Photo: IStock.com

# 5

# Projections and total effect of policies and measures

This chapter describes projections on Finnish greenhouse gas emissions and how the emissions are influenced by various factors such as energy consumption, production and policies and measures. Two projections are presented: ‘with measures’ and ‘with additional measures’, to show the projected greenhouse gas emissions from Finland up to 2035. The chapter also describes the total effect of policies and measures and supplementarity relating to Kyoto Protocol mechanisms. The chapter ends with a description of a sensitivity analysis of the projections and the methodology used in developing them.

# 5 Projections and total effect of policies and measures

## 5.1 Overview of WM and WAM projections

The projections presented in this chapter are based on data produced for the National Energy and Climate Strategy, the Medium-term Climate Change Policy Plan and the Climate Plan for the Land Use Sector. All three Government Reports were submitted to Parliament in 2022. For the reports, comprehensive modelling and assessments were conducted by experts from various research fields in an extensive project "Carbon neutral Finland 2035 – measures and impacts of the climate and energy policies" (HIISI project) financed by the Government's analysis, assessment and research activities. The analysis and results of the HIISI project have been complemented by other studies and updated with recent information and data.

The projections' starting point is 2020 (the most recent inventory year available in the annual greenhouse gas emission inventory submission to the UNFCCC in 2022). Policies and measures that have been implemented by July 2022 are included in the "With Measures" (WM) projection. The "With Additional Measures" (WAM) projection includes in addition policies and measures that are planned but not implemented before 1 August 2022. The policies and measures included in the WM and WAM projections, including estimated impacts on greenhouse gas emissions, are presented in more detail in Chapter 4. A pure "Without Measures Projection" (WOM) is not applicable for Finland's national circumstances and has therefore not been provided: mitigation policies and measures (such as measures related to energy efficiency improvements and use of renewable energy) have been implemented since the 1970s; any WOM projection created based on previous climate and energy strategies (e.g. 2016, 2013, 2008, or 2005) would therefore be very complicated and require significant effort, particularly in predicting the industrial structure. The technology development outlook in the energy sector would also be quite different without the current emissions trading system and binding renewable energy targets set by the EU. In other words, the outcome would be a quite arbitrary WOM projection. A more reliable and suitable approach is to compare current projections with WM projections from previous years. This is done in Section 5.4.

Most of the measures included in the WAM projection of the Seventh National Communication have been implemented and are now part of the WM projection. The most significant implemented new policy measures affecting future emissions compared to the Seventh National Communication are the group of measures promoting emissions-free and energy-efficient road transport, ban on energy use of hard coal, measures phasing out oil heating, and several new measures in agriculture, LULUCF and machinery.

The “With Additional Measures” projection (WAM) includes only a few measures additional to the WM projection, as the National Energy and Climate Strategy, the Medium-term Climate Change Policy Plan and the Climate Plan for the Land Use Sector have recently been approved, and most new measures are therefore adopted or implemented and included in the WM projection. The WAM projection includes the estimated impact of planned future measures regarding F-gases and in the agriculture and transport sectors. These WAM measures are described in Chapter 4.

Statistics Finland’s population forecast is used in the projections. The forecast, published in 2019, estimates that the population will increase only slightly from the current 5.53 million (2020) to 5.57 million in 2030. Based on the current development, Finland’s population will start decreasing in 2031. In 2050, the population will be some 100,000 lower than today. The average size of households will decrease slightly, while the number of households is expected to grow from 2.7 million to almost 2.9 million during the period. In this population forecast, the population is smaller and flattens out and starts to shrink, contrary to the forecast used in the projections for the Seventh National Communication, which anticipated continuous growth.

The economic outlook provided by the Ministry of Finance forms the basis for the estimate regarding the development of the Finnish economy in the near future, whereas longer-term development assumptions are based on the “What kind of expertise will Finland need in 2040?” report of Pellervo Economic Research PTT and Merit Economics[1], which has been complemented and updated in the HIISI project with industry-specific low-carbon strategies and recent energy and climate policies and measures. The macro-economic projections are described in the report “Macroeconomic scenarios: Carbon neutral Finland 2035 – measures and impacts of climate and energy policies”[2].

The Covid-19 pandemic and its assumed effects on the economy have been considered in the modelling. In contrast, the energy crisis following Russia’s unprovoked and unjustified invasion of Ukraine has not been included in the projections, as most of the modelling work was conducted before February 2022. For the LULUCF sector, the most recent results from the national forest inventory on a decline in tree growth were not yet available when the latest annual greenhouse gas inventory submission and the WM projection for the LULUCF sector were prepared (See Section 3.1). Thus, the estimates of carbon removals in the LULUCF sector will be re-evaluated in future.

1 Millaista osaamista Suomi tarvitsee 2040? What kind of expertise will Finland need in 2040? (in Finnish). PTT Reports 269. https://www.ptt.fi/julkaisut-ja-hankkeet/kaikki-julkaisut/millaista-osaamista-suomi-tarvitsee-vuonna-2040.html

2 Macroeconomic scenarios: Carbon neutral Finland 2035 – measures and impacts of climate and energy policies, Publications of the Government’s analysis, assessment and research activities 2021:65. http://urn.fi/URN:ISBN:978-952-383-295-4

According to the Ministry of Finance's forecast used in the modelling of the projections, economic growth would recover during 2021, but remain modest at first thereafter. During the 2020s, the world economy was expected to recover from the pandemic, which would also begin to impact Finland. It was assumed employment would recover during 2021, but towards the end of the decade, the shrinking working-age population would result in no new growth through labour input. Economic growth therefore depends on technological development and investment. By 2030, the projections expect technological development to generate growth of about 10 per cent compared to 2019 and about 20 per cent by 2040. Growth through capital is about half this. The average GDP growth rate is about 1.5 per cent, but per capita GDP growth will remain at 1.2 per cent. The conditions for economic growth will improve in the 2030s, so GDP growth may also be higher.

Regarding the forest industry, the growth assumptions are based on several sources, of which one of the most essential is the expertise of Pöyry Management Consulting, published in the "Suomen metsäteollisuus 2015–2035" report (Finland's forest industry 2015 to 2035)[3]. As some of the information is starting to be somewhat outdated, it has been updated and complemented by other sources that consist of two low-carbon roadmaps published in 2020 by the Finnish Forest Industries Federation and the Finnish Sawmills association and the expertise of Natural Resources Institute Finland (Luke). Pöyry bases its assessment on regional and global demand projections of pulp, paper, and wood products, the competitiveness of production facilities in Finland, and investment plans published by the forest industry. The Finnish Forest Industries' roadmap mainly follows the Pöyry report, but some production volumes have been updated in accordance with the association's more recent views. The Finnish Sawmills roadmap focuses only on the sawmill industry, whereas the experts from Natural Resources Institute Finland (Luke) provide valuable insights into recent changes in paper production capacities, capacity-derived production volumes, and how they will develop in the future. Compared to the figures used in the projections of the Seventh National Communication, the estimated production of printing and writing paper is 1.2 million tonnes lower in 2035, a total of only 2.1 million tonnes. The volume of sawmill products is also expected to be smaller than the previous estimate, whereas the production of other papers is expected to be 0.9 million tonnes higher than previously estimated, i.e. 6.1 million tonnes in 2035. The total volume of paperboard and corrugated cardboard is expected to be some 0.4 million tonnes lower in 2035 and that of market pulp 1.0 million tonnes higher than in the Seventh National Communication. The most remarkable difference between the new and previous projections is a new category, so-called new products, which consists of biomass-based biofuels, chemicals, bioplastics, and textiles, and which has the projected total volume in 2035 of 2 million tonnes.

3 Suomen metsäteollisuus 2015 – 2035 (Finland's forest industry 2015 to 2035) Final Report X304203, 19 January 2016, Pöyry Management Consulting, https://docplayer.fi/22653047-Suomen-metsateollisuus-2015-2035-19-tammikuuta-2016-loppuraportti-x304203.html

Table 5.1 shows a summary of the main assumptions of the WM projection for 2020 to 2035. The numerical values for key variables and assumptions are presented in Section 5.8.

**Table 5.1**
Assumptions of the WM projection

| Parameter | Trend 2020 to 2035 |
|---|---|
| GDP growth | 1.6 per cent annually |
| Structure of economy | Increasing share of services |
| Structure of industry | Less capital and energy intensive |
| Population growth | Increasing by 0.6 per cent in 10 years until to 2030, slowly decreasing after 2030 |
| Population structure | Ageing |
| Technology development | Gradual introduction of improved and more energy efficient technology, increased electrification |

# 5.2 "With Measures" projection

## 5.2.1 Total effects

Total emissions in the WM projection for 1990 to 2035 are shown in Figure 5.1 (total emissions without the LULUCF sector) and Table 5.2 (without and with the LULUCF sector).

Compared with the 1990 base year, the total greenhouse gas emissions without LULUCF are projected to be 58 per cent lower in 2030, and 65 per cent lower in 2035. The corresponding figures for $CO_2$ emissions are 62 and 69 per cent. $CH_4$ emissions are expected to continue to decline steadily, being 57 per cent lower in 2030 and 60 per cent lower in 2035 than in 1990. $N_2O$ emissions are projected to decrease slightly, being 32 per cent lower in 2030 and 34 per cent lower in 2035 than in 1990. The amount of emissions from F-gases is small and expected to decrease in the coming years.

**Figure 5.1**
Greenhouse gas emissions without LULUCF, with indirect $CO_2$, by gas according to the latest greenhouse gas emission inventory (1990 to 2020) and the WM projection (up to 2035), million tonnes $CO_2$ eq.

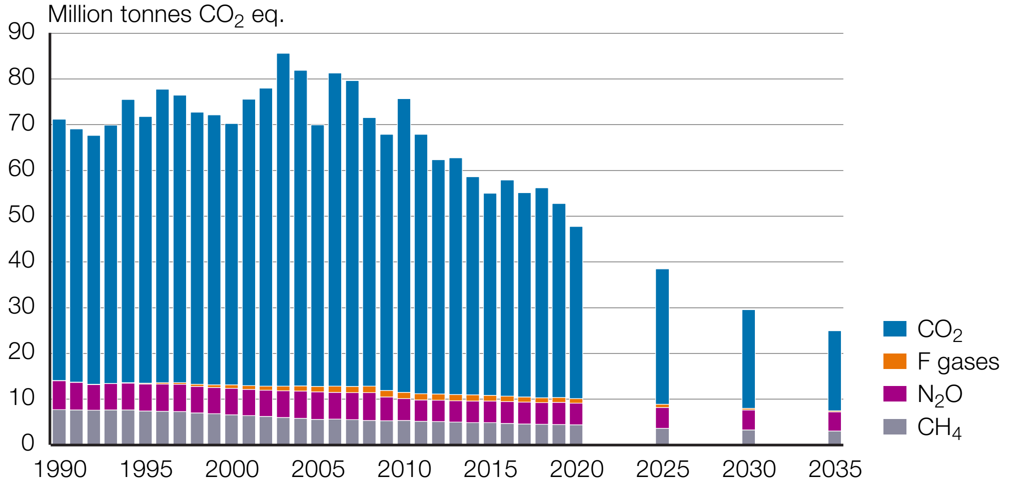


**Table 5.2**
Greenhouse gas emissions according to the most recent inventory data (1990 to 2020) and the WM projection (2025 to 2035)

| | GHG emissions and removals (kilotonnes $CO_2$ eq.) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| **Sector** | | | | | | | | | | |
| 1. Energy | 53,442 | 55,275 | 53,710 | 53,743 | 60,230 | 40,602 | 34,290 | 25,368 | 18,051 | 14,984 |
| 2. Industrial processes and product use | 5,398 | 5,064 | 5,988 | 6,765 | 6,159 | 5,704 | 5,124 | 5,763 | 4,649 | 3,471 |
| 3. Agriculture | 7,507 | 6,698 | 6,615 | 6,529 | 6,651 | 6,574 | 6,566 | 5,938 | 5,682 | 5,477 |
| 4. Land use, land-use change and forestry | −13,441 | −13,193 | −15,048 | −20,494 | −21,711 | −18,762 | −17,303 | −22,947 | −20,890 | −22,633 |
| 5. Waste | 4,669 | 4,596 | 3,817 | 2,812 | 2,562 | 2,092 | 1,736 | 1,383 | 1,152 | 984 |
| 6. Other | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Indirect $CO_2$ emissions | 166 | 133 | 108 | 88 | 70 | 55 | 66 | 41 | 31 | 26 |
| **Gas** | | | | | | | | | | |
| $CO_2$ emissions without net $CO_2$ from LULUCF[1] | 57,081 | 58,249 | 57,118 | 57,135 | 64,151 | 44,154 | 37,662 | 29,589 | 21,582 | 17,476 |
| $CO_2$ emissions with net $CO_2$ from LULUCF[1] | 39,976 | 41,468 | 38,574 | 33,308 | 39,361 | 22,576 | 17,571 | 3,868 | −2,095 | −7,975 |
| $CH_4$ emissions without $CH_4$ from LULUCF | 7,687 | 7,426 | 6,566 | 5,583 | 5,350 | 4,857 | 4,402 | 3,647 | 3,305 | 3,056 |
| $CH_4$ emissions with $CH_4$ from LULUCF | 9,219 | 8,876 | 7,912 | 6,788 | 6,325 | 5,653 | 5,168 | 4,443 | 4,151 | 3,942 |
| $N_2O$ emissions without $N_2O$ from LULUCF | 6,362 | 5,903 | 5,809 | 6,035 | 4,784 | 4,753 | 4,722 | 4,539 | 4,327 | 4,189 |
| $N_2O$ emissions with $N_2O$ from LULUCF | 8,494 | 8,040 | 7,959 | 8,164 | 6,888 | 6,773 | 6,744 | 6,517 | 6,268 | 6,122 |
| HFCs | 0 | 150 | 715 | 1,158 | 1,363 | 1,239 | 976 | 689 | 321 | 189 |
| PFCs | 0 | 2 | 3 | 4 | 3 | 1 | 2 | 1 | 1 | 1 |
| Unspecified mix of HFCs and PFCs | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| $SF_6$ | 52 | 37 | 26 | 22 | 22 | 22 | 19 | 27 | 29 | 31 |
| $NF_3$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Total (without LULUCF) | 71,016 | 71,632 | 70,130 | 69,849 | 75,602 | 54,971 | 47,716 | 38,452 | 29,534 | 24,916 |
| Total (with LULUCF) | 57,575 | 58,439 | 55,082 | 49,356 | 53,892 | 36,209 | 30,413 | 15,505 | 8,644 | 2,283 |
| **Total (without LULUCF, with indirect)** | **71,182** | **71,766** | **70,238** | **69,938** | **75,672** | **55,026** | **47,782** | **38,493** | **29,565** | **24,942** |
| **Total (with LULUCF, with indirect)** | **57,741** | **58,573** | **55,190** | **49,444** | **53,962** | **36,264** | **30,479** | **15,546** | **8,675** | **2,309** |

NO = not occurring

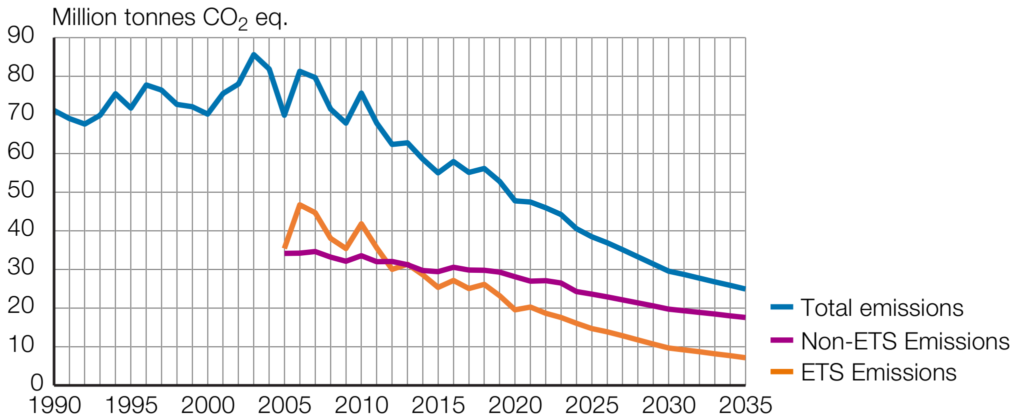
1) including indirect $CO_2$ emissions

The split of greenhouse gas emissions between the EU ETS sector and the non-ETS sector is illustrated in Figure 5.2. and Table 5.3. The historical ETS emissions correspond to the EU ETS scope in the emissions trading period from 2013 to 2020. The emissions in the EU ETS sector reached their peak in the mid-2000s and have declined since. In 2020, emissions in the EU ETS sector accounted for 41 per cent of the total greenhouse gas emissions, whereas the non-ETS sector accounted for 59 per cent. The ETS emissions are expected to decrease further in the future.

The emissions from the non-ETS sector have decreased steadily since 2005, and the decrease is expected to continue. In the WM projection, the emissions from the non-ETS sector in 2030 are 42 per cent, and in 2035, 49 per cent below the 2005 level when using the 2013–2020 scope for the EU ETS. Approximately 2.4 million tonnes $CO_2$ eq. non-ETS emissions in 2005 originate from sources that have since been moved to the ETS sector.

### Figure 5.2

The split of greenhouse gas emissions between the EU ETS sector and the non-ETS sector (2005 to 2020) based on the latest greenhouse gas inventory and the WM projection (until 2035). The development of the total emissions without the LULUCF sector is also presented.




### Table 5.3

Historical (2005 to 2020) and projected (2025 to 2035) greenhouse gas emissions in the Non-ETS and ETS sector and civil aviation based on the latest greenhouse gas inventory and the WM projection respectively

| | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|
| | 2005 | 2010 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | |
| Non-ETS | 34.2 | 33.6 | 28.1 | 23.6 | 19.7 | 17.6 |
| ETS | 35.5 | 41.9 | 19.6 | 14.7 | 9.7 | 7.2 |
| Civil aviation, $CO_2$ | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 |
| **Total emissions[1]** | **69.9** | **75.7** | **47.8** | **38.5** | **29.5** | **25.0** |

1) For the non-ETS and ETS split, the 2013 scope of EU ETS has been used

The development of total emissions regarding the number of inhabitants, primary energy use, and economic development is presented in Table 5.4. All indicators show a steady downward trend that continues in the WM projection. Today, the emissions are decoupled from both the GDP growth and energy use development and decline steadily.

**Table 5.4**
Greenhouse gas emission intensity based on the latest greenhouse gas inventory for 2010 to 2020 and the WM projection for 2025 to 2035

| | Historical | | | WM projection | | |
|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| Emissions per capita, tonnes $CO_2$ eq./capita | 14.08 | 9.56 | 8.70 | 6.92 | 5.31 | 4.49 |
| Emissions per GDP, kg $CO_2$ eq./EUR | 0.35 | 0.22 | 0.21 | 0.15 | 0.11 | 0.08 |
| Emissions per primary energy, tonnes $CO_2$ eq./MWh | 0.19 | 0.14 | 0.13 | 0.10 | 0.08 | 0.07 |

## 5.2.2 Sectoral emissions

### Energy

The energy sector is strongly affected by policy measures to reduce the emissions, enhance energy efficiency and increase the share of renewable energy sources. Both the supply and demand sides have faced significant changes in the last decade: part of the changes results from policy measures; part from technological development and the development of the energy and fuel markets. The transition is only half completed, and the emissions will decline further in the energy sector. As many of the changes involve or concern investments like power plants, the effects are robust and enduring.

The supply and demand situation in the Nordic-Baltic regional electricity market to which Finland belongs was a very important factor affecting the Finnish power supply's greenhouse gas emissions in the past. However, 85 per cent of the Finnish electricity production is emissions-free today and the positive development is expected to continue further, resulting in lower and less varying total greenhouse gas emissions for Finland.

In the WM projection, the most significant future changes in electricity and heat production are the start-up in 2022 of a new 1,600 MW nuclear power plant unit and the increase in the use of renewable energy sources and waste heat. Use of coal for energy will be banned from May 2029, and the use of peat will rapidly decrease in the 2020s due to high prices of emission allowances. All these changes reduce emissions.

Factors affecting the future energy demand are primarily energy efficiency measures, as well as the economic development and structural and technology changes within the industry. According to the WM projection, energy used to heat residential and service sector buildings will decrease, even though the volume of buildings is expected to increase continuously. The emissions from space heating are decreasing even faster than energy demand due to the increased use of renewable energy. District heat production from heat-only plants is expected to slightly increase its share at the expense of combined heat and power production, which has been struggling with feasibility. Low electricity prices in the 2010s and rising prices of emission allowances and fuel prices in the 2020s have challenged combustion-based heat and power production.

District heating, power generation, and industrial energy use are strongly affected by the EU ETS price, which makes the use of fossil fuel increasingly infeasible and with energy taxation, efficiently cuts emissions in these sectors. This trend will lead to increased electricity demand replacing some fossil fuel consumption, which is also reflected in the low-carbon roadmaps prepared by all major industries and sectors. In power generation, the emphasis is shifting from fossil fuels (especially coal and natural gas) and peat to renewables. In district heating and industry, fossil fuels are increasingly being replaced with renewables and waste heat recovery. In specific industrial sectors, electrolysis-based hydrogen production is also expected to take off, although the exact timing is difficult to predict. Carbon Capture in its various forms (such as CCS, CCSU, BECCS) could reduce emissions even further, but its timing is even more difficult to estimate, and it has therefore been omitted from the WM projection. Electrification is also true of other sectors like transport, due to which (with Finland's biofuel and other policies) the refining volumes of fossil oil are also decreasing.

The historical and projected emissions from the energy sector (excluding transport) in the WM projection are presented in Table 5.5. The emissions in the energy sector are mainly $CO_2$ emissions from the combustion of fossil fuels and peat. Most of the energy production, as well as the industrial energy use, belongs to the EU Emissions Trading System.

**Table 5.5**
Historical (1990 to 2020) and projected (2025 to 2035) greenhouse gas emissions from the energy sector (excluding transport) based on the latest inventory and the WM projection respectively

| | Historical | | | | | | | WM Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | | | | | |
| **Total emissions** | **41.3** | **44.0** | **41.6** | **40.9** | **47.6** | **29.7** | **23.8** | **17.3** | **11.5** | **9.6** |
| $CO_2$ | 40.8 | 43.2 | 40.9 | 40.0 | 46.7 | 29.0 | 23.2 | 16.6 | 10.9 | 9.0 |
| $CH_4$ | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 |
| $N_2O$ | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.5 | 0.4 | 0.4 | 0.4 | 0.3 |

Historically, emissions from space heating on site, as well as district heating, have varied according to heating demand (cold or warm winters). Likewise, emissions from condensing power have varied strongly, depending on the hydro situation in the Nordic-Baltic electricity market. In the projections, future years are assumed to be standard years (i.e. the long-term average plus the impact of climate change) with respect to heating demand and hydro levels. Consequently, the energy sector emissions are smoother in the future years (i.e. they have less interannual variability) of the WM projection than in the historical years.

The importance of $CH_4$ and $N_2O$ emissions within the energy sector is small. Less than 10 per cent of all $CH_4$ emissions in Finland come from incomplete combustion of fuel, which is mainly caused by fireplaces and small heating boilers. $CH_4$ emissions from power and heating plants are low.

Non-ETS emissions within the energy sector (excluding transport) are mainly the result of using fossil fuels for machinery and driers, space heating of buildings and industry outside the EU ETS. In the WM projection, the emissions from individual heating of residential and commercial buildings decrease from the recent 1.5 to 2 million tonnes $CO_2$ eq. to 0.6 million tonnes $CO_2$ eq. in 2030. The emissions from machinery are expected to decrease from their current level, i.e. 2.4 million tonnes $CO_2$ eq. to 1.6 million tonnes by 2030. The reasons for this favourable development are more efficient equipment (including some electric machinery) and a more efficient use of the equipment. The emissions from non-ETS industrial energy use remain at around the current level of 0.6 million tonnes $CO_2$ eq. in the WM projection at first and slightly decrease later, despite an increase in activity. The energy-related emissions from agriculture and forestry are 1.3-1.4 million tonnes $CO_2$ today, of which 0.8 million tonnes $CO_2$ eq. comes from machinery. By 2030, the energy-related emissions in agriculture and forestry are expected to decrease to 0.8 million tonnes $CO_2$ eq.

### Transport

The WM projection describes the likely evolution of GHG emissions from transport according to the best information available, and it includes, with a few exceptions, all measures for which there is a decision by August 2022 (a financing decision on measures requiring funding, or which are otherwise likely to occur). The WM projection contains the following themes, under which there are several measures: 1) replacing fossil fuels with alternative transport fuels; 2) improving the energy efficiency of vehicles; and 3) improving the energy efficiency of the transport system.

The effect of following recently implemented measures are not included in the WM projection because of difficulties in estimating the effects of the measures:

- Temporary reductions of taxable values of the company car benefit for battery electric vehicles and employer-provided charging for electric vehicles (long-term effects difficult to estimate)

– Changes to taxable values of employer-provided commuter tickets and bicycles (no assessment available).

A phenomenon with emissions reduction potential is the increase of remote work. Remote work is a new phenomenon created by the Covid-19 pandemic, which was unforeseeable in the NC7, but which is now included in the WM projection. During the pandemic in 2020, the number of remote workers more than doubled from pre-Covid numbers. This is assumed to be the maximum in the current regional and employment structure. The increase in remote work facilitates work and leisure coordination and mainly reduces emissions from transport as well, as it may reduce vehicle kilometres and the annual $CO_2$ emissions from passenger car traffic, with the reduction being approximately 61 kt $CO_2$ eq. in 2030 according to the WM projection.

According to the WM projection, GHG emissions from road transport will decrease significantly in the long term. Temporary changes in the biofuel distribution obligation in road transport will bring a short-term increase in emissions in 2022 and 2023. However, the tightening of the distribution obligation after a temporary reduction will create the most significant emissions reductions in the near future, while in the long term, the emissions reduction effect of vehicle fleet renewal will be highlighted. In particular, the EU Regulation[4] setting stricter $CO_2$ emission standards for cars and light commercial vehicles will contribute to a significant reduction in the WM projection, where domestic transport emissions will decrease by 49.4 per cent compared to 2005 emissions, i.e. close to the target of 50 per cent emissions reduction. The reduction in emissions takes place mainly in road transport. Compared to the current situation, emissions from water transport will also decrease slightly. Emissions from rail transport will remain the same. Greenhouse gas emissions from the transport sector are expected to decrease by 1.7 million tonnes from 2005 to 2020 and by 4.8 million tonnes from 2005 to 2030 (Table 5.6).

**Table 5.6**
Historical (1990 to 2020) and projected (2025 to 2035) greenhouse gas emissions from transport based on the latest greenhouse gas inventory and the WM projection, respectively

| | Historical | | | | | | | WM Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | | | | | |
| **Total emissions** | **12.1** | **11.3** | **12.1** | **12.9** | **12.7** | **10.9** | **10.4** | **8.1** | **6.6** | **5.4** |
| $CO_2$ | 11.8 | 11.1 | 11.9 | 12.7 | 12.6 | 10.8 | 10.3 | 8.0 | 6.5 | 5.3 |
| $CH_4$ | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $N_2O$ | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

4 2019/631/EU, adopted in 2019 and applied since 1 January 2020

### International bunkers

According to the most recent greenhouse gas emission inventory, the fuel consumption for international aviation was 11,873 TJ and for international marine transport 12,718 TJ in 2020. The Covid-19 pandemic has especially affected international aviation, as the corresponding fuel consumption prior to the pandemic in 2019 was 35,166 TJ for aviation bunkers and 13,563 TJ for marine bunkers.

According to the latest EUROCONTROL most-likely base scenario[5], the annual flight growth rate for Finland between 2019 and 2050 will be an average of 1.6 per cent. This scenario was prepared before the start of Russia's invasion of Ukraine, and it therefore does not take into account the current geopolitical situation, which greatly affects Finnish air transport. The annual growth rate by 2030 is estimated to be two per cent for international marine transport. Based on these assumptions and 2020 emissions, the total greenhouse gas emissions from bunker fuels are projected to be 2.2 million tonnes $CO_2$ eq. in 2030 (1.0 million tonnes $CO_2$ eq. from aviation bunkers and 1.2 million tonnes $CO_2$ eq. from marine bunkers). As the Covid-19 pandemic has impacted international transport and air transport especially strongly, the 2019 emissions can also be considered departure data. Using the emissions in 2019 as the basis, the total greenhouse gas emissions from bunker fuels are projected to be 4.4 million tonnes $CO_2$ eq. in 2030 (3.1 million tonnes $CO_2$ eq. from aviation bunkers and 1.3 million tonnes $CO_2$ eq. from marine bunkers). The most likely growth may be something between these two projections, although there are many uncertainties in the current geopolitical and market situation. The average of the above figures is therefore selected in Table 5.7.

These projected emissions of marine and aviation bunkers do not as such consider the impact of the measures presented in Section 4.4.3, which aim to improve energy efficiency and increase the use of alternative fuels.

**Table 5.7**
Historical (1990 to 2020) and projected (2025 to 2035) greenhouse gas emissions from international bunkers based on the latest greenhouse gas inventory and the WM projection, respectively

| | Historical | | | | | | | WM Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | | | | | |
| **Total emissions** | **2.9** | **1.9** | **3.1** | **2.9** | **2.3** | **2.9** | **1.9** | **3.0** | **3.3** | **3.6** |
| Aviation | 1.0 | 0.9 | 1.1 | 1.3 | 1.7 | 2.0 | 0.9 | 1.9 | 2.0 | 2.2 |
| Navigation | 1.9 | 1.0 | 2.1 | 1.6 | 0.7 | 0.9 | 1.0 | 1.1 | 1.3 | 1.4 |

5 EUROCONTROL Aviation Outlook 2050. Main Report April 2022; https://www.eurocontrol.int/sites/default/files/2022-04/eurocontrol-aviation-outlook-2050-main-report.pdf

## Industrial processes and other product use

The most important greenhouse gas emission sources in this sector are iron and steel, hydrogen, and cement production. The main factors affecting the development of emissions include changes in industrial production volumes and technology. In the WM projection, the growth of the industrial production volumes increases these emissions. Most of the emissions other than F-gases in this sector are part of the EU ETS, which is also the main measure for reducing process emissions. Other measures driving low-carbon technology investments in the manufacturing industry are increased funds for new technology investments and the reduction of the electricity tax.

In the WM projection, it is assumed that the industrial use of fossil fuels decreases thanks to the above measures. In carbon steel production, Finland's largest steel mill has disclosed plans to replace the existing two blast furnaces with electric arc furnaces and the use of carbon-free direct reduced iron (or sponge iron), which is produced in and imported from Sweden. However, the exact timing of this shift is still a significant uncertainty, but the assumption in the WM projection for the first blast furnace is by 2030 and for the second one by 2035. In the chemical industry, the share of fossil fuels will probably decrease due to the largest plastic producer's plans to replace the existing chemical cracking furnace with an electric cracking process. In the WM projection, the replacement will be implemented by 2030. The low-carbon roadmaps prepared by different industries also include additional but more high-level measures that are not yet finally decided but are expected to decrease industrial emissions further in the future.

The WM projection for F-gases includes the impacts of the EU regulation on F-gases[6] and the EC directive related to emissions from air-conditioning systems in motor vehicles[7]. Emissions from refrigeration and air-conditioning equipment are expected to decline because of the regulatory measures.

The main features of the F-gas regulation in cutting F-gas emissions are a phase down of HFCs that can be placed on the EU market, bans on the use of HFCs in certain applications and obligations related to leak checking and repairs, F-gas recovery and technician training.

Emissions from electricity distribution equipment have declined from the peak level because of the industries' voluntary actions. A steady increase of emissions is assumed in the future, but the peak level of emissions in the 1990s will not be reached. Restrictions forced by the EU regulation will have a decreasing effect on emissions from foam blowing and aerosols in the future. Emissions from other sources are expected to remain quite steady. Emissions from refrigeration and air-conditioning equipment account for more than 90

6 2014/517/EU

7 2006/40/EC

per cent of Finnish F-gas emissions, and the projected overall emissions trend is therefore declining.

Emissions from solvent and other product use are expected to remain at their present level in the WM projection. Historical and projected greenhouse gas emissions from industrial processes and other product use are presented by gas in Table 5.8.

**Table 5.8**
Historical (1990 to 2020) and projected (2025 to 2035) greenhouse gas emissions from industrial processes and other product use based on the latest greenhouse gas inventory and the WM projection respectively

| | Historical | | | | | | | WM Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | | | | | |
| **Total emissions** | **5.4** | **5.1** | **6.0** | **6.8** | **6.2** | **5.7** | **5.1** | **5.8** | **4.6** | **3.5** |
| $CO_2$ | 3.7 | 3.4 | 3.9 | 4.0 | 4.6 | 4.2 | 3.9 | 4.8 | 4.0 | 2.9 |
| $CH_4$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $N_2O$ | 1.7 | 1.5 | 1.4 | 1.6 | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 |
| F gases | 0.1 | 0.2 | 0.7 | 1.2 | 1.4 | 1.3 | 1.0 | 0.7 | 0.4 | 0.2 |

## Agriculture

In recent years, changes in the emissions from agriculture have been small. The projections were updated in 2022. In the WM projection, the total emissions from the agricultural sector are expected to decrease[8]. Emissions from the agricultural sector will decrease by around 0.9 million tonnes of $CO_2$ eq. by 2030 and 1.1 million tonnes of $CO_2$ eq. by 2035 (compared to the 2020 level) (Table 5.9).

The decline in livestock numbers and increase in use of feed additives will reduce methane emissions from cattle's digestion. In addition, the decrease in cattle and pig numbers will reduce emissions from manure processing and manure application. However, there is uncertainty about the future price and scale of adoption of feed additives and thus the emissions reduction from cattle.

Measures identified to reduce $N_2O$ emissions from organic soils will also affect the $CO_2$ emissions from the LULUCF sector. The increasing grass area in crop rotations and continuous use of catch crops will increase the emissions of plant residues but reduce nitrogen mineralisation emissions from mineral soils, leaving the net effect in the agricultural sector small per hectare but positive for the climate. Energy-related emissions related to agriculture are reported in the energy sector and are not included in Table 5.9.

8 Miettinen et al. (2022)

**Table 5.9**
Historical (1990 to 2020) and projected (2025 to 2035) greenhouse gas emissions from agriculture based on the latest greenhouse gas inventory and the WM projection, respectively

| | Historical | | | | | | | WM Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | | | | | |
| **Total emissions** | **7.5** | **6.7** | **6.6** | **6.5** | **6.7** | **6.6** | **6.6** | **5.9** | **5.7** | **5.5** |
| $CO_2$ | 0.6 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| $CH_4$ | 2.8 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.5 | 2.1 | 2.0 | 1.9 |
| $N_2O$ | 4.1 | 3.7 | 3.7 | 3.7 | 3.8 | 3.8 | 3.8 | 3.6 | 3.5 | 3.3 |

## LULUCF

The land use, land-use change, and forestry sector (LULUCF) as a whole is expected to be a net sink in the WM projection (Table 5.10).

**Table 5.10**
Historical (1990 to 2020) and projected (2025 to 2035) greenhouse gas emissions and removals from the LULUCF sector based on the latest greenhouse gas inventory and the WM projection respectively

| | Historical | | | | | | | WM Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | | | | | |
| **Total emissions and removals** | **−13.4** | **−13.2** | **−15.0** | **−20.5** | **−21.7** | **−18.8** | **−17.3** | **−22.9** | **−20.9** | **−22.6** |
| $CO_2$ | −17.1 | −16.8 | −18.5 | −23.8 | −24.8 | −21.6 | −20.1 | −25.7 | −23.7 | −25.5 |
| $CH_4$ | 1.5 | 1.5 | 1.3 | 1.2 | 1.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 |
| $N_2O$ | 2.1 | 2.1 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 |

The measures mentioned in the Climate Plan for the Land Use Sector aim to reach the annual net climate impact of at least three million tonnes of carbon dioxide equivalent by 2035 (Table 5.11). The measures target agricultural land, forest, and land-use changes. In 2035, the net sink of the land-use sector is estimated to be −22.6 million tonnes of carbon dioxide equivalent. The net sink is expected to increase by a total of 5.3 million tonnes of carbon dioxide equivalent by 2035 compared to the 2020 level, exceeding the minimum target set for the Plan.

In the WM projection for the agricultural sector, measures targeted at organic soils are also expected to decrease emissions in the LULUCF sector by around one million tonnes of $CO_2$ eq. by 2030, 1.3 million tonnes of $CO_2$ eq. by 2035, and around 1.6 million tonnes of $CO_2$ eq. by 2040 (compared to the 2020 level). This is due to a reduction in land clearing and conversion of land from cropland and grassland to afforested land and wetlands. In addition, grassland cultivation with increased water levels and paludiculture are expected to decrease emissions from organic soils.

The projections for the agricultural sector and the LULUCF sector include to some extent different measures for cropland and grassland, different implementation areas, and different assumptions about the cultivation history, i.e. different parameters. The LULUCF projection also includes a few measures targeted at organic soils that are not included in the WM projection for agriculture. The LULUCF sector projection therefore produces higher emissions reductions for cropland and grassland than using the measures and parameters of the agriculture WM projection.

Finland's National Forest Strategy (NFS), adopted by the Government in February 2015 and operationalising government policy, specifies the main objectives for forest policy and forest-based business and activities until 2025[9]. The vision of the Strategy is "Sustainable forest management is a source of growing welfare".

The strategy is implemented by ten key projects. NFS projects were updated in 2019. According to the NFS, climate change mitigation and adaptation in forests are supported by diversifying forest management. Forests' viability, i.e., growth and health will be maintained and enhanced through active forest management. Over the long term, forest management techniques must be adapted to new and changing climate conditions. Timely and careful forest management can improve the growth but also the resistance of growing stock to damage, while safeguarding the ecosystem services of forests and producing wood biomass sustainably. Current forest legislation and ongoing measures for climate- and forest-related objectives are briefly described in Section 4.3.5.

Forests will be a key part of the Finnish bioeconomy, and the NFS therefore aims to increase the use of wood to replace fossil resources with renewable biomass. In the WM projection, the harvesting increases by up to 80 million cubic metres (including the use of wood for bioenergy) in 2026 to 2035, the estimated carbon sink of forests (including trees and soil) will be approximately at the level of −22.6 million tonnes of $CO_2$ eq. per annum by 2035. The decreasing trend in emissions from wetlands is due to the decreasing energy use of peat, resulting in a smaller area being needed for peat extraction.

9 Ministry of Agriculture and Forestry 2019

**Table 5.11**
Preliminary climate impacts in 2030 and 2035 of the measures presented in the Climate Plan for the Land Use Sector (million tonnes of carbon dioxide equivalent)

| Measure | Area | Climate impact in 2030, million tonnes $CO_2$ eq. | Climate impact in 2035, million tonnes $CO_2$ eq. |
|---|---|---|---|
| Owner policy of Metsähallitus | | 0.4 | 0.7–0.9 |
| Preventing the conversion of forests into fields | about 1,700–1,900 ha per year | | 0.5 |
| Act on fixed-term support for afforestation | 3,000 ha per year, of which 40% in peat production areas | 0.09 | 0.11 |
| Afforestation of low-yield fields | 9,000 ha in 2024–2028 | 0.09 | 0.10 |
| Raising the groundwater level in peaty agricultural lands (grasslands) –30 cm | 2030: 20,000 ha<br>2035: 32,500 ha | 0.135 | 0.219 |
| Paludiculture, groundwater level –30 cm | 2030: 5,000 ha<br>2035: 10,000 ha | 0.047 | 0.094 |
| Paludiculture, groundwater level –5 – –10 cm | 2030: 2,500 ha<br>2035: 5,000 ha | 0.047 | 0.094 |
| Managed wetlands | 2030: 4,000 ha<br>2035: 7,500 ha | 0.072 | 0.136 |
| Perennial grasslands without tilling | 2030: 40,000 ha<br>2035: 40,000 ha | 0.081 | 0.081 |
| Wetting of low-yield, thick-peat fields to establish wetlands | 2030: 10,000 ha<br>2035: 10,000 ha | 0.181 | 0.181 |
| Comprehensive planning of peatland forest management (avoidance of remedial ditching) | – | – | – |
| Comprehensive planning of peatland forest management (continuous cover forestry in mires) | 6,000 ha per year | 0.21 | 0.21 |
| Ash fertilisation of peatland forests | 26,000 ha per year | 0.18 | 0.40 |
| Promotion of forest fertilization on mineral soils | 25,000 ha per year | 0.46 | 0.28 |
| Increasing the carbon stocks of decaying wood in commercial forests due to biodiversity and climate considerations by leaving retention trees in place | – | – | – |
| **Total** | | **1.99** | **3.11–3.31** |

Source: Natural Resources Institute Finland 2022

## Waste

Greenhouse gas emission projections for the waste sector include $CH_4$ from landfills and anaerobic digestion and $CH_4$ and $N_2O$ emissions from composting and wastewater treatment. Emission figures for the waste sector do not include emissions from waste incineration, which are reported in the energy sector.

The landfilling of waste is increasingly replaced with recycling and energy recovery. In 2010, the amount of municipal waste incinerated at waste incineration plants was approximately 0.24 million tonnes. Several new waste incineration plants have since been constructed, and the incinerated amount was already more than 1.7 million tonnes in 2019. Currently, waste co-incineration is included in the emissions trading sector, whereas waste incineration plants are in the effort-sharing sector.

Greenhouse gas emissions from the waste sector will decrease in the WM projection (Table 5.12). The main reason for this reduction is the implementation of the Landfill Directive[10] and national legislation[11] and strategies aimed at reducing the amount of waste generated and minimising the amount of waste disposed at landfills. Over a longer period, the amount of greenhouse gases from landfills will decline because of the restrictions on organic waste landfilling.

**Table 5.12**
Historical (1990 to 2020) and projected (2025 to 2035) greenhouse gas emissions from the waste sector based on the latest greenhouse gas inventory and the WM projection respectively (waste incineration not included)

| | Historical | | | | | | | WM Projection | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | | | | | |
| **Total emissions** | **4.7** | **4.6** | **3.8** | **2.8** | **2.6** | **2.1** | **1.7** | **1.4** | **1.2** | **1.0** |
| $CH_4$ | 4.6 | 4.5 | 3.7 | 2.7 | 2.4 | 2.0 | 1.6 | 1.3 | 1.0 | 0.9 |
| $N_2O$ | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

## Indirect $CO_2$ emissions

The WM projection for indirect $CO_2$ assumes that their share of the total national emissions without LULUCF will remain at the present level, 0.1 per cent of total national emissions without the LULUCF sector.

10 Landfill Directive 99/31/EC

11 Government decree on Landfills (331/2013)

## 5.3 "With Additional Measures" projection

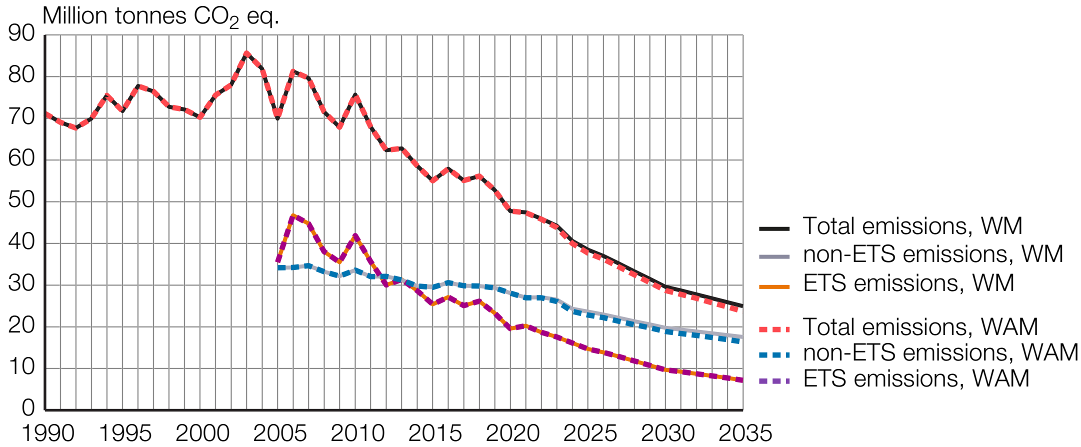
The WAM projection presented in this chapter includes measures already decided at a governmental level and described in Chapter 4. There are planned measures for the transport sector, machinery, F-gases, agriculture, and the waste sector.

With a few exceptions, all the planned measures described in Chapter 4 are included in the WAM projection. Measures for which the impact on the energy balance or the emissions remains unknown or has not been assessed have not been included in the WAM projection. Such measures are:

- Improving energy efficiency and promoting the use of alternative fuels in machinery (no assessment available yet)
- Amendment of the waste tax legislation (only minor impact on emissions, difficult to estimate, no assessment available)
- Influencing the age structure of cattle (measures not yet defined)
- Promoting agroforestry (measures not yet defined).

The effect of the policies and measures included in the WAM projection on the total greenhouse gas emissions is illustrated in Figure 5.3. Solid lines portray the WM projection, and dashed lines the WAM projection. The effect of the additional measures is aimed at the 2020s except for the transport sector, where the additional measures increasingly diminish emissions in the 2030s.

**Figure 5.3**
Greenhouse gas emissions in EU ETS and non-ETS sectors in the WAM projection (dashed lines) compared to the WM projection (solid lines) in 2021 to 2035 and historical emissions for 1990 to 2020 based on the most recent inventory




The total greenhouse gas emissions (without the LULUCF sector) in 2030 are 29.6 million tonnes $CO_2$ eq. in the WM projection and 28.7 million tonnes $CO_2$ eq. in the WAM projection. The additional emissions reduction measures in the WAM projection will only affect transport, industrial processes and agriculture in the non-ETS sector (Table 5.13). The emissions in the ETS sector remain the same as in the WM projection.

**Table 5.13**
Historical (2005 to 2020) and projected (2025 to 2035) greenhouse gas emissions in the Non-ETS and ETS sectors and civil aviation based on the latest greenhouse gas inventory and the WAM projection, respectively

| | Historical | | | WAM Projection | | |
|---|---|---|---|---|---|---|
| | 2005 | 2010 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | | |
| Non-ETS | 34.2 | 33.6 | 28.1 | 22.8 | 18.9 | 16.4 |
| ETS | 35.5 | 41.9 | 19.6 | 14.7 | 9.7 | 7.2 |
| Civil aviation, $CO_2$ | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 |
| **Total emissions** | **69.9** | **75.7** | **47.8** | **37.7** | **28.7** | **23.8** |

Table 5.14 presents a summary of the WAM projection emissions and the difference between them and the emissions levels in the WM projection.

**Table 5.14**
Greenhouse gas emissions on a gas-by-gas basis for the WAM projection and the difference between them and the WM projection between 2025 and 2035, million tonnes $CO_2$ eq. (the greenhouse gas emissions in 2010 and 2020 are based on the most recent inventory and shown for comparison.)

| | Historical | | WAM Projection | | |
|---|---|---|---|---|---|
| | 2010 | 2020 | 2025 | 2030 | 2035 |
| | million tonnes $CO_2$ eq. | | | | |
| $CO_2$ | 64.2 | 37.7 | 29.1 | 21.1 | 16.6 |
| $CH_4$ | 5.4 | 4.4 | 3.6 | 3.2 | 3.0 |
| $N_2O$ | 4.8 | 4.7 | 4.4 | 4.2 | 4.1 |
| F-gases | 1.4 | 1.0 | 0.6 | 0.2 | 0.1 |
| **Total** | **75.7** | **47.8** | **37.7** | **28.7** | **23.7** |
| Difference to WM | | | –0.8 | –0.8 | –1.2 |

When the different emission sectors are examined, the sectoral WAM projections do not differ from the WM projections in the following cases:

- the energy sector, excluding transport
- international bunkers
- industrial processes and product uses other than F-gases
- the LULUCF sector
- waste management.

The WAM projections differ from the WM projections for transport, F-gases, and agriculture, and marginally, for indirect $CO_2$ emissions. Of the sectors with separate WAM projections, transport has the largest absolute difference between WM and WAM emissions, whereas F-gases have the largest relative difference.

The WAM projection includes those transport measures that had not been finally decided or financed by August 2022 or were uncertain for other reasons. It contains the following themes, under which there are several measures: 1) replacing fossil fuels with alternative transport fuels (additional measures); 2) improving the energy efficiency of vehicles (additional measures); and 3) improving the energy efficiency of the transport system (additional measures).

Transport sector emissions decrease somewhat faster in the WAM projection than in the WM projection in the 2020s. From 2030, the difference in emissions increases significantly faster along with the heavily increasing share of biofuels in the WAM projection. In the long term, fossil fuel substitution will have the greatest emissions reduction effect, bringing GHG emissions from road transport close to zero in 2045. The impact of the renewal of the vehicle fleet in the WAM projection remains the smallest of these categories and the most uncertain of all. It is estimated that the emissions reductions in transport achieved by these additional measures, including the effect of increased remote work, will be 0.5 million $CO_2$ eq. in 2030 compared to the WM projection.

The current F-gas measures in the WM projection will already cut the emissions strongly. The WAM projection of F-gases is based on a few additional measures that will slightly accelerate the decrease of emissions. These additional measures include the revision of the F-gas Regulation, improved control of F-gas banks and recovery of F-gases, and promotion of alternative non-HFC technologies. It is estimated that the emissions reduction achieved by these additional measures will be 0.2 million tonnes $CO_2$ eq. in 2030.

The WAM projection of agriculture[12] was updated in 2022 and assumes gradual changes in consumers' diet until 2035, which in turn will affect agricultural production and the use of arable land. In the agricultural sector, the estimated additional total emissions reduction is 0.2 million tonnes of $CO_2$ eq. by 2030 and 0.2 million tonnes of $CO_2$ eq. by 2035. However, the WAM projection involves major uncertainties. For example, the change in food consumption may differ for different population groups. Large changes in consumers' diet cannot be achieved by economic policy instruments alone.

The Government of Finland has set an emissions reduction target of 29 per cent for Finnish agriculture by 2035 (emissions should decrease by 4.6 million tonnes $CO_2$ eq. by 2035 compared to 2019). It is likely that agriculture will not fully achieve this emissions reductions target with the actions of the WAM scenario alone. The existing actions should be intensified, and new actions should be developed.

12 Miettinen et al. (2022)

For cropland and grassland, the WAM measures also have effects on emissions from the LULUCF sector. The WAM scenario, with fewer livestock, less organic matter spread on fields in manure, and fewer grasslands, implies a lower carbon input into soils and slightly higher LULUCF emissions from soils compared with the WM scenario. However, the difference is small, 0.1 to 0.2 million tonnes of $CO_2$ eq. and less than the achieved emissions reductions of the agricultural sector in the WAM scenario, especially after 2035. Measures identified to reduce $N_2O$ emissions from organic soils will also affect emissions from the LULUCF sector (see Table 5.10).

For the LULUCF sector, the WAM projection does not differ from the WM projection. Hence, the abovementioned impacts of the additional measures included in the WAM projection for the agricultural sector are not included in the WAM projection for the LULUCF sector.

The assumptions for indirect $CO_2$ emissions are the same in the WAM and WM projections, i.e. emissions equal 0.1 per cent of total national emissions without the LULUCF sector. The absolute amount of indirect $CO_2$ emissions is therefore marginally smaller in the WAM projection than in the WM projection.

## 5.4 Assessment of aggregate effect of policies and measures

The aggregated estimates for the greenhouse gas reduction impacts of individual WM policies and measures presented in Chapter 4 are 25 and 52 million tonnes $CO_2$ eq. for 2020 and 2030 (without LULUCF) respectively. The WAM measures will increasingly reduce greenhouse gas emissions in the 2020s, reaching an additional annual reduction of approximately 0.8 million tonnes $CO_2$ eq. in 2030. The small addition of the planned measures results from the fact that most of the previously planned measures (WAM measures) are now labelled as implemented or adopted measures (WM measures). New planned measures are currently in the development stage, and decisions on their implementation will be taken in the coming years. The total effect of the current policies and measures calculated bottom-up is shown in Table 5.15.

**Table 5.15**
The total i.e. aggregate effect of the policies and measures (PaMs) calculated based on the estimated impact of PaMs (see Tables 4.2, 4.5, 4.7, 4.8 and 4.12) for 2020, 2025, 2030 and 2035 (million tonnes $CO_2$ eq). The total emissions in 2020 based on the most recent inventory are also given for comparison

| | Total emissions in 2020* | Total effects of PaMs | | | |
|---|---|---|---|---|---|
| | | 2020 | 2025 | 2030 | 2035 |
| WM measures | 47.8 | 24.9 | 44.2 | 52.0 | 55.0 |
| WAM measures[1] | | 0.0 | 0.2 | 0.8 | 0.9 |

* Without LULUCF

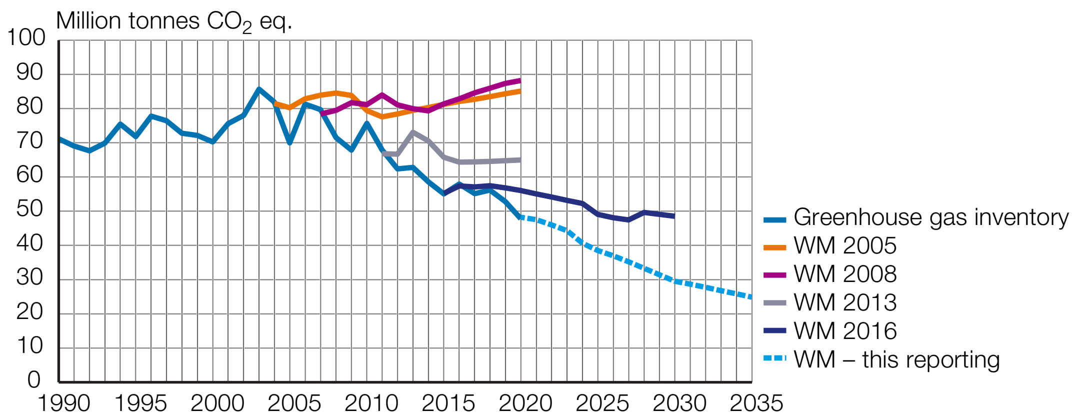
1 In addition to the total effect of PaMs included in the WM projection

The estimated total effect of policies and measures contains noticeable uncertainties. The mitigation impact has not been estimated for all policies and measures. Furthermore, the impact estimates of individual policies and measures are not always fully additive, which may result in an overestimation of the mitigation impact in certain sectors. The overlapping effect of measures has been paid due attention in the case of the simultaneous increase of biofuel content and energy efficiency in machinery, the transport sector, and heating, for example. Altogether, the total emissions reduction is probably larger than the reported total effect.

A top-down assessment of the overall effect of mitigation policies and measures is possible by comparing the greenhouse gas emissions of this reporting with WM projections from earlier reporting rounds. Figure 5.4 shows Finland's greenhouse gas emissions in the WM projections in the last four national climate and energy strategies, i.e. strategies from 2005, 2008, 2013, and 2016, as well as in this reporting. The WM projections in the national climate and energy strategies projected significantly higher emissions for 2020 than those reported in the latest greenhouse gas inventory and in the projections of this reporting. This suggests that the additional measures implemented in the 2010s have had a substantial impact on total emissions.

**Figure 5.4**

Greenhouse gas emissions according to the most recent inventory for 1990 to 2020 and in the WM projections of the climate and energy strategies published in 2005, 2008, 2013 and 2016 until 2020 and 2030 respectively, and the WM projection of this reporting




The main difference between the projections shown in Figure 5.4 is that most measures from previous WAM projections have been implemented since the previous reporting and are therefore included in the following WM projections. The biofuel quota obligation in road transport is one of the measures with the greatest impact. Another significant difference since the WM projections of 2013 and earlier years is the result of domestic conventional condensing power capacity being shut down almost entirely. Furthermore, combined heat and power plants are struggling with their feasibility and are being shut down ahead of time due to market circumstances and the prohibition of coal energy use. The electrification of society and the introduction of new emissions-free technology in all sectors are accelerating earlier and faster than previously expected. The projections have been updated accordingly to reflect the most recent development. The use of fossil fuels and greenhouse gas emissions are therefore significantly lower than anticipated in the previous National Communications.

The total effect of implementing additional measures can be seen in the emission development trend after 2015, which levelled off in the 2013 and 2016 projections, whereas it continued to increase in the projections from 2005 and 2008. In turn, the WM projection of this reporting points clearly downwards.

For comparison purposes, the WM projections from 2005 and 2008 can be considered reasonable WOM (Without Measures) projection substitutes, even though they already include some mitigation measures. The gap between the projections for 2005 to 2008 and the projection of this reporting is up to 40 million tonnes $CO_2$ eq. in 2020. By 2030 the gap would presumably increase to at least 60 million tonnes $CO_2$ eq. if the old projections would have extended that far into the future. This is well in line with the bottom-up estimation of the total effect of policies and measures considering that not every single measure has been assessed and included in the estimation. The bottom-up approach gives 52 million tonnes $CO_2$ eq. emissions reduction in 2030, which added to the emissions of the WAM projection would result in an emission level of at least 81 million tonnes $CO_2$ eq. in 2030 for a WOM projection.

## 5.5 Economic impacts

Most of the effects of the WM projection on the economy stem from the need to invest in new carbon-free and energy-efficient technologies in the energy sectors, industry, and the transport sector. These very large investments will probably dominate economic activity for most of the next two decades and entail current account deficits, but once completed, they will facilitate a structural shift of the economy towards an energy- and material-efficient low-carbon economy, in which many of the current industries will become newly competitive and create export growth.

Economic growth and changes in the structure of the economy also play a key role in the estimation of energy consumption and emissions. The rate of economic growth is determined by the growth rates of labour input and average labour productivity. In the long term, economic growth is determined almost solely by the growth of labour productivity because labour input cannot grow without limits. However, in the short and medium term, factors affecting labour input growth also matter because changes in labour input directly affect the economy's potential output. In Finland, the ageing population is the single most significant factor in terms of its effect on labour input and thus the development of the national economy in the short and medium term. Another factor that will affect the availability of labour is the level of structural unemployment.

The above new investments will result in both increased costs and changes to economic consumption and production structures. At the microeconomic level, the WM projection assumes that businesses make mostly profitable investments. Nevertheless, less profitable investments are also necessary to meet the strict emission targets. Such investments usually require subsidies or investment aid from the Government, which contributes to households being susceptible to a decline in their purchasing power due to the additional costs of cutting emissions. The costs typically include different direct and indirect taxes and other policies. For example, if the government implements a costly investment aid scheme to reduce emissions, it is likely that part of the funding will need to come from income tax increases. Indirect taxes can mean higher costs of fossil fuels, and other policies may even force households to make new investments such as purchasing electric vehicles if new gasoline cars are no longer available in the future. In absolute terms, the impact is most significant on households that consume the most energy and energy-intensive commodities and services, i.e. middle- and high-income households. However, in relative terms, the impact may be even more significant for lower-income households, because energy is a necessity in modern societies.

Yet at the macroeconomic level, the new structures are expected to lead to improved economic efficiency, including labour productivity and new business opportunities especially adding value to exports. Structural changes in the economy will also have impacts on employment. The total employment rate is expected to grow slightly thanks to new investments, but as is often the case, some sectors will benefit more than others. It is expected that industrial and construction sectors will receive most of the benefits, whereas agriculture and services especially will add fewer jobs.

## 5.6 Sensitivity analysis of the projections

Energy use and hence greenhouse gas emissions are sensitive to the assumptions made for economic growth. Two sensitivity analyses have therefore been carried out for the WM projection, varying the economic growth of industry and service branches. No sensitivity analysis of the transport sector was made, but lower economic growth could generally have both a reducing and an increasing impact on energy use and greenhouse gas emissions for transport. On the one hand, the need for transport is likely to be lower; on the other, the renewal of the transport fleet will be slower. The situation is similar for buildings in which lower economic growth results in slower growth of the building volume, but also in less investment in energy efficiency. In the sensitivity analyses, energy uses in the transport sector and buildings remain unchanged.

The manufacturing industry uses about 45 per cent of both the country's final energy and electricity. The forest industry has a significant impact on the energy sector, including renewable energy production, energy consumption, and electricity generation. Iron and steel production is another energy-intensive branch, the development of which significantly influences the projections. The energy balance projections for these branches are based on product-group-specific volume estimates. Both branches develop generally positively in the WM projection, even though some product groups already decrease (e.g. paper manufacturing) in the base case WM. In the sensitivity analysis, the annual growth of the product volumes in the forest and metal industries varies by 1 percentage point in both directions from 2020 compared to the WM projection.

In addition to the branches and sectors mentioned above, the annual growth rate of the other industry and service branches was varied by plus and minus 1 percentage point from the WM assumptions. No dynamic effects were considered.

The results of the sensitivity analyses are presented in Table 5.16 below. The overall effect of a lower economic growth (WM –) results in a steadily decreasing final energy consumption in contrast with higher economic growth (WM +), which steadily increases the energy use in the period from 2021 to 2030. In turn, in the base case WM projection, the final energy consumption is almost flat.

In 2030, the final energy consumption would be only 284 TWh in the low growth case, but 307 TWh in the high growth case compared to 295 TWh in the base case WM. The corresponding figures for primary energy consumption are 364 TWh (WM –), 391 TWh (WM +), and 377 TWh (base case WM). The relative impact of economic growth is therefore somewhat higher on final energy consumption than on primary energy. The greenhouse gas emissions in 2030 differ in both cases in total by about 0.9 to 1.0 million tonnes of $CO_2$ eq. from the emissions in the base case WM projection.

Most of the emission increase and reduction respectively would take place in the ETS sector, with only 0.2 to 0.4 million tonnes of $CO_2$ eq. reduction in the non-ETS sector.

**Table 5.16**
Main results for the sensitivity analysis on how the economic growth rate affects the overall energy balance and GHG emissions

| | Unit | 2020 | 2030 | | | 2035 | | |
|---|---|---|---|---|---|---|---|---|
| | | | WM | WM + | WM – | WM | WM + | WM – |
| **GHG emissions** | | | | | | | | |
| Total excluding LULUCF | million tonnes $CO_2$ eq. | 47.8 | 29.6 | 30.6 | 28.7 | 24.9 | 26.1 | 23.9 |
| Total ETS | million tonnes $CO_2$ eq. | 19.6 | 9.7 | 10.5 | 9.0 | 7.2 | 8.1 | 6.4 |
| Total non-ETS | million tonnes $CO_2$ eq. | 28.1 | 19.7 | 19.9 | 19.5 | 17.6 | 17.9 | 17.4 |
| Primary energy consumption | TWh | 354.7 | 376.6 | 390.6 | 363.8 | 371.4 | 393.1 | 352.4 |
| Gross final energy consumption | TWh | 285.0 | 294.9 | 307.2 | 283.7 | 292.0 | 311.0 | 275.3 |

WM +, projection with higher economic growth than the WM projection
WM –, projection with lower economic growth than the WM projection

Source for historical data: Energy Statistics and Finnish Energy

## 5.7 Supplementarity relating to the Kyoto Protocol mechanisms

Finland's total greenhouse gas emissions in the first commitment period from 2008 to 2012 were 338,353,531 t $CO_2$ eq., approximately five per cent lower than the assigned amount, which was 355,017,545 tonnes CO2 eq. Finland met its commitment by retiring 338,353,531 Kyoto Protocol units at the end of the commitment period.

Of the total amount, 12,273,471 were CERs, and 4,088,755 were ERUs. These Kyoto Protocol mechanisms units were acquired by Finnish ETS operators which, according to EU ETS legislation, were entitled to cover part of their EU ETS obligations through Kyoto Protocol mechanisms. Finland did not retire any Kyoto Protocol mechanisms units to cover its emissions from the non-ETS sector.

Finland has requested 6,798,242 CERs and 2,917,220 ERUs to be carried over to the second commitment period of the Kyoto Protocol. When CERs and ERUs generated in the second commitment period are also considered, Finland has a total of 9,986,208 CERs and 2,912,592 ERUs that are eligible for the second commitment period. Finland can further request 14,018,572 AAUs to be carried over from the first to second commitment period. The AAU amount includes 10,000,000 AAUs transferred by the European Union from the Union Registry to Finland's party holding account. The transfer was designed to enable Finland's compliance with its commitments in the second commitment period under the Kyoto Protocol after the international LULUCF accounting rules were changed by Decision 2/CMP.7.

As mentioned in Section 4.1.2 based on the GHG inventory data, Finland will also fulfil its commitments under the second commitment period of the

Kyoto Protocol. Due to the additional burden arising from KP LULUCF activities, Finland will also have to use additional emission units transferred from the previous Kyoto Protocol commitment period or acquired from the Clean Development Mechanism or Joint Implementation. Any use of Kyoto Mechanisms would be supplemental to domestic actions.

## 5.8 Methodology

### 5.8.1 Approach and responsibilities

The approach and responsibilities in preparing the projections have not changed since the preparation of the Seventh National Communication.

The reported WM–and WAM-projections are integrated energy and climate projections that were originally modelled for the preparation of three Government Reports, namely the National Energy and Climate Strategy, the Medium-term Climate Change Policy Plan, and the Climate Change Plan for the Land Use Sector. The modelling and assessments were conducted by experts from various research fields in the "Carbon neutral Finland 2035 – measures and impacts of the climate and energy policies" project (HIISI project)[13] financed by the Government's analysis, assessment, and research activities. The analysis and results of the HIISI project were complemented in 2022 by the current information and updates of sectoral projections.

Finland uses a sectoral approach with detailed sector-specific modelling that is coordinated and manually interlinked across sectors. The preparation of the reported WM and WAM projections was coordinated by the Ministry of Economic Affairs and Employment. The Ministry of Economic Affairs and Employment was responsible for the projections regarding the amount of energy used by industry, households and services and for the calculations of fuel and carbon dioxide emissions in the energy production sectors as a whole. The Ministry of the Environment was responsible for the projection regarding space heating, the analysis of the regional and urban structure, and emission projections and calculations for F-gases, waste and machinery. The duty of the Ministry of Transport and Communications included projections for fuel and electricity use, as well as emissions from the transport sector and international bunkers. The Ministry of Agriculture and Forestry oversaw the calculation of emissions and removals in the agriculture and land use, land-use change, and forestry sectors. The Ministry of Finance was responsible for forecasting short-term economic development and taxation.

The sectoral projections, assessments of policies and measures, and other calculations, modelling, and analysis were made by expert organisations, research institutes, and consultants selected for the purpose by the

13 Koljonen, T. et al. 2021, https://urn.fi/URN:ISBN:978-952-383-257-2

ministries. The following authorities and expert organisations contributed to the reporting in 2022: the Energy Authority; the Finnish Environment Institute; VTT Technical Research Centre of Finland Ltd; Motiva Ltd; Natural Resources Institute Finland; the Finnish Institute for Health and Welfare; Pellervo Economic Research PTT; the Finnish Transport and Communications Agency; Sitowise Group Oyj; and Statistics Finland.

The main models and methods used in the work are briefly described in Section 5.8.3.

### 5.8.2 Assumptions underlying calculations

A summary of key variables and assumptions is presented in Table 5.17.

**Table 5.17**

Key variables and assumptions used in the projections analysis for 1990 to 2035

| | Unit | Historical | | | | | | | Projected | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| Population | Million inhabitants | 5.00 | 5.12 | 5.18 | 5.26 | 5.38 | 5.49 | 5.53 | 5.56 | 5.57 | 5.56 |
| Gross Domestic Product | Million EUR, 2020 prices | 146,000 | 143,000 | 183,000 | 208,000 | 218,000 | 219,000 | 232,000 | 257,000 | 276,000 | 297,000 |
| Coal wholesale price | EUR/GJ LHV, 2020 prices for history, 2022 prices for the future | NA* | 3 | 4 | 5 | 5 | 8 | 10 | 3 | 3 | 3 |
| Crude oil wholesale price | EUR/GJ LHV, 2020 prices for history, 2022 prices for the future | NA* | 4 | 7 | 9 | 9 | 8 | 9 | 12 | 14 | 15 |
| Natural gas wholesale price | EUR/GJ LHV, 2020 prices for history, 2022 prices for the future | NA* | 4 | 5 | 6 | 9 | 13 | 13 | 6 | 6 | 7 |
| Emission allowance price | EUR/t nominal prices | NO | NO | NO | 23 | 14 | 7 | 25 | 25 | 30 | 35 |
| **Tax components: **** | | | | | | | | | | | |
| Electricity, tax category I | cent/kWh, 2020 prices for history, 2022 prices for the future | NA* | NA* | NA* | NA* | 0.98 | 2.33 | 2.24 | 2.24 | 2.24 | 2.24 |
| Electricity, tax category II | cent/kWh, 2020 prices for history, 2022 prices for the future | NA* | NA* | NA* | NA* | 0.28 | 0.72 | 0.69 | 0.05 | 0.05 | 0.05 |
| **Calculation basis of excise duty rates for heating, power plant and machinery fuels (coal, natural gas)** | | | | | | | | | | | |
| Energy content component | EUR/MWh LHV, 2020 prices for history, 2022 prices for the future | NA* | NA* | NA* | NA* | NA* | 6.92 | 7.63 | 10.33 | 10.33 | 10.33 |
| Carbon dioxide component*** | EUR/t lifetime $CO_2$ emissions, 2020 prices for history, 2022 prices for the future | NA* | NA* | NA* | NA* | NA* | NA* | 53.00 | 53.00 | 53.00 | 53.00 |
| **Calculation basis of excise duty rates for liquid transport fuels** | | | | | | | | | | | |
| Energy content component | EUR/MWh LHV, 2020 prices | NA* | NA* | NA* | NA* | NA* | 59.90 | 58.72 | 60.52 | 60.52 | 60.52 |
| Carbon dioxide component*** | EUR/t lifetime $CO_2$ emissions | NA* | NA* | NA* | NA* | NA* | 60.32 | 62.00 | 77.00 | 77.00 | 77.00 |

* No data available or regarding taxes, the taxation structure was significantly different from the present and thus not comparable
** The values in the table represent base case rates. Several reductions and exemptions exist (more information in Section 4.5)
***For combustion only, the value would be 20% higher.

In addition, please note that the historical data on population and gross domestic production represents the data used in the projections and may slightly differ from the latest statistics

Sources: AFRY, Statistics Finland

Finland's population will increase only slightly from the current 5.53 to 5.57 million in 2030. In 2031, the population will start to decrease. The population's age structure will change significantly over the next couple of decades as the share of older age groups increases. The number of households is expected to grow from the current 2.7 million to almost 2.9 million by 2050. However, at the same time, the average size of households will decrease. The number, structure, and location of households will have an impact on energy demand.

The impact of the Covid-19 pandemic was also considered when projecting the economic development and to the extent possible in the sector projections. Economic growth will recover during 2021, but it will remain modest at first thereafter. During the 2020s, the world economy is expected to recover, which will also begin to have an impact in Finland. The average annual GDP growth rate in the 2020s is 1.5 per cent in the projections. The activities that will sustain most growth in production in the 2020s are expected to be machinery and equipment manufacturing, the forest industry, and the financial and insurance business.

The fuel taxation structure was recently overhauled to make energy content and carbon dioxide the main components. They are applied to two categories shown in the table above and described in more detail in Section 4.5. The electricity tax is divided into two categories, of which the lower (category II) is applied to industry and heat pumps in district heat production, and the higher mostly to consumers, for example. As the table illustrates, the ongoing trend is that electricity for industry is taxed less and combustion fuels more. The 2025 figures in the table correspond to taxation in 2022. After 2025, the taxation structure and levels remain constant in the projections, as no changes are currently planned.

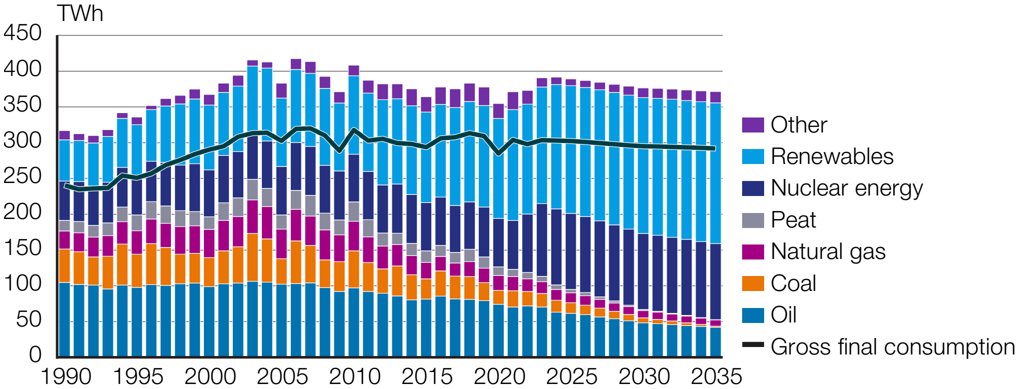
Assumed fossil fuel prices in the world market and the assumed prices of emissions allowances in the EU's emissions trading system correspond to the recommended harmonised values provided by the EU Commission for greenhouse gas emission projections before the current energy crisis in Europe.

The primary energy by source, energy sources for district heat and combined heat and power production, electricity supply, electricity consumption in the forest industry and energy sources in the transport sector are presented in Tables 5.18 to 5.22.

Gross final energy consumption is levelled off in the projections because of increased energy efficiency in all sectors. The decreasing energy sector emissions are the result of policy measures that replace fossil fuels with renewables and electricity. Despite the flat final consumption projection, the primary energy consumption significantly varies in the projections. The main reason for this is the substantial changes in domestic nuclear power production (increase in early 2020s and 2030s), which replaces electricity imports. Expressed in primary energy, the value of nuclear power is three times that of imported electricity, despite the same amount of electricity fed to consumption. The development of the primary energy supply and gross final energy consumption in the WM projection is shown in Figure 5.5 and Table 5.18.

### Figure 5.5

Historical development (1990 to 2020) and WM projection (until 2035) of the primary energy supply by energy source and gross final energy consumption (solid line), TWh




Source for historical data: Energy Statistics

### Table 5.18

Primary energy by energy source and gross final energy in 2010, 2015, 2020 and in the WM projection for 2025, 2030 and 2035, TWh

| | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| Oil | 97.2 | 81.6 | 74.3 | 61.7 | 48.2 | 42.1 |
| Coal | 51.8 | 28.3 | 19.5 | 14.8 | 7.2 | 1.5 |
| Natural gas | 41.3 | 22.9 | 20.7 | 13.8 | 10.0 | 8.8 |
| Peat | 27.2 | 16.1 | 12.0 | 4.9 | 1.6 | 0.4 |
| Nuclear energy | 66.3 | 67.7 | 67.7 | 106.2 | 106.2 | 106.2 |
| Renewables | 109.9 | 126.3 | 139.6 | 178.4 | 189.8 | 196.6 |
| Other | 14.6 | 21.4 | 20.9 | 9.6 | 13.6 | 15.8 |
| Gross final consumption | 317.7 | 293.9 | 285.0 | 302.4 | 294.9 | 292.0 |

Source for historical data: Energy Statistics

The trend of replacing fossil fuels and peat with renewables and electricity is also clear in the district heating sector, as the table 5.19 below illustrates. The share of waste heat recovery especially is expected to grow rapidly in the coming years, being three times the 2020 level after 2025. Most of the increase is attributed to heat pumps, as almost all the waste heat streams that can be directly utilised are already harnessed. The table also presents the fact that the total district heat consumption, and therefore the energy sources, is in decline due to buildings' improving energy efficiency.

**Table 5.19**
Energy sources for district heat (heat-only boilers and CHP-heat) and CHP-electricity in 2010, 2015, 2020 and in the WM projection for 2025, 2030 and 2035, TWh

| | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| Fuel oils | 3.5 | 1.5 | 0.8 | 0.6 | 0.3 | 0.3 |
| Coal | 14.2 | 11.7 | 6.9 | 0.6 | 0.0 | 0.0 |
| Natural gas | 25.7 | 11.9 | 9.1 | 3.6 | 1.5 | 0.9 |
| Peat | 13.3 | 9.3 | 7.7 | 2.0 | 0.4 | 0.2 |
| Wood-based fuels | 19.5 | 24.1 | 27.9 | 24.4 | 23.4 | 19.6 |
| Other renewables (mainly biogas and renewable part of waste) | 1.0 | 2.3 | 3.0 | 2.7 | 2.8 | 2.7 |
| Other fossil fuels (mainly non-renewable part of waste) | 1.0 | 1.9 | 2.5 | 2.3 | 2.1 | 2.1 |
| Other sources (mainly waste heat and electric boilers, includes both electricity and heat of heat pumps) | 1.2 | 2.6 | 4.5 | 9.4 | 10.4 | 11.1 |

Source for historical data: Energy Statistics

In electricity supply, the share of wind power especially will probably grow even more rapidly than in the past (Table 5.20). At the same time, the share of wood-based fuels is expected to grow to some extent, and that of fossil fuels to decrease. The need for electricity imports depends on many factors, but the annual net import should generally remain substantially lower than in the past, despite the continuously growing electricity demand that results from decarbonisation and electrification.

**Table 5.20**
Electricity supply in 2010, 2015, 2020 and in the WM projection for 2020, 2030 and 2035, TWh

| | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| Hydro | 12.7 | 16.6 | 15.7 | 14.3 | 14.4 | 14.5 |
| Wind and solar | 0.3 | 2.3 | 8.2 | 20.6 | 25.6 | 33.9 |
| Wood-based biomass | 10.0 | 10.1 | 10.3 | 13.6 | 13.6 | 13.7 |
| Other renewables (mainly renewable part of waste) | 0.4 | 0.6 | 0.6 | 0.7 | 0.5 | 0.6 |
| Nuclear | 21.9 | 22.3 | 22.4 | 35.0 | 35.0 | 35.0 |
| Oil | 0.4 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 |
| Coal | 13.6 | 4.8 | 2.3 | 1.3 | 0.3 | 0.0 |
| Natural gas | 11.0 | 5.1 | 3.9 | 2.9 | 2.3 | 2.2 |
| Peat | 5.9 | 2.9 | 2.0 | 0.8 | 0.2 | 0.0 |
| Others (mainly fossil part of waste) | 0.4 | 0.3 | 0.9 | 0.6 | 0.5 | 0.5 |
| Imports | 10.5 | 16.3 | 15.0 | 1.7 | 6.1 | 7.9 |

Source for historical data: Energy Statistics

The forest industry is both a significant energy consumer and an electricity and heat producer. Pulp mills especially produce large amounts of electricity and heat from black liquor, which is the main by-product from the kraft process, which digests pulpwood into paper pulp. In addition, biomass by-products from the forest industry, such as bark and sawdust from the mechanical forest industry, are utilised as fuels in both the forest industry and the energy sector. For example, these by-products equated to approximately 24 TWh and black liquor to 46 TWh in 2021. At the same time, the total use of wood-based fuels was approximately 110 TWh.

Conventionally, all black liquor has been combusted in specially designed boilers for heat and electricity. In the WM projection, it is expected that some black liquor will be converted into biofuels for transport in the future. Large amounts of black liquor should be available, as the market trends seem to decrease print, special, and soft paper production but increase the production of pulp and new products (such as textiles, chemicals, and bioplastics) that generate black liquor as a by-product. The table 5.21 below shows historical and projected electricity consumption in the forest industry. The product volumes are included in the table listing LULUCF parameters (Table 5.26a).

**Table 5.21**
Electricity consumption in the forest industry in 2010, 2015 2020 (historical) and 2025, 2030 and 2035 (WM projection)

| | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| **Electricity consumption, TWh** | | | | | | |
| Pulp and paper | 20.6 | 17.5 | 15.6 | 16.5 | 16.4 | 16.4 |
| Mechanical forest industry | 1.6 | 1.3 | 1.4 | 1.3 | 1.4 | 1.3 |

Source for historical data: Statistics Finland

In the transport sector, greenhouse gas emissions are influenced by a decline in specific energy consumption and especially by replacing fossil fuels with alternative transport fuels (Tables 5.22 and 5.23). The WM projection's annual distribution obligation percentages for biofuels for 2022 to 2030 are 12, 13.5, 28, 29, 29, 30, 31, 32, and 34 per cent (from 2030 onwards). The share of biofuels in consumption increases, and respectively, the share of fossil fuels in consumption decreases. Biogas and electric fuels are included in the distribution obligation between 2022 and 2050. In the WM projection, the bio-share of transport gas will increase by 5 per cent units per year until the share reaches the 99 per cent level. Biogas replaces biodiesel in fulfilling the distribution obligation: biogas consumption increases, and the corresponding amount of energy decreases from the consumption of biodiesel. In the WAM projection, the share increases to 100 per cent in 2045.

### Table 5.22

Energy sources in transport in 2010, 2015, 2020 and in the WM projection for 2025, 2030 and 2035, TWh

| | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| Gasoline, fossil | 17.8 | 15.8 | 13.6 | 12.9 | 11.1 | 8.5 |
| Diesel, fossil | 27.1 | 23.4 | 24.5 | 15.6 | 11.9 | 10.1 |
| Biofuels | 1.5 | 5.8 | 4.7 | 11.6 | 11.6 | 9.0 |
| Aviation fuels, fossil | 1.6 | 1.2 | 1.0 | 1.1 | 1.1 | 1.1 |
| Light fuel oil | 1.7 | 1.6 | 1.3 | 1.3 | 1.1 | 1.0 |
| Heavy fuel oil, gas, hydrogen | 0.5 | 0.1 | 0.2 | 0.8 | 1.2 | 2.0 |
| Electricity | 0.7 | 0.7 | 0.8 | 2.1 | 4.6 | 7.9 |

Source for historical data: Energy Statistics

### Table 5.23

Main assumptions for the transport sector

| | Unit | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|---|
| | | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| **Number of vehicles – in total** | **pieces** | **3,340,794** | **3,461,862** | **3,461,451** | **3,566,784** | **3,656,316** | **3,706,248** |
| Passenger cars | pieces | 2,486,283 | 2,612,922 | 2,748,448 | 2,797,311 | 2,891,542 | 2,938,448 |
| Vans | pieces | 289,824 | 307,706 | 338,389 | 331,924 | 327,795 | 329,174 |
| Buses | pieces | 11,610 | 12,455 | 9,955 | 11,573 | 12,615 | 13,409 |
| Trucks | pieces | 94,334 | 95,250 | 94,691 | 99,247 | 104,451 | 110,180 |
| Motorcycles, mopeds, 4-wheels | pieces | 458,743 | 433,529 | 269,968 | 326,729 | 319,913 | 315,037 |
| **Passenger cars by operating forces** | | | | | | | |
| Petrol and Diesel | % | 100 | 100 | 97 | 85 | 68 | 48 |
| Battery Electric and Plug-in Hybrid | % | 0 | 0 | 2 | 14 | 30 | 48 |
| CNG Gas and Flexible Fuel Vehicles | % | 0 | 0 | 1 | 1 | 1 | 1 |
| Hydrogen | % | 0 | 0 | 0 | 0 | 0 | 3 |
| **Vehicle kilometres – in total** | **Million kilometers** | **54,860** | **56,365** | **49,668** | **53,060** | **57,639** | **64,333** |
| Passenger cars | Million kilo-meters | 46,245 | 47,355 | 39,092 | 42,166 | 46,597 | 53,138 |
| Others | Million kilo-meters | 8,615 | 9,010 | 10,576 | 10,894 | 11,042 | 11,195 |

The main assumptions for the F-gases are listed in Table 5.24. Significantly more than 90 per cent of the emissions of F-gases originate from refrigeration and air-conditioning equipment. The single most significant emission source is commercial refrigeration. The sector is comprised of refrigeration in food retail stores and professional kitchens. The most significant factor affecting the emissions of F-gases is the replacement of HFC refrigerants with natural refrigerants (carbon dioxide and hydrocarbons). By 2035, it is assumed that all the remaining HFC refrigerants will have been replaced by natural refrigerants in existing commercial refrigeration equipment. The replacement is assumed to be slightly faster in the WAM scenario.

**Table 5.24**
Main assumptions for F gases

| | Historical | | | Projection | | |
|---|---|---|---|---|---|---|
| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| | % | | | | | |
| **WM projection** | | | | | | |
| Share of centralized refrigeration systems with $CO_2$ or hydrocarbons annually in use | | | | | | |
| in food retail stores | 3 | 8 | 15 | 36 | 83 | 100 |
| in professional kitchens | NO | NO | 10 | 25 | 65 | 100 |
| **WAM projection** | | | | | | |
| Share of centralized refrigeration systems with $CO_2$ or hydrocarbons annually in use | | | | | | |
| in food retail stores | 3 | 8 | 15 | 36 | 89 | 100 |
| in professional kitchens | NO | NO | 10 | 25 | 75 | 100 |

Source: Finnish Environment Institute

For agriculture, the development of livestock numbers has been estimated using the Dremfia agricultural sector model[14], which considers the prices of agricultural inputs and outputs and agricultural policy.

Farm sizes and productivity are increasing in dairy cattle farming, which will see a large-scale shift from single dairy robot units to units of two or more robots between the 2020s and 2030s. Total milk production will fall by 3 per cent from the 2020 level by 2035, but the number of dairy cows will be reduced by approximately 15 per cent. Fewer cows will be needed to produce the same amount of milk because the average milk yield of dairy cows will increase in the future.

The development in the dairy sector is reflected in the lower numbers of calves and heifers. Instead, the number of suckler cows will increase by about 1,500 cows by 2035. The slow reduction in the real price of beef and the expected constant agricultural subsidy for cattle do not give economic opportunities for greater suckler cow production growth.

Production of pork and poultry meat, and hence also animal numbers, depends on domestic demand. Pork consumption is decreasing, but the annual consumption of poultry meat is expected to reach 150 million kilograms and remain at this level. It has been assumed that the number of sheep will remain the same.

In the Dremfia model, total fertilisation and synthetic nitrogen fertilisation, which complements nitrogen from manure, are determined according to

14 Lehtonen 2001

nitrogen yield response and nitrogen and plant product prices. The amount of manure decreases as the numbers of farmed animals decrease. Hence, the amount of nitrogen input from the application of manure will decrease by 8 per cent between 2020 and 2035. The nitrogen requirement of crops is complemented by synthetic nitrogen fertilisation, the amount of which will increase by 2 per cent between 2020 and 2035. Rising synthetic nitrogen fertiliser prices caused by rising fossil energy prices will reduce the growth of synthetic fertiliser application.

The increasing grassland area and use of catch crops will increase the nitrogen emission of crop residues returned to soils. The area of agricultural land will decrease by 2035 as more agricultural land will be converted to other land uses than new agricultural land is cleared. Reduction is proportionately strongest on cultivated organic soils, the area of which will decrease by 3 per cent between 2020 and 2035.

**Table 5.25**
Main assumptions for the agricultural sector

| | Unit | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|---|
| | | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| Livestock | | | | | | | |
| Dairy cattle | 1,000 heads | 289 | 285 | 260 | 238 | 231 | 219 |
| Non-dairy cattle | 1,000 heads | 636 | 630 | 587 | 566 | 537 | 525 |
| Sheep | 1,000 heads | 126 | 155 | 140 | 140 | 140 | 140 |
| Pig | 1,000 heads | 1,340 | 1,239 | 1,104 | 1,010 | 984 | 967 |
| Poultry | 1,000 heads | 9,587 | 12,927 | 13,577 | 14,072 | 13,896 | 13,829 |
| Nitrogen input from application of synthetic fertilizers | kt nitrogen | 157 | 143 | 139 | 148 | 143 | 142 |
| Nitrogen input from application of manure | kt nitrogen | 73 | 74 | 71 | 69 | 67 | 65 |
| Nitrogen in crop residues returned to soils | kt nitrogen | 87 | 99 | 91 | 84 | 89 | 92 |
| Area of cultivated organic soils | 1,000 hectares | 317 | 327 | 338 | 341 | 336 | 328 |

The main assumptions for the LULUCF sector are presented in Table 5.26a, with additional information in Table 5.26b. Assumptions are based on three scenario studies: the HIISI scenario; the updated HIISI for agriculture; and the scenario for the Climate Plan for the Land Use Sector. The HIISI scenario for the LULUCF sector was compiled in 2021. It was updated with the Climate Plan for the Land Use Sector in 2022. At the same time, the HIISI scenario for agriculture was updated. The LULUCF projection in this NC8 is a compilation of these three scenarios. The whole LULUCF projection was not updated in 2022, because a new scenario study will start at the beginning of 2023.

## Table 5.26a
Main assumptions for the LULUCF sector

| | Unit | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|---|
| | | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| **4.A Forest land** | | | | | | | |
| Forest harvest removals for energy use | 1,000 $m^3$ | 7,734 | 9,186 | 10,308 | 9,300 | 10,800 | 10,800 |
| Forest harvest removals for non- energy use | 1,000 $m^3$ | 51,957 | 58,849 | 58,546 | 61,800 | 67,800 | 67,800 |
| Forest increment | 1,000 $m^3$ | 106,400 | 105,640 | 105,640 | 106,800 | 108,600 | 108,600 |
| Forest land remaining forest land | 1,000 ha | 21,781 | 21,754 | 21,754 | 21,723 | 21,692 | 21,676 |
| Land converted to forest land | 1,000 ha | 162 | 130 | 95 | 118 | 156 | 161 |
| **4.B Cropland** | | | | | | | |
| Cropland | 1,000 ha | 2,474 | 2,490 | 2,502 | 2,489 | 2,475 | 2,465 |
| **4.C Crassland** | | | | | | | |
| Grassland | 1,000 ha | 238 | 238 | 243 | 245 | 243 | 241 |
| **4.D Wetlands** | | | | | | | |
| Peat extraction sites | 1,000 ha | 108 | 112 | 111 | 99 | 67 | 47 |
| Other wetlands | 1,000 ha | 6,336 | 6,325 | 6,322 | 6,306 | 6,305 | 6,310 |
| **4.E Settlements** | | | | | | | |
| Lands converted to settlements | 1,000 ha | 232 | 252 | 227 | 212 | 190 | 175 |
| **4.G Harvested wood products** | | | | | | | |
| Production of sawn wood | 1,000 $m^3$ | 9,473 | 10,640 | 10,916 | 11,580 | 12,260 | 12,350 |
| Production of wood panels | 1,000 $m^3$ | 1,347 | 1,314 | 1,206 | 1,291 | 1,286 | 1,288 |
| Production of paper and paperboard | 1,000 tonnes | 10,508 | 10,247 | 10,120 | 7,713 | 7,919 | 8,217 |
| Export of pulp | 1,000 tonnes | 2,159 | 3,136 | 4,333 | 5,222 | 5,744 | 6,139 |

$m^3$ = cubic meters, ha = hectares

**Table 5.26b**
Main assumptions for the LULUCF sector

| | Assumption | Source |
|---|---|---|
| **Forest** | | |
| Roundwood demand | Based on production volumes of different branches of forest industry and roundwood import | HIISI scenarios |
| Energy wood demand | | HIISI scenarios |
| Wood prices | Average of 2008 to 2017 | Forest Statistics |
| Costs of silviculture | Average of 2007 to 2026 | Forest Statistics |
| Climate | Increase in temperature and $CO_2$ concentration has increased increment of trees | HIISI scenarios |
| Avoidance of remedial drainage | 1,000 hectares less annually on drained most fertile and poorest peatland forests | Climate Plan for the Land Use Sector |
| Comprehensive peatland forest management, thinning from above | 6,000 hectares annually on most fertile drained peatland forests | Climate Plan for the Land Use Sector |
| Ash fertilisation on peatland forests | 50,000 hectares per year | Climate Plan for the Land Use Sector |
| Forest fertilisation on mineral soils | 67,000 hectares per year | Climate Plan for the Land Use Sector |
| Increased volume of dead wood in commercially utilised forests | Increase of up to 7 cubic meters per hectare | Climate Plan for the Land Use Sector |
| Immediate regeneration after regeneration felling | No delays | Climate Plan for the Land Use Sector |
| **Agricultural lands** | years 2025, 2030, 2035 | |
| Raising the groundwater level in peaty agricultural lands (grasslands) –30 cm | 7,500, 20,000, 32,500 hectares | Climate Plan for the Land Use Sector, Updated HIISI AGRI |
| Paludiculture, groundwater level –30 cm | 2,000, 5,000, 10,000 hectares | Climate Plan for the Land Use Sector, Updated HIISI AGRI |
| Perennial grasslands without tilling | 40,000, 40,000, 40,000 | Climate Plan for the Land Use Sector, Updated HIISI AGRI |
| **Land-use change** | | |
| Afforestation of arable lands and peat production areas 2021 to 2023 | 3,000–4,000 hectares per year | Climate Plan for the Land Use Sector |
| Afforestation of low-yield fields 2024 to 2028 | 9,000 hectares per year | Climate Plan for the Land Use Sector |
| Deforestation, from forest to arable land | Decrease of 900 hectares per year on organic soils and 800 hectares per year on mineral soils | Climate Plan for the Land Use Sector |
| Wetting of poorly productive, thick-peaty fields to establish wetlands | 4,000, 10,000, 10,000 hectares | Climate Plan for the Land Use Sector |
| Managed wetlands, peaty arable land to wetland (no longer in agricultural use) | 1,500, 4,000, 7,500 hectares | Climate Plan for the Land Use Sector, Updated HIISI AGRI |
| Paludiculture, groundwater level –5 – –10 cm, peaty arable land to wetland | 1,000, 2,500, 5,000 hectares | Climate Plan for the Land Use Sector |

The main assumptions for waste sector are listed in Table 5.27. The landfilling of waste is increasingly replaced with recycling and energy recovery. In 2010, the amount of municipal waste incinerated at waste incineration plants was approximately 244,000 tonnes (2,444 TJ) and in REF burning plants 313,000 tonnes (6,260 TJ). Several new waste incineration plants have been constructed in recent years and in 2020 the incinerated amount outside the emissions trading sector was already more than 18,400 TJ[15]. The WM projection estimates from 2023 onwards the incinerated amount outside the emissions trading sector to be 20,200 to 20,400 TJ. Since 2017, there has been a comprehensive landfill ban on biodegradable waste and biodegradable waste could only go to landfills in waste batches (e.g. rejects) with a very low biodegradable fraction. In the WM projection, it is assumed that 15 thousand tonnes of municipal waste would go to landfills per year from 2021. The share of methane recovery from landfills WM-projection is assumed to be 25 per cent of the total methane generation for years 2025, 2030 and 2035. No new recovery plants are assumed to be built and no changes are assumed to the technical level of the plants' operation in the current situation.

**Table 5.27**
Main assumptions for the waste sector

| | Unit | Historical | | | WM Projection | | |
|---|---|---|---|---|---|---|---|
| | | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 |
| Municipal solid waste (MSW) going to landfills | tonnes | 1,093,000 | 316,000 | 15,000 | 15,000 | 15,000 | 15,000 |
| Share of $CH_4$ recovery in $CH_4$ generation (excluding industrial wastes) from landfills | % | 33 | 33 | 24 | 25 | 25 | 25 |

For the projections, the split of emissions in those included in the EU Emissions Trading System (EU ETS) and those outside the EU ETS is based on a data set of greenhouse gas emissions covering 2005 to 2020 and provided by Statistics Finland. The relative shares of EU ETS and non-ETS emissions to be used in the projections are set for the individual branches and greenhouse gases and are listed in Table 5.28. The individual shares are assumed to remain constant for each branch over time in the projections.

15 also including small amounts of fuels other than municipal waste

Table 5.28
Projected EU ETS and non-ETS shares of GHG emissions
The split is based on GHG inventory data for the years 2018 to 2020

| | EU ETS | Non-ETS |
|---|---|---|
| | % | % |
| **$CO_2$ emissions** | | |
| **Energy sector** | | |
| Energy industries excl. small plants | 100 | 0 |
| Energy industries, small plants | 0 | 100 |
| Waste incineration plants | 0 | 100 |
| Food industries and manufacture of beverages | 60 | 40 |
| Manufacture of wood and of products of wood | 9 | 89 |
| Manufacture of paper and paper products | 92 | 8 |
| Petroleum refining | 96 | 4 |
| Chemical industry excl. petroleum refining | 80 | 20 |
| Manufacture of non-metallic mineral products | 89 | 11 |
| Manufacture of basic metals, iron and steel production | 100 | 0 |
| Manufacture of basic metals, non-ferrous metal production | 0 | 100 |
| Other manufacturing industry | 7 | 93 |
| Civil aviation | 99 | 1 |
| Transport sector excl. civil aviation | 0 | 100 |
| Machinery | 0 | 100 |
| Building specific heating | 0 | 100 |
| Agriculture | 0 | 100 |
| Fishing | 0 | 100 |
| Other energy sector emissions | 0 | 100 |
| Fugitive emissions | 90 | 10 |
| **Industrial processes** | | |
| Mineral industry | 89 | 11 |
| Chemical industry, hydrogen production | 100 | 0 |
| Chemical industry, production of phosphoric acid and other chemicals | 0 | 100 |
| Metal industry, iron and steel production | 100 | 0 |
| **Other** | | |
| $CO_2$ captured | 100 | 0 |
| Liming | 0 | 100 |
| Other product and solvent use | 0 | 100 |
| Indirect $CO_2$ emissions | 0 | 100 |
| **$N_2O$ emissions** | | |
| Fuel combustion incl. transport and machinery | 0 | 100 |
| Nitric acid production | 100 | 0 |
| Manure management | 0 | 100 |
| Agricultural soils | 0 | 100 |
| Waste disposal and treatment | 0 | 100 |
| Other emissions | 0 | 100 |
| **$CH_4$ emissions** | | |
| Fuel combustion incl. transport and machinery | 0 | 100 |
| Fugitive emissions | 0 | 100 |
| Enteric fermentation | 0 | 100 |
| Manure management | 0 | 100 |
| Waste disposal and treatment | 0 | 100 |
| **F gas emissions** | | |
| F gas use | 0 | 100 |

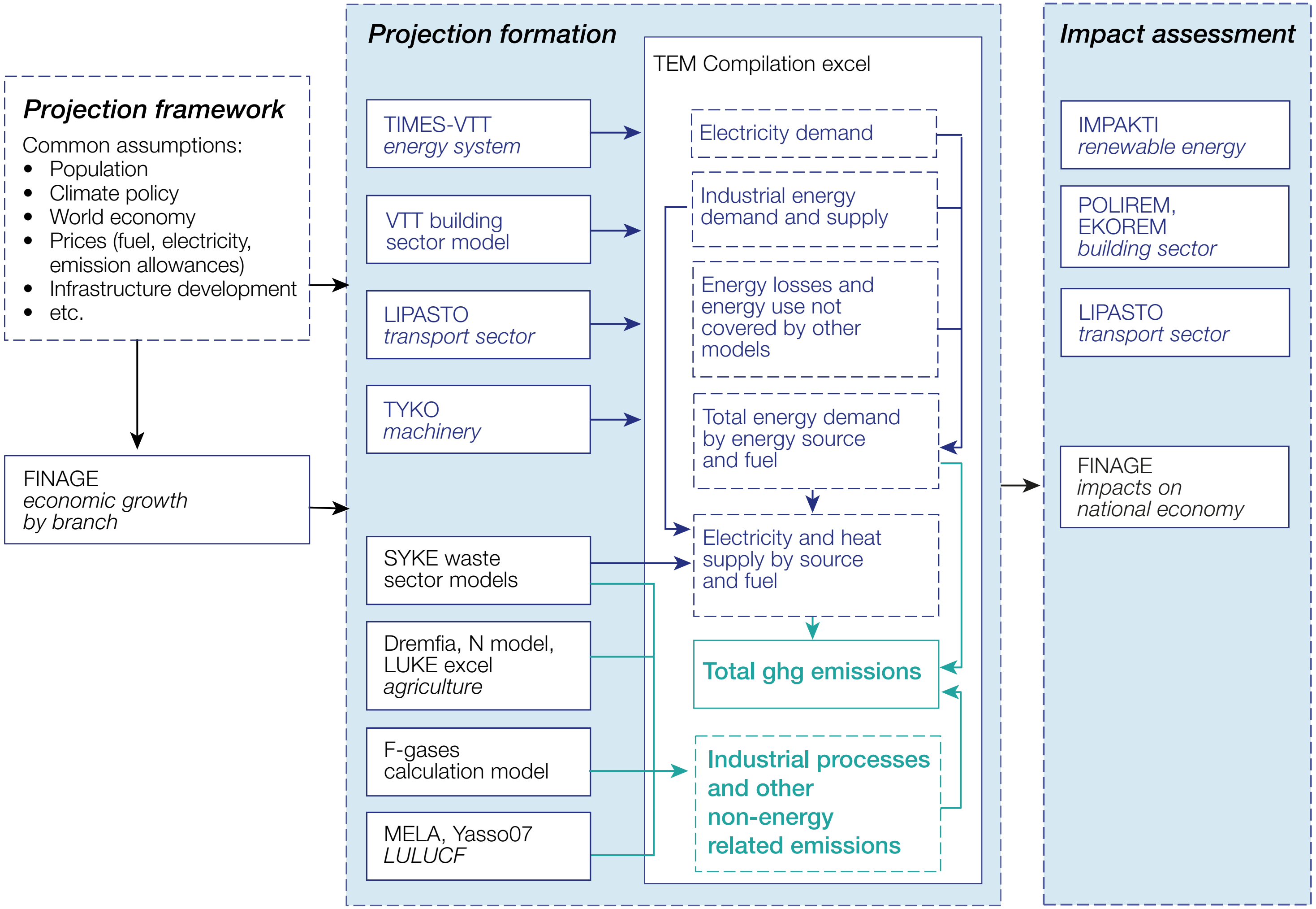
Assumptions and data sources for the different sectors are presented in more detail in the background reports that were prepared for the National Climate and Energy Strategy[16].

### 5.8.3 Description of models and methods

A fairly large number of models are applied for the preparation of the greenhouse gas emission projections and impact assessment of policy measures. The individual models that are central for energy and greenhouse gas emission projections are described in the sections below. The relationship and data flow between the different models is shown in Figure 5.6. Data from sector-specific models and studies are compiled by the Ministry of Economic Affairs and Employment in the module named "TEM Compilation excel" in Figure 5.6. The same Excel spreadsheet is used to calculate the projected energy balances and greenhouse gas emissions of the industry and the electricity and district heat production. The methodology for this is presented below under the Energy demand and production heading.

16 Koljonen, T. et al., 2021, 2022 https://publications.vtt.fi/pdf/technology/2022/T402.pdf https://urn.fi/URN:ISBN:978-952-383-257-2

**Figure 5.6**
Schematic diagram of the relationship and data flow between the different models applied in the projections and impact assessment of policy measures



### Buildings

The development of the energy consumption of the building stock has been modelled in accordance with the Long-term Renovation Strategy (LTRS)[14], which follows the EPBD 2018/844/EU revision and covers the 2020 existing building stock. The calculation of the goals of the LTRS and the data were created by VTT and SYKE experts. To implement the strategy in Finland, three key actions were identified: 1) removal of buildings and improving spatial efficiency; 2) improvements in energy efficiency in connection with maintenance and repairs; and 3) ceasing the use of fossil fuels in heat production. The guidance of the Energy Efficiency of Buildings Directive (EPBD) applies to residential and non-residential buildings in permanent use. Leisure, agricultural, industrial and storage buildings are therefore excluded.

The energy consumption scenario for buildings considers climate change, the removal of buildings, development of heating methods, repair measures and maintenance giving up the use of heating oil. The primary sources for the scenario are the data describing the building stock of Statistics Finland and energy certificates defined by Ministry of the Environment Regulation 1048/2017 of the register maintained by ARA.

The removal of buildings has been modelled by examining the life cycle of the building stock based on building register data. Based on this information, the expected service life has been calculated for buildings of different ages. The development of the strategy's heating methods was modelled[17] as part of the PITKO project[18] based on 2018 Statistics Finland data. The development of heating sources is based on the results of the TIMES-VTT optimisation model. The effect of global warming was considered in the strategy so that it reduced the heating energy demand of buildings and increased the cooling energy demand. The impact of repairs on the energy consumption of old buildings is based on energy efficiency improving measures in exterior envelope repairs and technical system repairs. The calculation assumes that terraced houses and apartment buildings will give up property-specific oil heating by 2030, and detached houses and non-residential buildings by 2050. It is assumed that fossil fuels and the electricity they consume will be replaced by heat pumps. An exception is that it is assumed that a small part of non-residential buildings will continue to be heated by oil. It is assumed that this oil heating will be completely covered by bio-oil in non-residential buildings in 2050. The Government Regulation[19] on energy subsidies for residential buildings from 2020 to 2022 has also been considered – it is assumed that a third of the energy savings will be realised as an improvement in structural energy efficiency, and two thirds through an increase in the use of heat pumps.

17 Kangas et al. 2020

18 Koljonen, T. et al. 2019, https://urn.fi/URN:ISBN:978-952-287-656-0

19 1341/2019

The methodology and modelling of the building sector projections described above are new for the Eighth National Communication. The building sector projections in the Seventh National Communication were based on modelling by the Finnish Environment Institute[20].

The impacts of policies and measures in the WM projection were estimated using the EKOREM and POLIREM models. The EKOREM[21] model is a bottom-up building stock calculation model developed by the unit of Construction Management and Economics at Tampere University of Technology and VTT Technical Research Centre of Finland. The calculation model is based on part D5 (2007) of the National Building Code of Finland: "Calculation of energy needs for heating of buildings". The model can be used to calculate energy consumption and greenhouse gas emissions and to analyse the energy savings and greenhouse gas emissions reduction potentials achieved by various policy scenarios. These scenarios can include building-related structural measures, as well as changes in the energy production structure. The model is further developed, and a calculation and visualisation approach for energy use and greenhouse gas emissions is presented.

In the EKOREM model, the building stock is divided into building-type categories like those used by Statistics Finland, so that official building statistics can be used as a basis for the calculations. Building stock data can further be divided into different age classes to better describe the methods of construction in different eras. The model includes a great deal of descriptive data such as U-values[22] for structures, technical specifications for ventilation, and information about electricity consumption. The model also includes heating system distributions for the different building types. These distributions and emission coefficients are used to determine greenhouse gas emissions ($CO_2$ eq.) for the studied building stock.

One of the main purposes of the model has been to produce assessments for the climate and energy policy reporting that show how developments in Finnish climate policies have affected the energy consumption and the greenhouse gas emissions of the Finnish building stock.

POLIREM is also a bottom-up building stock model. It covers less technical details than the EKOREM model. Instead, it considers the different primary energy sources in a more detailed manner than EKOREM. The POLIREM model uses official energy and building stock statistics of Finland and is suitable for analysing the impacts of policy measures on emissions, the use of renewable energy resources and the division of impacts between the ETS

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20 Mattinen, M. et al. 2016, https://helda.helsinki.fi/handle/10138/166673

21 Heljo et al. 2005

22 U-values (sometimes referred to as heat transfer coefficients or thermal transmittances) are used to measure how effective elements of a building's fabric are as insulators: how effective they are at preventing heat from transmitting between the inside and the outside of a building

and non-ETS sectors. These two modelling tools have been used for previous National Communications.

Strengths and weaknesses of the EKOREM and POLIREM models can be summarised as follows. Strengths include the following: (1) Strong methodological basis; (2) The data of the models is carefully selected from official statistics and research data, so that the model describes national conditions well; (3) Detailed technical characteristics are a strength of the bottom-up approaches, allowing the models to be used for examining various alternative technologies. Weaknesses include the following: (1) Insufficient information about changes in the heating method of old buildings and the selection of heating methods for new buildings; (2) Many default values and their updateability.

### Energy demand and production

The Ministry of Economic Affairs and Employment compiles the projections for energy production, using demand projections for each consumption sector as a basis. Except for the energy used by industry, households, and services, as well as the energy used for other smaller consumption purposes, the demand projections are produced by other organisations using the models described in this section. The energy demand projections for industry and services are determined by industrial production per product group (pulp and paper, basic metals), branch-specific economic growth (other industry, public, and commercial services), specific energy use trends, and expected energy efficiency improvements. The household projection is based on population and household forecasts. The demand projection assumptions are based on statistics, expert judgements, and surveys by consultants, research organisations, and branch organisations.

The global TIMES-VTT energy system model is the main tool for the energy system modelling. The energy needed from power and heat generation plants (main activity producer plants) is based on modelling the total electricity and heat demand, the calculated electricity and heat generated by the industry itself (auto-producer plants), as well as assumptions about electricity net imports. Information on existing and planned power plants and their possible dismantling and construction schedule respectively is used.

The TIMES-VTT model has been developed by VTT Technical Research Centre of Finland Ltd, which also runs the model and produces projections and analyses for the ministry. TIMES-VTT contains a detailed representation of the Finnish, Swedish, Norwegian and Danish energy systems and data on other countries in a more aggregated form. The model is based on the global ETSAP TIAM model, which was developed through international cooperation, building on the IEA ETSAP TIMES modelling system. Methodologically, it is a so-called partial equilibrium model, which maximises the total economic surplus of consumers and producers. The model includes detailed descriptions of both the current system of energy production and consumption and future technologies in terms of several different investment options. The TIMES-VTT model's strength lies in its sector integrating and holistic modelling ability as well as in the model's large geographical coverage. The TIMES-VTT model's extensive database contains a detailed description of the current energy system, including the energy production and distribution system, building stock, energy uses in housing and services, the stock of cars and other vehicles, processes and plants for manufacturing energy-intensive industrial products, other industrial energy end uses, as well as energy use in agriculture and forestry. The model database also covers estimates for energy system removals such as removals from energy production plants, buildings and vehicles. However, the downside is that largest part of the database naturally consists of technological descriptions of investment options and assumptions in future energy systems, including estimated trends in their costs and technical performance (energy production efficiencies, service life, usability, etc.). The model also depicts regional technical potential of energy commodities, the global fuel trade, emissions trading, including trade in $CO_2$ transport and storage services. The TIMES-VTT model and its databases have been discussed in several scientific articles[23]. Finally, energy sector $CO_2$ emission projections are obtained by multiplying the fuel consumption of different fuels by the corresponding emission factors. Historical emissions and amounts of fuel are used to calculate $CH_4$ and $N_2O$ emissions.

As for policy measures, the IMPAKTI calculation tool[24] is used to calculate the emissions mitigation impact of measures that promote the use of renewable energy. The IMPAKTI calculation tool assumes that forest chips, wind power, and biogas from digesters will not be used without existing policies and measures. The aggregated impact of policies and measures promoting the use of these energy sources is therefore estimated based on energy production (wind power and biogas plants) or fuel use (forest chips) and the assumptions concerning the energy source that is being replaced by the renewable energy source. It is assumed that forest chips will mainly replace peat in power and heat production and other fuels to a small extent. For agricultural farms, it is assumed that the use of forest chips will replace light fuel oil. It is assumed that the electricity produced by renewable energy sources (wind, biogas) will mainly replace marginal electricity, i.e. electricity produced by condensing power plants using fossil fuels or peat. However, as these marginal production modes may not be in operation at each point of time, it is assumed that the production of electricity using renewables may also replace other electricity generation modes or electricity imports. The emission factor used for replaced electricity (600 t $CO_2$/GWh) is therefore smaller than the emission factor used for electricity production in condensing power plants that use fossil fuels or peat (an average of 850 t $CO_2$/

23 Koljonen, T. & Lehtilä, A. 2012, https://www.sciencedirect.com/science/article/pii/S0140988312001053?via%3Dihub#ec0005

24 Lindroos, T. J. et al. 2012, https://www.vtt.fi/inf/pdf/technology/2012/T11.pdf

GWh). The emission factor for electricity defined in the IMPAKTI calculation tool (600 t $CO_2$/GWh) is also used to estimate the mitigation impact of the energy efficiency measures presented in Chapter 4. Strengths of the IMPAKTI model include the strong methodological basis, consisting both of scientific knowledge and up-to-date understanding of the developments in the policy area, transparency owing to the relatively simple methodology and suitability to the national circumstances. A weakness of the model is the lack of disaggregated impact by policy and measure. Due to strong interlinkages of policies and measures promoting renewable energy, the approach used in IMPAKTI would not produce meaningful results for disaggregated policies and measures.

### Transport

The transport sector projections are compiled using the LIPASTO calculation system, which is also used to estimate emissions for the greenhouse gas inventory (see Finland's National Inventory Report for a description of the methodology). The LIPASTO calculation system[25] includes five sub-models: LIISA for the road transport inventory; ELIISA for road transport scenarios; RAILI for the railway inventory; MEERI for the waterborne transport inventory; and TYKO for the non-road mobile machinery inventory. LIPASTO models are updated and compiled by VTT Technical Research Centre of Finland. Since 2022, the road transport scenarios are being calculated using a new stand-alone model called ELIISA, which is an upgraded version of its predecessor ALIISA. ELIISA computes the development of the vehicle fleet, kilometrage, consumption, and GHG emissions (includes $CO_2$, $CH_4$, and $N_2O$) until 2050. ELIISA considers all possible powertrain options for vehicles in Finland. The changes in the vehicle fleet are based on the estimated annual sales of new vehicles and imported vehicles and the vehicle scrappage rate. Fuel and energy consumption estimates are based on actual fuel sales.

One of the strengths of the LIPASTO submodels is that the method is compliant with the 2006 "IPCC Guidelines for National Green House Gas Inventories" and the EMEP/EEA's "Emission Inventory Guidebook". However, the transport sector is changing rapidly, e.g. as a result of the electrification of traffic. As technical calculation models, LIPASTO's sub-models do not necessarily fully take into account rapid economic changes in an up-to-date manner which is their weakness (see also Section 3.2.5.2 in Finland's National Inventory Report 2022).

The kilometrage projections for transport are based on the national projections modelled by Finnish Transport and Communications Agency. Since the national projection is produced only every four years, and road transport scenarios produced typically once a year, the national kilometrage projection is implemented through vehicles' average annual kilometrage (estimated per vehicle type, for passenger vehicles, also per powertrain, as in the national

25 http://lipasto.vtt.fi/en/inventaarioe.htm

kilometrage projection). As vehicle fleet estimates change, road transport kilometrage estimates therefore also change and may not fully match the national projection.

In rail transport, the kilometrage development forecasts are based on the estimates given by the Finnish State Railways, VR Ltd. The developments in emission coefficients are based on research carried out at VTT and in other countries. The projection for waterborne transport emissions is based on estimates by the Finnish Transport Agency. The future development of the emissions coefficients for navigation is based on estimates and research results from other countries.

### Machinery

Emissions for machinery are estimated with the TYKO model[26] which is part of LIPASTO. TYKO is a deterministic model that gives results of emissions and the amounts of fuels used. The emissions for the following gases are calculated: carbon monoxide (CO); hydrocarbons (HC); nitrogen oxides ($NO_x$); particles (PM); methane ($CH_4$); nitrous oxide ($N_2O$); sulphur oxide ($SO_2$); carbon dioxide ($CO_2$). The period of the calculations is 1980 to 2040, and the model includes 50 types of machinery.

The calculation is based on the following key elements: performance and related emission factors (g/kWh); and fuel usage (g/kWh). For example, the method is widely used in the Nonroad model used by the US EPA (Environmental Protection Agency) and the CORINAIR Off-Road vehicle and Machines model. It has been adjusted for Finnish circumstances, e.g. the age and attrition of the machinery. The method is compliant with the 2006 "IPCC Guidelines for National Green House Gas Inventories" and the EMEP/EEA's "Emission Inventory Guidebook" which is one of its strenghts. The TYKO model is the only machinery-model of its kind in Finland, but it needs renewal. The typical usage of machinery in different sectors is estimated based on secondary data; more research is needed to improve model assumptions, as usage of machinery is a key factor affecting the model's output. The model also needs technical improvements: the extension of the time series until 2060 and inclusion of CNG-powered, hybrid, and electric machinery. Development funds have been granted, and it is planned that the development project will begin at the end of 2022.

### F-gases

The F-gas emission projections (including HFCs, PFCs, and $SF_6$) are prepared by the Finnish Environment Institute.

The total F-gas emission projections are sums of the subsector emission scenarios. The F-gas emission sectors are: refrigeration and air-conditioning equipment; foam blowing and the use of foam products; aerosols; electrical equipment; and

26 TYKO model http://lipasto.vtt.fi/inventaario.htm (in Finnish), a part of the LIPASTO http://lipasto.vtt.fi/en/inventaarioe.htm (in English)

grouped emission sources (e.g. fixed firefighting systems and semiconductor manufacturing). The calculation model[27] for F-gas emissions and emission projections in the refrigeration and air conditioning equipment sector (CRF 2.F.1) are part of the official Finnish GHG emission inventory reporting system. The model has 15 different subsectors (equipment types), and the total F-gas emissions of sector 2.F.1 are sums of the subsector emissions. Each of the 15 subsectors is linked to one of the six 2.F.1.a-f reporting sectors under the UNFCCC GHG inventory reporting. The model covers 1990 to 2050. The emissions estimation methodology in the model is the Tier 2 emission factor approach of the 2006 IPCC Guidelines (Volume 3, chapter 7.5).

Emission projections of F-gas sectors other than refrigeration and air-conditioning equipment (CRF 2.F.1) are calculated in separate simplified Excel spreadsheet calculation modes and are based on the calculation spreadsheets used in GHG emission inventory reporting.

A particular strength of the calculation model is that the emissions of the future years are also calculated with the same methodologies within the same model as the historical years. Whenever the emission calculation of the historical years is updated, the effects to the emission projections are visible in real time. The greatest challenges in the emission projections are related to defining the predicted future refrigerant shares and filling rates and leakage rates in different applications.

### Agriculture

An economic model and several greenhouse gas calculation models were used to compile the projections for the agricultural sector ($CH_4$, $N_2O$). Natural Resources Institute Finland has prepared the projections for the agricultural sector.

Future agricultural production intensity was estimated using the Dremfia[28] agricultural sector model, which considers the prices of agricultural inputs and outputs and agricultural policy. The model has frequently been used to evaluate the impacts of agricultural and agri-environmental policies. The model has therefore also been continuously updated and revalidated based on the available statistical information about input and output prices, food consumption, use of inputs, production, land use, and productivity in agriculture. The parameters and principles of agricultural policy have been updated annually, as well when necessary. The results from Dremfia were fed into the calculation models, which are used for the greenhouse gas emission inventory (see the National Inventory Report for details). Dremfia produced most of the input data for the greenhouse gas modelling: the area

27 Finland's NIR (Chapter 4.7.2) contains a detailed description of the calculation model.

28 Lehtonen, H. & Niemi, J.S. (2018) Effects of reducing EU agricultural support payments on production and farm income in Finland, https://doi.org/10.23986/afsci.67673

of cultivated farmland; the use of mineral fertilisers; and the numbers for the most important animal species in agriculture. In addition, the development of some variables (not included as such in the Dremfia model) in the future was estimated using expert judgements: the area of organic soils; the spread of manure management systems; and developments in the weight of cattle and N excretion of animals. It was assumed that the number of horses, sheep, fur animals, reindeer, and turkeys would remain stable.

Strengths and weaknesses of the Dremfia model can be summarised as follows. Strengths include the following: (1) Regional disaggregation of the model is well suited for analysing effects of agricultural policy; (2) The data of the model is carefully selected from official statistics and research data so that the model includes relevant country specific bio-physical and economic relationships; (3) The model allows simultaneous imports and exports of the same commodity (Armington assumption); (4) The model includes endogenous technological and structural change of dairy sector which accounts approximately 50 per cent of the value of production; (5) Flows of nitrogen and phosphorous are very close to published studies on nutrient balances.

Weaknesses include the following: (1) Some sensitivity of crop area allocation on exogenous EU prices; (2) almost entirely exogenous food demand per capita; (3) fully exogenous farmland area per region; (4) adding new products to the model requires a lot of data and validation work, and (5) The model excludes horticulture, reindeers, fur animals, horses, lambs and goats.

The method and assumptions were done in the same way in previous National Communications. The method makes it possible to consider all measures that are related to agricultural policies, and it produces time series that are consistent with the reported emissions.

### Waste

The Finnish Environment Institute calculates the projections for the waste sector. The waste scenarios are based on statistics and modelling following IPCC guidelines. The scenario tool is thus primarily an emissions calculation model, which is complemented by expert judgements on how rapidly the measures will affect the waste sector. The same basic modelling tool has been used for previous National Communications.

The scenario calculations are based on assumptions concerning developments in the amount of waste related to standard population projections and the rate at which different waste treatment facilities are introduced. The modelling deals separately with solid municipal waste, municipal sludge, industrial sludge, industrial solid waste, and building waste. Different treatments are considered separately (landfilling, biological treatment, incineration, recycling). Emissions from wastewater treatment, composting, and anaerobic digestion are dealt with separately, and methane collection from landfills is also considered. $CH_4$

and $N_2O$ emissions are treated separately. After the waste amounts have been defined, the greenhouse gas emissions are calculated according to the IPCC instructions and the methods used in the Finnish inventories.

The modelling builds on aggregating information for the waste sector, and there are therefore only limited opportunities to project the detailed effects of individual policy measures in terms of emissions reductions. There has thus far been only limited information about the costs and benefits of the measures included in the analyses. There are no direct overlaps with projections from other sectors, as the projections of the waste sector do not include emissions from waste incineration, which are reported in the energy sector.

### LULUCF

The LULUCF projection is a compilation of the projections for different land-use categories and harvested wood products (HWP). Projections are prepared for forest land, cropland, grassland, wetlands, and settlements. The emissions ($CO_2$, $CH_4$, $N_2O$) and removals ($CO_2$) are estimated and calculated using several models and GHG inventory calculation procedures modified for projections. Natural Resources Institute Finland has prepared the projection.

To produce the emission projections, areas for each land use and land-use change category were estimated applying trends in land-use changes based on historical GHG inventory data complemented the policy targets – for example, the increase in afforestation. The land-use input from the agricultural and energy sectors was considered. The area needed for peat extraction was based on the TIMES-VTT modelled peat consumption for energy. New land areas required for the construction of wind power and solar-power plants were also based on TIMES-VTT modelling. The applied method is developed for LULUCF scenario work[29].

The development of forest resources was estimated using MELA software. The modelled results on tree biomass stocks, harvest volumes of commercial timber and energy wood, and natural mortality were used to estimate $CO_2$ emissions and removals of trees. Roundwood demand was determined from the wood consumption of the forest industry and production volumes (see Section 5.1). The demand for and consumption of wood energy use was derived from the TIMES-VTT energy system model results. Annual carbon stock change in living tree biomass was estimated as a difference between tree biomass stocks in two sub-periods divided by 10 years (which is a sub-period of the total calculation period). The change in biomass is converted to carbon multiplying by 0.5. This differs from the method applied in the GHG inventory, in which a gain – loss method is applied. The MELA model also provided the input data for the Yasso07 soil model[30] (carbon stock changes in mineral forest soils)

29 Haakana et al. 2015
30 https://en.ilmatieteenlaitos.fi/yasso

and $CO_2$ emission calculation from drained peat forest soils. $N_2O$ and $CH_4$ emissions from soils were calculated using the GHG inventory methodology.

MELA has a long development history, starting with being an analysis tool for wood production potential. It is currently a tool for forest resource modelling, used for policy support and decision making at national and regional levels. The MELA programme has two parts: 1) an automated stand simulator based on individual tree growth and development models; and 2) an optimisation package based on linear programming. National forest inventory data are used to establish the initial state for the modelling. It is possible to incorporate climate scenarios into the programme. For these projections, the effects of changes in historical long-term temperature and $CO_2$ concentration on the increment of trees are included. MELA is developed for Finnish conditions and uses several country-specific models applying Finnish forest management recommendations. Due to optimisation, MELA seeks the best solution to reach the target. Compatibility with the historical GHG inventory data may therefore be weak.

Strengths of the MELA include: (1) For the initial stage of the modelling, the measured regional National Forest Inventory data on forest resources are used; (2) Measured individual tree-level data is the base for modelling; (3) The applied growth models are calibrated employing the measured increment tree of NFI data; (4) The long term growth indices are used to eliminated occasional interannual variability, for example, due to weather factors; (5) The family of integrated growth models is well documented[31]; (6) The optimization problem and decision variables can be defined by the user; (7) The model produces the input data for the soil modelling.

Weaknesses include: (1) Creation of the initial data from the NFI data is time-consuming; (2) Novel forest practices can easily be implemented into the management selection, but the lack of appropriate growth models is the limiting factor; (3) The use of growth indices can also be seen as a weakness, if in a long term there is a change in the growth trend, but at the same time the use of growth indices prevents temporary changes in growth to impact too much on future growth trend in scenario. (4) The method applied to estimated future carbon stock changes in tree biomass is based on the MELA results on tree biomass stocks for 10 years sub-periods (national biomass models are applied in MELA). The annual change in biomass was estimated as a difference between two sub-periods divided by 10. A gain - loss method is applied in the GHG inventory: tree volume increment and total drain are converted to biomass by biomass expansion and conversion factors computed from the data measured in the NFI. In theory, if the GHGI method would be applied to the scenario data, the result should be the same as the stock change method produces. In practice, these two methods have given different history results. Thus, there is in consistency between scenario and historical data.

31 Hynynen et al. 2002, http://urn.fi/URN:ISBN:951-40-1815-X

The projections for cropland and grassland were produced with the GHG inventory methods, including the use of the Yasso07 soil carbon model for mineral croplands. The Dremfia agricultural sector model provided input data for the modelling. For some new policy measures which are not yet included in the GHG inventory, either national research-based or IPCC emission factors were used. This applies mainly to new measures for agricultural land. Yasso07 is a dynamic model for cycling the organic carbon in mineral soils. The model was applied for forest land, cropland, and land-use transition areas in the same way as in the GHG inventory.

The HWP projection was estimated with a model modified from the production-approach-based GHG inventory HWP model (see National Inventory Report, Chapter 6.11). The assumed production of the forest industry (see above) was an input in the model.

### *Main differences in the LULUCF projection in the current NC8 compared to the NC7*

Changes in assumptions and methods have been applied in the projection estimation due to model development and changes in the GHG inventory methods.

Updated assumptions on
- production of the forest industry
- harvest rates for commercial wood and energy wood
- development of land use and land-use changes, including afforestation and deforestation
- prices of timber assortments and costs of silviculture in MELA

Changes in methods:
- The development of forest resources was modelled with MELA2016, whereas the MELA2012 version was used for NC7. The main changes were: (1) the growth calibration model for trees was modified to better fit the new increment data measured by the National Forest Inventory (NFI); (2) simulations for the previous projections produced a higher stem number and volume for small trees, meaning a high natural mortality rate for small trees for the first years of the simulations as well. This part of the modelling was modified to better match the natural mortality measured in the NFI. Other changes can be found in the MELA2016 Reference Manual[32].
- The proportion of cutting waste of harvest removal was calibrated based on the 12th NFI.
- The SF-GTM model was not used to estimate wood use and demand.

32 Hirvelä, H., Härkönen, K., Lempinen, R., & Salminen, O. (2017) MELA2016 Reference Manual. Natural Resources Institute Finland (Luke). 547 p. URN: http://urn.fi/URN:ISBN:978-952-326-358-1

In the NC7 projection, the LULUCF's sink decreased from the reported 26.0 million tonnes of $CO_2$ eq. to close to 4 million tonnes of $CO_2$ eq. in 2025 and 2030. In the new projection, the net sink is 23 and 21 million tonnes of $CO_2$ eq. respectively. The main reason is the forest projections, but it is impossible to specify the reasons and effect of different components. Presumably, the changes in MELA modelling are an important factor.

### Economic effects

FINAGE is a dynamic applied general equilibrium (AGE) model of the Finnish economy. FINAGE is based on the MONASH model developed at the Centre of Policy Studies. MONASH-style models are used in countries ranging from China and South Africa to the United States and Australia[33]. In Europe, models based on MONASH have been developed for Denmark, Finland, and the Netherlands. VATTAGE, a precursor of FINAGE, is described in detail in Honkatukia (2009).

Several factors explain the popularity of MONASH. The main ones are the advanced and user-friendly software packages that facilitate data handling and the setup of complicated policy simulations, and that also allow a very detailed post-simulation analysis of simulation results. MONASH-type models are also very adaptable to analyses of different types of policies and different timeframes. In a forward-looking policy analysis, MONASH-type models offer a disciplined way to forecast the baseline development of the economy. Last, but not least, they also allow the user to replicate and explain the historical development of an economy in greater detail, which is not true for most AGE models.

In FINAGE, there are normally three types of inter-temporal links connecting the consecutive periods in the model: (1) the accumulation of fixed capital; (2) the accumulation of financial claims; and (3) lagged adjustment mechanisms, notably in the labour markets and for balancing the public sector budgets. Together, these mechanisms result in gradual adjustments to policy shocks to the economy. In the model, capital is sector-specific, which means it takes time for an industry to adjust to the increased energy costs caused by emissions trading and increased energy taxes. In energy-intensive industries, a rise in energy costs lowers the return on capital, which slows down investments until a new equilibrium is reached. In other industries, similar effects are caused by a rise in domestic energy taxes. However, some industries gain from the subsidies granted to renewable energy, and even in energy-intensive industries, subsidies can dampen the rise in costs if they can substitute renewable energy for fossil fuels. The model assumes sluggish real-wage responses to policy shocks. Real wages will adjust sluggishly to deviations from the expected equilibrium wage growth, with the result that in the short run, adjustments will occur partly through increased unemployment levels. In the long run, wages will adjust fully to one-off shocks, and full employment will be restored. However, in the case of gradually tightening emissions targets, the shocks are not one-off, implying sustained above-equilibrium unemployment rates.

33 Dixon and Rimmer 2002

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