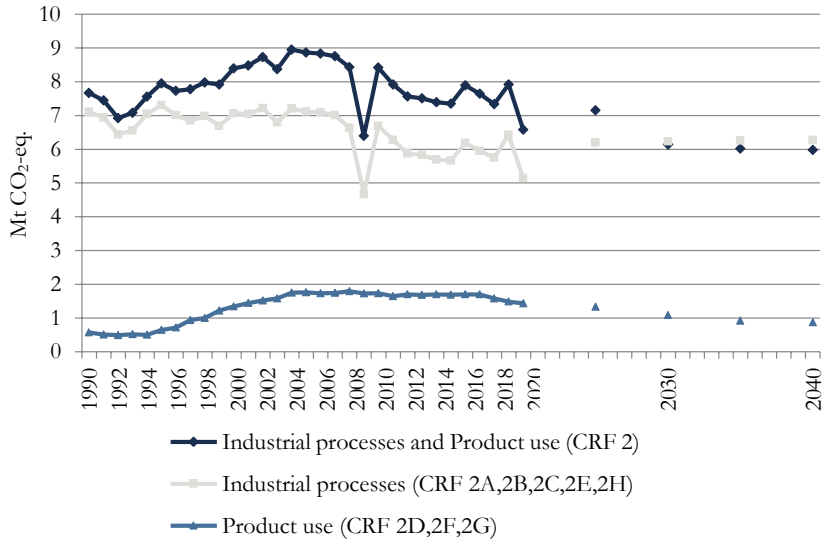

Figure 5.6 Historical and projected emissions of greenhouse gases from industrial processes and product use.

Greenhouse gas emissions from industrial processes and product use are projected to decrease slightly to 2040, see Table 4.8 and Figure 4.6. This decrease is due to a decrease in emissions of fluorinated greenhouse gases but also a decrease in emissions from carbon dioxide are expected after 2030.

Carbon dioxide emissions are expected to decrease to 2040. The decrease is mainly due to a decrease in emissions from the metal industry until 2040 and especially after 2030, due to a shift to fossil-free technology in a part of the iron and steel industry. The emissions of carbon dioxide from the mineral industry are expected to slightly increase until 2040 compared with 1990 due to a projected continuing increase in constructing new buildings. The emissions of greenhouse gases from chemical industry are assumed to remain around the same level as in 2019. The emissions from fuel combustion in industry are reported in the energy.

Emissions of fluorinated greenhouse gases are expected to decrease to 2040 due to a ban on their use that resulted from EU regulations.

Table 5.8 Historical and projected emissions of greenhouse gases from industrial processes and product use sector (million tonnes CO_2-equivalents).

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	6.0	5.3	6.2	5.4	5.4	5.4	-10%	-10%
Methane	0.03	0.01	0.01	0.01	0.01	0.01	-65%	-66%
Nitrous oxide	1.0	0.2	0.2	0.2	0.2	0.2	-78%	-79%
Fluorinated greenhouse gases	0.7	1.0	0.8	0.5	0.4	0.4	-21%	-48%
Total emissions	**7.7**	**6.6**	**7.2**	**6.1**	**6.0**	**6.0**	**-20%**	**-22%**

5.3.6 Domestic transport

Emissions from domestic transport, especially from road transport, are projected to decrease to 2040 for several reasons, see Table 5.9, Table 5.10 and Figure 5.7. The decrease in emissions is mainly due to large reductions from cars. One reason for this decrease is an ongoing improvement of energy efficiency due to EU CO_2 requirements that limits the emissions from new cars, heavy duty and light-duty lorries. Another reason for the decrease is a greater use of biofuels. It is in particular the obligatory low-blend of biofuels in petrol and diesel by which suppliers must reduce carbon dioxide emissions.

Emissions from domestic aviation have decreased in recent years, mostly due to higher efficiency. In the projection, travel is assumed to increase from today's level over the entire projection period, resulting in increasing emissions. Emissions from domestic navigation have varied between 0.5 and 0.7 Mt CO_2-eq. Emissions are assumed to be around 0.7 million tonnes until 2040. Emissions from railways are low during the projection period.

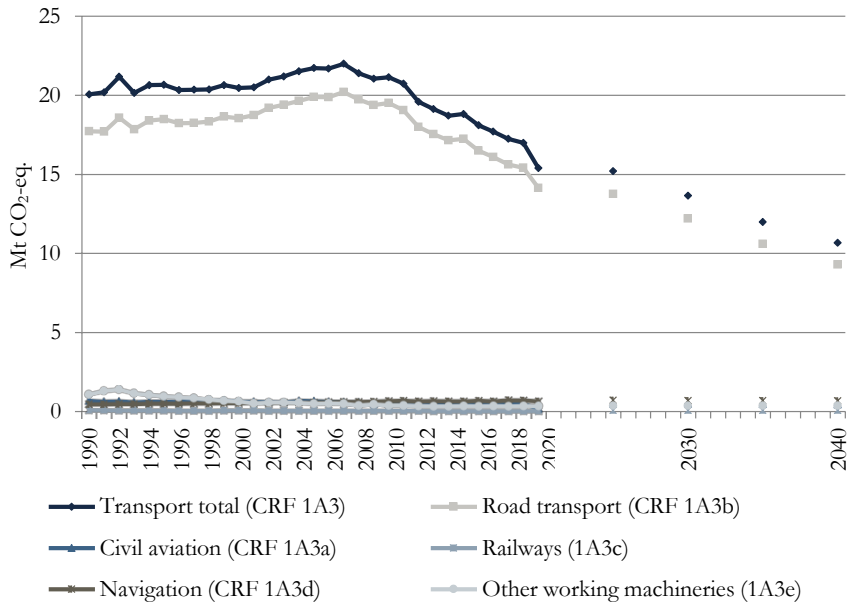

Figure 5.7 Historical and projected emissions of greenhouse gases from the domestic transport sector.

Table 5.9 Historical and projected emissions of greenhouse gases from different transport modes (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Road transportation	17.7	14.1	13.7	12.2	10.6	9.3	-31%	-48%
Civil aviation	0.7	0.2	0.5	0.5	0.5	0.5	-28%	-34%
Navigation	0.5	0.7	0.7	0.7	0.7	0.7	50%	44%
Railways	0.1	0.04	0.06	0.06	0.06	0.07	-43%	-36%
Other	1.1	0.4	0.4	0.4	0.4	0.4	-67%	-67%

Table 5.10 Historical and projected emissions of greenhouse gases from domestic transport (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	19.7	15.2	14.9	13.4	11.7	10.4	-31%	-46%
Methane	0.2	0.05	0.04	0.04	0.04	0.04	-78%	-79%
Nitrous oxide	0.2	0.2	0.2	0.2	0.2	0.2	24%	15%
Total emissions	**20.0**	**15.4**	**15.2**	**13.6**	**12.0**	**10.7**	**-31%**	**-46%**

5.3.7 Waste

Methane emissions from landfill are projected to decrease by 96 % to 2040 compared to 1990, see Table 4.11 and Figure 4.8. This decrease is mainly due to a ban, from 2002, on depositing combustible materials in landfills and a ban, from 2005, on depositing organic materials in landfill. Furthermore, a tax on depositing waste in landfill was introduced in 2000.

Emissions of carbon dioxide from waste incineration and nitrous oxide from wastewater treatment are low and are expected to remain stable during the entire projection period. However, emissions of nitrous oxide and methane from biological treatment of solid waste are expected to increase slightly during the period, due to increased production of biogas.

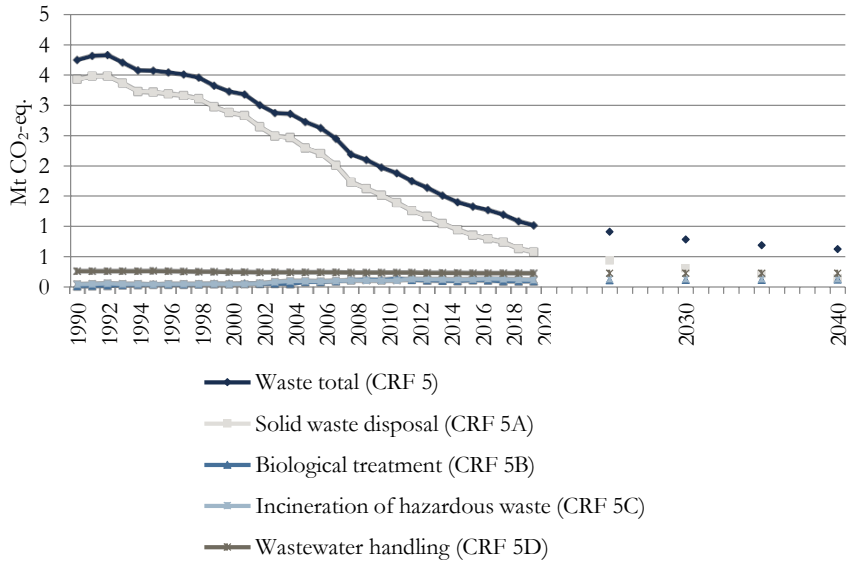

Figure 5.8 Historical and projected emissions of greenhouse gases from the waste sector.

Table 5.11 Historical and projected emissions of greenhouse gases from the waste sector (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	0.04	0.1	0.1	0.1	0.1	0.1	189%	189%
Methane	3.5	0.7	0.6	0.4	0.3	0.3	-88%	-92%
Nitrous oxide	0.2	0.2	0.2	0.2	0.2	0.2	0%	0%
Total	**3.7**	**1.0**	**0.9**	**0.8**	**0.7**	**0.6**	**-79%**	**-83%**

5.3.8 Agriculture

Greenhouse gas emissions from agriculture have decreased since 1990, mainly due to improved production efficiency and fewer cattle. This in turn has led to lower methane emissions from the digestion process in ruminant animals and reduced emissions of methane and nitrous oxide from manure. Emissions of nitrous oxide from agricultural land have also declined as a result of reduced cereal acreage, reduced use of fertilizers, reduced nitrogen leaching and a transition from solid manure to slurry management.

Emissions from agriculture are estimated to decrease as a result of a continuously declining cattle population, see Table 5.12, Table 5.13 and Figure 5.9. The reduced numbers of dairy cows until 2040 are primarily a result of increased productivity, product pricing mechanisms and continuous adaptation to EU agricultural policy regulations.

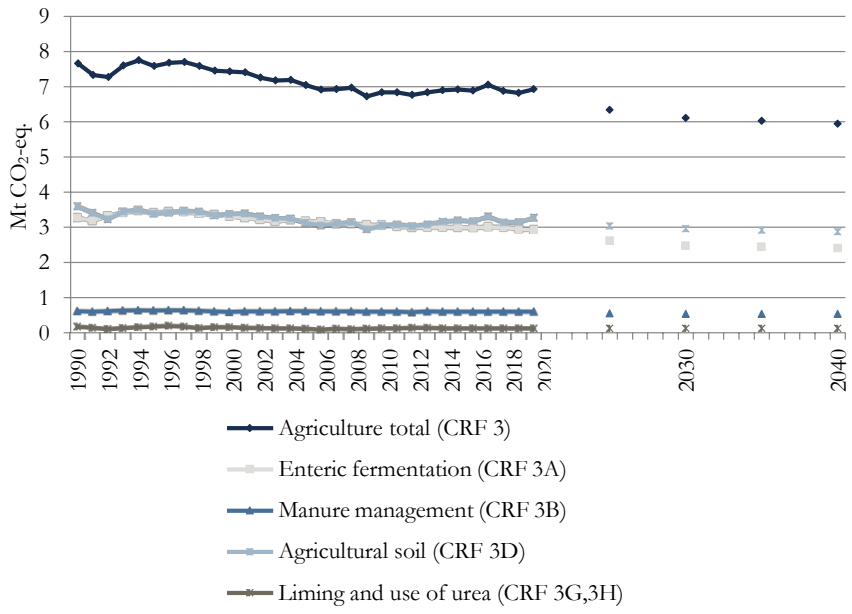

Figure 5.9 Historical and projected emissions of greenhouse gases from agriculture.

Table 5.12 Historical and projected emissions of greenhouse gases from agriculture per gas (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Methane	3.5	3.2	2.9	2.7	2.7	2.6	-23%	-25%
Nitrous oxide	4.0	3.6	3.3	3.3	3.2	3.2	-18%	-20%
Carbon dioxide	0.2	0.1	0.1	0.1	0.1	0.1	-29%	-29%
Total emissions	**7.7**	**6.9**	**6.3**	**6.1**	**6.0**	**5.9**	**-20%**	**-22%**

Table 5.13 Historical and projected emissions of greenhouse gases from agriculture (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Enteric fermentation	3.3	2.9	2.6	2.5	2.4	2.4	-24%	-27%
Manure management	0.6	0.6	0.6	0.5	0.5	0.5	-12%	-12%
Agricultural land	3.6	3.3	3.0	3.0	2.9	2.9	-18%	-20%
Liming/Use of urea	0.2	0.1	0.1	0.1	0.1	0.1	-29%	-29%
Total emissions	**7.7**	**6.9**	**6.3**	**6.1**	**6.0**	**5.9**	**-20%**	**-22%**

5.3.9 Land use, Land Use Change and Forestry (LULUCF)

The LULUCF sector contributed to the total greenhouse gas budget with an annual net removal of greenhouse gases in Sweden during the period 1990–2020. Net removals for LULUCF are expected to increase slightly to 2040, see Table 5.14, Table 5.15 and Figure 5.10. This trend is mainly due to a increase in removals from forest land. The projections for removals of carbon dioxide from forest land is based on the assumption that the current harvest intensity (2015-2019) persist over time and a climate effect which gives a positive effect on the annual gross increment.

The projections are based on a number of assumptions which are characterised by uncertainties. A sensitivity analysis has been performed for the LULUCF projection, simulating forest land using the same settings but without the climate effect which gives a positive effect on the annual gross increment. The net removals for the LULUCF-sector are instead projected to decrease to 2040. See also section 5.6.

Net emissions from cropland have varied during the period 1990–2020. The emissions are projected to decrease slightly based on a projected slight decrease in area and the average net emissions per area for the latest ten years. Net emissions from settlements are caused by felling due to

urbanisation and the establishment of power lines and forest roads. These emissions are projected to be at the same level for the entire projection period as the average for the last ten years. The carbon stock changes in grassland and wetlands were small during the period 1990–2020 and are projected to stay low during the projection period.

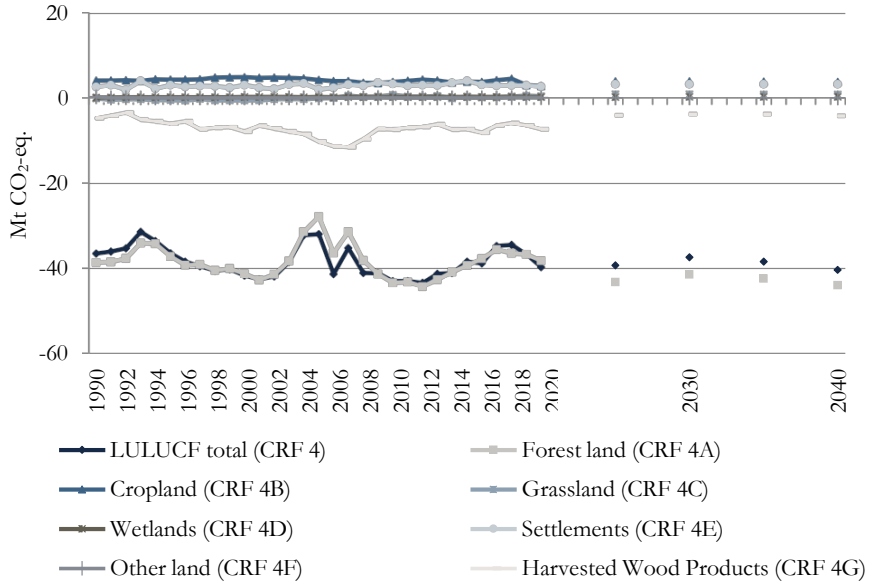

Figure 5.10 Emissions (+) and removals (-) from the LULUCF sector and its subcategories in Mt CO2-equivalents per year.

Table 5.14 Historical and projected emissions (+) end removals (-) of greenhouse gases from LULUCF (million tonnes CO_2-equivalents) [56]

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Forest land	-38.7	-38.3	-43.2	-41.5	-42.4	-44.0	7%	14%
Cropland	4.1	2.8	3.9	3.8	3.8	3.7	-7%	-10%
Grassland	-0.1	0.3	0.8	0.8	0.8	0.7	996%	968%
Wetlands	0.1	0.2	0.2	0.2	0.2	0.3	181%	216%
Settlements	2.6	2.6	3.2	3.2	3.2	3.2	23%	23%
Other land	0.2	-0.02	-0.005	-0.005	-0.005	-0.005	-102%	-102%
HWP	-4.8	-7.4	-4.1	-3.9	-3.8	-4.3	-20%	-11%
Total net removals	**-36.6**	**-39.8**	**-39.3**	**-37.4**	**-38.4**	**-40.4**	**2%**	**10%**

[56] The projections are based on historical data in National Inventory Report submission 2021, For this Eighth National Communication the presented historical emissions and removals of greenhouse gases are based on National Inventory Report submission 2022. The historical net emissions and removals for the LULUCF-sector were recalculated in the inventory submission 2022. This means that the projections are not fully consistent with the historical data in this table.

Table 5.15 Historical and projected emissions (+) end removals (-) of greenhouse gases from LULUCF per gas (Mt CO_2-eq.)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Carbon dioxide	-38.3	-41.5	-37.4	-40.9	-38.9	-41.9	2%	10%
Methane	0.5	0.4	0.4	0.4	0.4	0.4	-9%	-11%
Nitrous oxide	1.2	1.3	1.1	1.1	1.1	1.1	-5%	-6%
Total net removals	**-36.6**	**-39.8**	**-39.3**	**-37.4**	**-38.4**	**-40.4**	**2%**	**10%**

5.3.10 International transport

Emissions from bunkers for international transport are projected to increase to 2040, mainly due to increased emissions from international aviation, see Table 5.16 and Figure 5.11. This increase is explained by an expected increase in private consumption during the projection period, resulting in increased number of passengers.

The increased use of fuel for international navigation is due to an increase in passenger traffic, growth in exports of goods and increased refuelling in Sweden. The projection is based on the assumption that transport volumes will increase as transportation becomes more efficient. This leads to projected emissions from international navigation at about the same level during the projection period. The number of international bunkers counted in Sweden also depends largely on where international ships and airplanes choose to refuel.

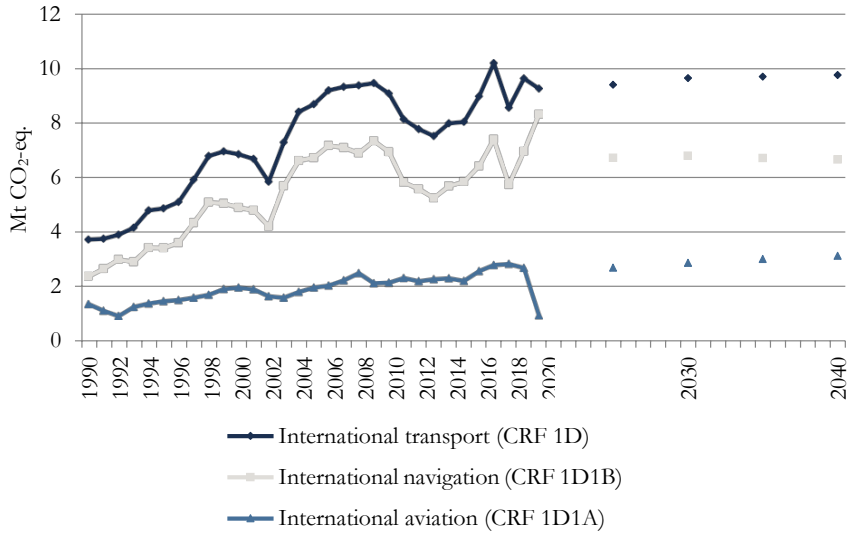

Figure 5.11 Historical and projected emissions of greenhouse gases from international bunkers.

Table 5.16 Historical and projected emissions of greenhouse gases from international bunkers (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Navigation	2.4	8.3	6.7	6.8	6.7	6.6	186%	180%
Aviation	1.4	0.9	2.7	2.9	3.0	3.1	111%	130%
Total emissions	**3.7**	**9.3**	**9.4**	**9.6**	**9.7**	**9.8**	**159%**	**162%**

5.4 Sensitivity analysis

Sensitivity calculations were produced by varying some parameters in the energy sector (incl. transport) and some in the transport sector. Aggregated for all sectors, the sensitivity calculations show that the emission level in 2040 may be 40 to 46 % lower than 1990 levels, depending on the sensitivity projection, see Table 5.17. However, this does not include uncertainty in the calculations, which may expand the percentage span between the projections.

Table 5.17 Historical and projected total emissions of greenhouse gases for different projections in the sensitive analysis excl. LULUCF (million tonnes CO_2-equivalents)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Projections WEM	71.4	46.3	47.0	43.2	41.0	39.4	-39%	-45%
Energy sector including transport								

Projection "Lower fossil fuel prices"			48.1	43.9	42.8	42.5	-38%	-40%
Projection "Lower GDP"			46.9	42.9	40.4	38.6	-40%	-46%
Transport sector								
Projections "Lower mileage"			46.9	42.9	40.6	38.9	-40%	-45%

Two sensitivity projections were calculated for the energy sector including transport: one projection with 30 % lower fossil fuel prices and one with 30 % lower economic growth than in the reference projections. Lower fossil fuel prices also result in higher economic growth than in the reference projections. All other assumptions are identical to the assumptions in the reference projection.

Results of the sensitivity projections show that the projection with lower fossil fuel prices results in higher emissions in 2040 compared to the reference projection, as expected. A lower fossil fuel price decreases the incentive to replace fossil fuels and increase energy efficiency in industry, giving higher emissions in the transport sector.

The projection with lower economic growth than in the reference projection results in lower emissions in the energy and transport sectors compared to the reference projection. The main reason for the decreased emissions is a lower energy demand, due to lower production in the industrial sector. Lower economic growth leads to a lower demand for the transportation of both goods and people.

For the road transportation sector, a projection with lower mileage were performed separately. All other assumptions are identical to the ones in the reference projections. In the projection, mileage is assumed to be 10 % lower in 2040 compared to the reference projection. Results show that the projections with lower mileage result in reductions in emissions.

5.4.1 Sensitivity calculations for the LULUCF-sector

The projections for the LULUCF-sector is based on a number of assumptions which are characterised by uncertainties. The result should be interpreted with that in mind. A sensitivity projection has been calculated for the LULUCF sector. In the reference projections a positive climate effect which gives a positive effect on the annual gross increment by 21 % 2070-

2100 compared to 1970-2000 was included for forest management and HWP. In the sensitivity projections no positive climate effect is included. All other assumptions are identical to the ones in the reference projection.

The calculations of the sensitivity projections show that the projection with no climate effect results in a decrease in net removals until 2040 instead of an increase as in the reference projection. The emissions are projected to be around 30 million tonnes in 2040 which is about 11 million tonnes lower compared to the reference projection with climate effect.

Table 5.18 Historical and projected emissions and removals of greenhouse gases for different projections in the sensitive analysis for the LULUCF sector (Mt CO_2-eq.)

	1990	2020	2025	2030	2035	2040	1990-2030	1990-2040
Total LULUCF with climate effect	-36.6	-39.8	-39.3	-37.4	-38.4	-40.4	2%	10%
Total LULUCF without climate effect	-36.6	-39.8	-35.4	-30.3	-30.7	-29.1	-17%	-20%

5.5 Comparison with the Seventh National Communication

The projections presented in 2018 in Sweden's Seventh National Communication (NC7) were based on the inventory submission of 2017. The projections presented in this report are based on the inventory submission of 2022.

The projections presented in 2018 in Sweden's Seventh National Communication and Third Biennial Report (BR3) showed reductions in total greenhouse gas emissions of 36 % between 1990 and 2030. The projections set out here, in the Eighth National Communication (NC8) and the Fifth Biennial Report (BR5), uses partly different assumptions and assessments based on trends over the last few years, see Table 5.18. The new projections show a decrease in total greenhouse gas emissions of 39 % between 1990 and 2030. A comparison of percentage changes in emissions overall and by sector is shown in Figure 5.12.

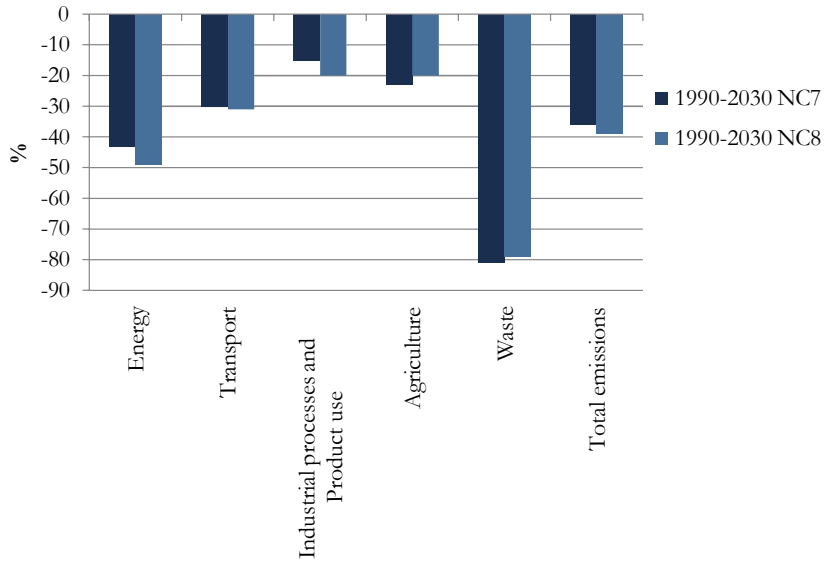

Figure 5.12 Percentage changes in emissions between 1990 and 2030 respectively as projected in NC7 and NC8, overall and by sector.

The projections presented here indicate a larger reduction of emissions by 2030 for some sectors compared with those in NC7. The difference is mainly due to differing assumptions, for instance regarding fossil fuel prices, and assumptions based on the trend over the last few years.

Table 5.19 Key assumptions in the Seventh National Communication and Eighth National Communication

	NC7	NC8
	2013-2035	**2015-2035**
GDP (annual change %)	2.28	1.72
	2030 *(2013 prices)*	**2030** *(2016 prices)*
Price of crude oil (USD/barrel)	117	89
Price of coal (USD/tonne)	110	86
Price of natural gas (USD/MBtu)	12	6
Emissions trading (Euro/tonne CO_2)	42	30
Electricity prince (SEK/kWh)	0.53	0.33
Electricity certificates (new renewable electricity compared with 2012)	28.4 TWh by 2020	28.4 TWh by 2020

5.6 Assessment of aggregate effects of policies and measures

This section describes the overall effects of the instruments introduced since 1990 and reported and quantified in Chapter 4. Table 5.20 presents the aggregate effects of the instruments implemented, for which estimates have been made.

Table 5.20 Estimated effects of economic instruments implemented, by sector (million tonnes CO_2 equivalent/ year) (summary of account in Chapter 4)

Sector	2015	2020	2025	2030
Electricity and district heating	18	19	15	6
Residential and service sector	1.4	0.4	1.1	1
Industry	0	0.3	-	0.5 (3.5*)
Transport	6	9	9.4	16.6
Waste	1.7	1.9	1.9	N.E.
Total	**27.1**	**30.6**	**27.4**	**24.1 (27.1*)**

*Depending on the success of BECCS.

Further, the table includes only the policies and measures for which effects per year have been estimated. Other policies and measures presented in chapter 4 also affect the emissions.

5.7 Progress towards targets under the UNFCCC, the Kyoto protocol and the EU

Under the UNFCCC, the EU and its Member States committed to achieving a joint quantified economy-wide greenhouse gas emission reduction target of 20 per cent below the 1990 level by 2020 ("the Cancun pledge"). It is therefore a joint pledge with no separate individual targets for Member States under the Convention. The UK remains part of the joint EU 2020 target together with the 27 EU Member States.

The EU has jointly committed to its UNFCCC target and implemented it internally through EU legislation in the 2020 EU Climate and Energy Package. In this package, the EU introduced a clear approach to achieving the 20 % reduction in total GHG emissions from 1990 levels, by dividing the effort between the sectors covered by the EU Emissions Trading System (EU ETS) and the sectors under the Effort Sharing Decision (ESD). Binding national targets were set for Member States under the Effort Sharing Decision. The achievement of EU internal compliance under the 2020 Climate and Energy Package including the national targets under the ESD is not subject to the UNFCCC assessment of the EU's joint commitment under the Convention.

The EU has substantially overachieved its reduction target under the Convention, which means that also its Member States and the UK have fulfilled their emission reduction obligations. As stated in the 2022 EU GHG inventory submission to the UNFCCC, total GHG emissions, excluding LULUCF and including international aviation, decreased by 34 % in the EU-27 + UK compared to the base year 1990 or 1.94 billion tons of CO_2-eq. (For more information see Sweden's Fifth Biennial Report chapter 2) In addition to the Convention target, the EU and its Member States have a commitment under the Kyoto protocol for the period 2013–2020.

For the EU as a whole, the Kyoto commitment is the same as the Convention target except that it also includes LULUCF (excluding aviation emissions). This means that the Swedish part and the EU jointly commitment is the same as under the Convention (-17% under ESD). Together with the ESD target Sweden will account for the mandatory parts in article 3.3 and 3.4 in the Kyoto Protocol for LULUCF. Sweden has chosen commitment period accounting. The Swedish commitment under the Kyoto Protocol is explained in the Swedish Initial report for the second commitment period.

5.7.1 Sweden's commitment according to the Effort Sharing Decision

Under the EU Climate and Energy Package, greenhouse gas emissions from the EU are to be reduced by 20 % compared with 1990 by 2020. Emissions from installations included in the EU Emissions Trading System (EU ETS) are to fall by 21 % between 2005 and 2020 for the EU as a whole. Emissions not covered by the trading system are to be reduced in line with the Effort Sharing Decision (ESD) (EU Decision 406/2009/EC). For Sweden, this decision means that emissions must decrease by 17 % between 2005 and 2020, in line with a target emissions trajectory. This means that the ESD emissions must decrease linearly from 41.7 Mt in 2013 to 36.1 Mt in 2020[57].

Furthermore, Sweden can use credits from international project activities to meet the target. The annual use is restricted to 3 % of 2005 emissions[58], which equals 10.9 million tonnes for the entire period 2013–2020. In addition, 1 % of 2005 emissions can be used in international projects fulfilling certain requirements. This corresponds to 3.6 million additional

[57] In 2017 the target for 2020 was adjusted from 37.2 to 36.1 million, because the historical emissions are lower due to methodological changes. Commission Decision 2017/1471 amending decision 2013/162/EU to revise Member States' annual emissions allocations for the period from 2017 to 2020.

[58] According to National Inventory Report submission 2012

tonnes for the entire period 2013–2020. The maximum possible annual use of international credits thus amounts to a maximum of 1.8 million tonnes. A Member State may transfer up to 5 % of their allocated Annual Emissions Allocations (AEA) for a given year to other Member States. Furthermore, 5 % of the own AEAs can be carried over from the following year, and if there is a surplus of allowances it can be banked to following years or transferred to other Member States.

For the years 2013-2020, Sweden's ESD-emissions have been lower than the ESD-targets, see Figure 5.13. The surplus amount of AEAs was over 5 million tonnes per year compared to the Swedish ESD target, see Table 5.21. The surplus for 2013-2019 was cancelled. The government has proposed to the Swedish Parliament that also the surplus for 2020 should be deleted. Compliance for 2020 is planned to be performed in 2023.

The target for Sweden is set to 36.1 Mt CO_2-eq. in 2020 (EU Decision C (2013)1708). ESD emissions were 29.4 million tonnes in 2020. The overachievement in 2020, compared to the Swedish target, is estimated to be over 6 million tonnes, without the use of international credits. Note that these figures are preliminary and compliance are planned to be performed in 2023 after review.

Table 5.21 Sweden's historical and projected emissions of greenhouse gases (based on National Inventory Report submission 2022) presented as total emissions, ETS emissions, CO_2-emissions from domestic aviation and emissions covered by the Effort Sharing Decision (ESD) in relation to ESD target (scope 2013 - 2020, excl. aviation). (Million tonnes CO_2-equivalents)

	2013	2014	2015	2016	2017	2018	2019	2020	2030	2040
Total emissions	55.8	53.9	54.1	53.7	53.1	52.2	50.8	46.3	43.2	39.4
ETS emissions	20.1	19.3	19.2	19.7	19.6	19.9	18.8	16.7	16.6	16.5
Domestic aviation	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.5	04
ESD emissions[59] [60]	35.2	34.1	34.4	33.4	32.9	31.8	31.6	29.4	26.1	22.5

[59] ESD emissions include emissions that are covered by the Effort Sharing Decision and are calculated as total emissions excl. LULUCF minus CO_2 emissions from domestic aviation minus emissions from EU ETS.

[60] Historical emissions are presented according to National Inventory Report submission 2022. The ESD emissions for compliance are based on relevant submission and the ESD-emissions in 2013 according to submission 2016 were 35.3 Mt CO_2-eq. which means a surplus of 6.4 million AEAs deleted. Emissions in 2014 were 34.5 Mt CO_2-eq. (sub 2016) a surplus of 6.5 million AEAs was deleted. Emissions in 2015 were 33.9 Mt CO_2-eq. (sub2017), a surplus of 6.5 million AEAs deleted. Emissions in 2016 were 32.6 Mt CO_2-eq. (sub2018), a surplus of 7.2 million AEAs was deleted. Emissions in 2017 were 32.5 Mt CO_2-eq. (sub2019), a surplus of 5.3 million AEAs was deleted. Emissions in 2018 were 31.4 Mt CO_2-eq. (sub2020), a surplus of 5.8 million AEAs was deleted. Emissions in 2019 were 31.7 Mt CO_2-eq. (sub2021), a surplus of 5.0 million AEAs was deleted. Emissions in 2020 were 29.4 Mt CO_2-eq. (sub.2022).

ESD target[61]	41.7	41.0	40.4	39.8	37.8	37.2	36.7	36.1		

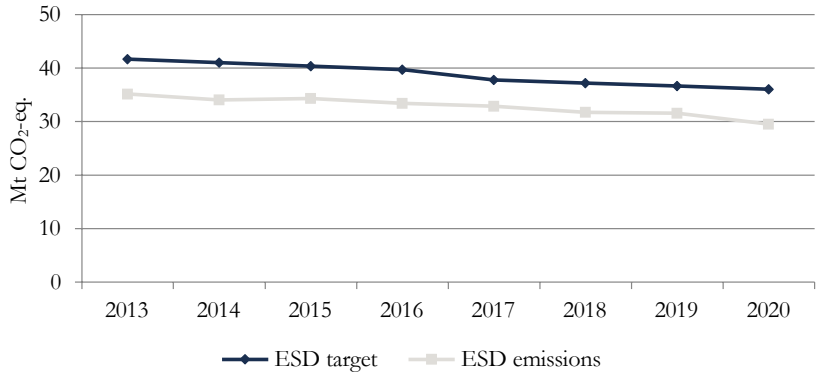

Figure 5.13 The Swedish ESD targets and ESD emissions 2013-2020 (submission 2022). (

5.8 Target fulfilment in relation to domestic targets

According to the 2009 climate policy resolution of the Swedish Parliament, the Swedish target for emissions that are not included in the EU ETS, must be reduced by 40 %, or around 20 Mt CO_2-eq., between 1990 and 2020[62], of which one third can be reduced through emission reductions in other countries.

In 2020, the national target will preliminarily be 28.7 Mt CO_2-eq.. Preliminary data indicate that emissions will decrease to around 29.4 Mt CO_2-eq. and there will be a gap to target of approximately 0.7 Mt CO_2-eq. in 2020. Note that numbers are preliminary until 2022–2023, when a definitive calculation can be done, based on reviewed inventory data. If a gap to the target still remains, it can be closed by emission reductions in other countries.

In June 2017, the Parliament in Sweden adopted a climate policy framework including targets for 2045. By 2045, Sweden is to have no net emissions of greenhouse gases into the atmosphere and should thereafter achieve negative emissions. Emissions outside the EU ETS should be at least 63 % lower by 2030 than emissions in 1990, and at least 75 % lower by 2040. To achieve

[61] According to the revised targets in EU decision C(2013) 1708 on determining Member States' annual emission allocations for the period from 2013 to 2020 pursuant to Decision No 406/2009/EC.

[62] This was equivalent to a decrease of 33 % between 2005 and 2020 when the target was adopted in 2009 (EU ETS scope 2008–12). In the third period of EU ETS, 2013–2020, the scope of the EU ETS was extended to include additional sectors. The target was consequently adjusted corresponding to emissions in the transferred sectors.

these targets, no more than 8 and 2 percentage points, respectively, of the emissions reductions may be realised through supplementary measures such as increase in carbon sinks, verified emissions reductions through investments in other countries and carbon capiture and storage of biogenic carbon dioxide. A reduction of 63 % means that the target is preliminary set to 17 Mt CO_2-eq. in 2030. The emissions outside EU ETS are projected to decrease to 26 Mt CO_2-eq. by 2030, which indicate a gap of around 9 Mt CO_2-eq. In addition, emissions from domestic transport are to be reduced by at least 70 % by 2030, compared to 2010. Emissions from domestic transport are projected to decrease by 35 % between 2010 and 2030.

5.9 References

Commission decision (EU) (2017/1471) of 10 August 2017 amending Decision 2013/162/EU to revise Member States' annual emission allocations for the period from 2017 to 2020

Commission Decision (2013/162/EU) of 26 March 2013 on determining Member States' annual emission allocations for the period from 2013 to 2020 pursuant to Decision No 406/2009/EC of the European Parliament and of the Council *(notified under document C(2013) 1708)*

Commission Implementing decision (2013/634/EU) of 31 October 2013 on the adjustments to Member States' annual emission allocations for the period from 2013 to 2020 pursuant to Decision No 406/2009/EC of the European Parliament and of the Council

EU Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020.

EU Decision C (2013) 1708 on determining Member States' annual emission allocations for the period from 2013 to 2020 pursuant to Decision No 406/2009/EC.

EU regulation No 525/2013 of the European parliament and of the Council Decision on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC

EU regulation No 2018/1999 of the European parliament and of the Council Decision on on the Governance of the Energy Union and Climate Action.

Govt. Bill 2020/21:1 *Budgetpropositionen för 2021.* Ministry of Finance

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National Inventory Report Sweden, Submission 2021.

National Inventory Report Sweden, Submission 2022.