5

PROJECTIONS AND TOTAL EFFECTS 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 2030. 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.

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5 PROJECTIONS AND TOTAL EFFECTS OF POLICIES AND MEASURES

5.1 Overview of WM and WAM projections

The projections presented in this chapter are based on the National Energy and Climate Strategy for 2030 and the Medium-term Climate Change Policy Plan. The Energy and Climate Strategy was presented by the Government in November 2016. The Medium-term Climate Change Policy Plan was approved in September 2017. The projections were formulated in 2016 and 2017 by a working group consisting of experts from ministries that are central to Finland's climate policy.

The 'With Measures' projection (WM) describes a development in which the energy and climate related policy measures already implemented and adopted are continued. The WM projection represents a development path that would be likely to take place if no new energy or climate policy measures were adopted. Most of the measures included in the WAM projection of the Sixth National Communication have been implemented and are now part of the WM projection. The most significant new, implemented policy measures affecting future emissions compared to the Sixth National Communication are a regulation ensuring improvements of energy and resource efficiency in renovation and alteration of buildings and a new regulation reducing the amount of organic waste disposed to landfills.

In previous National Communications it has been assumed that Finland will be self-sufficient in electricity on a yearly basis from 2020 onwards. During the last years domestic conventional generation capacity has, however, been shut down and while Finland is part of the integrated Nordic-Baltic electricity market self-sufficiency in electricity supply is no longer a feasible aim nor a reasonable assumption. This change in the assumptions affects the emission projections (both WM and WAM projections) by cutting and smoothening out the total emissions.

The 'With Additional Measures' projection (WAM) includes a set of cost-efficient additional energy and climate policy measures that the Government has agreed upon in order to attain the targets specified in the Government Programme and adopted in the EU for 2030.

The WAM projection includes new measures particularly to reduce the use of fossil fuels, to promote renewable energy, to improve energy efficiency as well as to further reduce greenhouse gas emissions in the non-energy sectors. These WAM measures are described in Chapter 4.

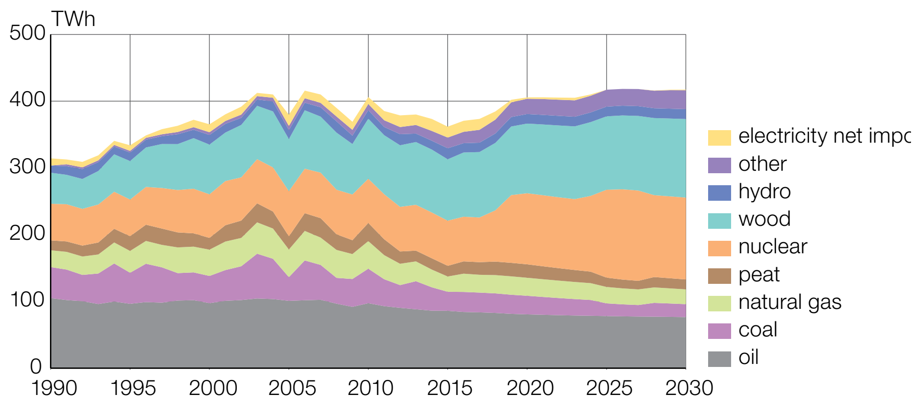
Economic growth and the change in the structure of the economy play a key role in the estimation of energy consumption and emissions. The rate of economic growth is determined by the growth rates of labour input and average labour productivity. In the long term, economic growth is determined almost solely by the growth of labour productivity, because labour input cannot grow without bounds. In the short and medium term, however, factors affecting labour input growth matter, too, because changes in labour input affect directly the potential output of the economy. In Finland, the ageing population is the single most significant factor in terms of its effect on labour input and thus 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 population forecast of Statistics Finland is used in the projections. It estimates that the population will increase from the current 5.5 million to 5.9 million by 2035. The average size of households will decrease slightly, while the number of households is expected to grow from 2.6 million to 3.0 million during the period.

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 a study published by the VATT Institute for Economic Research[1].

In 2016, the Finnish economy returned to a growth path after a long period of recession that began in 2009. The growth has been driven by increase in private consumption and recovery of public and private investment. Foreign trade still accounts for a very significant share of total output, even though the level of exports has not yet returned to the same level as in years preceding the global recession in 2009. The Finnish economy has experienced a structural change in the 2010s, where the role of services has increased and traditional industries have been forced to adapt to changes in global demand and competition. The Government is carrying out major reforms in order to cut expenditures of the public sector and to bring the Finnish economy onto a path of sustainable growth and higher employment. The impact of the reforms is included in the economic growth assumptions of the WM and WAM projections. Due to the Government's reforms the economic growth expectation after 2020 is clearly higher than in the assumptions used in the Sixth National Communication. The starting level is due to the prolonged recession, however, lower. The economy is expected to reach the same level as in the projections of the Sixth National Communication around 2030.

Gross final energy consumption is leveled off in the projections as a result of increased energy efficiency in all sectors. The WAM projection includes additional energy efficiency measures particularly in transport, but also an increased energy use in biorefineries. Altogether the gross final consumption level is therefore about the same in the WAM projection as in the WM projection – just over 310 TWh in the 2020s. Nevertheless, the energy related emissions are substantially lower in the WAM projection. The lower emissions are the result of policy measures that replace fossil fuels with renewables and electricity.

Figure 5.1
Historical development (1990 to 2015) and WM projection (up to 2030) of the primary energy supply, TWh



1 http://vatt.fi/suomen-talous-2015-2030-laskelmia-politiikkatoimien-vaikutuksista

Despite the flat final consumption projection the primary energy consumption varies clearly in the projections. The main reason for this is the substantial changes in domestic nuclear power production (increase in late 2010s and mid-2020, decreases in the late 2020s), which replaces or is replaced by electricity import. Expressed in primary energy, the value of nuclear power is three-fold that of imported electricity, despite the same amount of electricity fed to consumption. The development of the primary energy supply in the WM projection is shown in Figure 5.1.

Table 5.1 shows a summary of the main assumptions of the WM projection for 2016 to 2030. Numerical values for key variables and assumptions are presented in Section 5.8. The assumptions regarding international fuel prices on the world market are consistent with the estimates of the International Energy Agency (IEA 2015).

Table 5.1
Assumptions of the WM projection

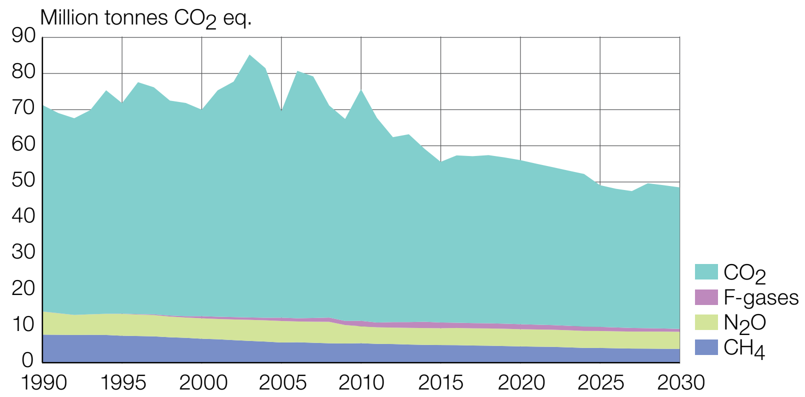
Parameter	Trend 2016–2030
GDP growth	2.3 per cent annually
Structure of economy	Increasing share of services
Structure of industry	Less capital and energy intensive
Population growth	Increasing 0.4 per cent annually
Population structure	Ageing
Technology development	Gradual introduction of improved and more energy efficient technology

5.2 'With Measures' projection

5.2.1 Total effects

Total emissions in the WM projection for the years 1990 to 2030 are shown in Figure 5.2 (total emissions without the LULUCF sector)[2] and Table 5.2 (without and with the LULUCF sector). Compared with the base year of 1990, the total greenhouse gas emissions without LULUCF are projected to be 21 per cent lower in 2020 and 32 per

Figure 5.2
Greenhouse gas emissions without LULUCF by gas according to the latest greenhouse gas emission inventory (1990 to 2015) and the WM projection (up to 2030), million tonnes CO_2 eq.



2 Unless otherwise specified, total emissions refer to total national emissions without LULUCF

Table 5.2
Greenhouse gas emissions according to the most recent inventory data (1990 to 2015) and the WM projection (2020 to 2030)

	GHG emissions and removals (kilotonnes CO_2 eq.)								
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Sector									
1. Energy	53,558	55,328	53,755	53,715	60,166	40,816	41,441	34,870	34,509
2. Industrial processes and product use	5,370	4,914	5,827	6,497	6,260	6,076	6,349	6,471	6,493
3. Agriculture	7,525	6,838	6,466	6,457	6,576	6,481	6,611	6,446	6,378
4. Land use, land-use change and forestry(5)	–12,672	–12,369	–21,710	–27,068	–27,297	–25,991	–10,644	–4,274	–4,221
5. Waste	4,672	4,596	3,850	2,823	2,583	2,134	1,629	1,311	1,112
6. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO
Gas									
CO_2 emissions without net CO_2 from LULUCF	56,949	58,124	57,026	57,031	64,007	44,382	45,392	39,204	39,157
CO_2 emissions with net CO_2 from LULUCF	41,466	43,026	32,679	27,473	34,449	16,205	33,168	33,495	33,514
CH_4 emissions without CH_4 from LULUCF	7,746	7,448	6,614	5,576	5,373	4,875	4,498	4,069	3,817
CH_4 emissions with CH_4 from LULUCF	9,285	8,903	7,963	6,783	6,352	5,795	4,771	4,208	3,952
N_2O emissions without N_2O from LULUCF	6,377	6,040	5,660	5,956	4,696	4,659	4,757	4,700	4,727
N_2O emissions with N_2O from LULUCF	7,649	7,314	6,948	7,239	5,979	5,925	6,064	5,996	6,013
HFCs	0	27	559	892	1,485	1,547	1,343	1,085	751
PFCs	0	0	13	16	1	7	4	4	4
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	52	37	26	22	22	38	36	37	38
NF_3	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	71,125	71,676	69,899	69,493	75,585	55,507	56,031	49,098	48,493
Total (with LULUCF)	58,453	59,307	48,189	42,425	48,288	29,516	45,387	44,825	44,272
Indirect CO_2 emissions	165	129	104	85	69	52	NE	NE	NE
Total (without LULUCF, with indirect)	**71,291**	**71,805**	**70,003**	**69,578**	**75,654**	**55,559**	**NE**	**NE**	**NE**
Total (with LULUCF, with indirect)	**58,618**	**59,436**	**48,293**	**42,510**	**48,356**	**29,568**	**NE**	**NE**	**NE**

NO = not occurring, NE = not estimated
1) Indirect emissions are not included in the above emissions/removal estimates by sector and gas

cent lower in 2030. Correspondingly, the CO_2 emissions are projected to be 20 per cent lower in 2020 and 31 per cent lower in 2030. CH_4 emissions are expected to continue to decline steadily being 42 per cent lower in 2020 and 51 per cent lower in 2030 than in 1990. N_2O emissions are projected to remain at current levels, which is one fourth lower than in 1990. The amount of emissions from F-gases is small and expected to decrease in the coming years.

The split of greenhouse gas emissions between the EU ETS sector and the non-ETS sector is illustrated in Figure 5.3. The emissions in the EU ETS sector have reached their peak in the mid-2000s and are expected to decline further. In 2015, emissions in the EU ETS sector counted for 46 per cent of the total greenhouse gas emissions, whereas the non-ETS sector counted for 54 per cent. 2015 was warmer than average years, which reduced the heating demand and lowered the emission level of the EU ETS sector more than the emission level of the non-ETS sector. The split between EU ETS and non-ETS sector emissions is expected to remain roughly in the same order of magnitude during the current and next decade even though a slightly slower decline in the non-ETS emissions is expected.

The emissions from the non-ETS sector have steadily decreased since 2005 and the decrease is expected to continue (Figure 5.4). In the WM projection, the emissions from the non-ETS sector in 2020 are 15 per cent and in 2030 22 per cent below the 2005 level when taking into account the change of scope of the EU ETS. The development of the

Figure 5.3
The split of greenhouse gas emissions between the EU ETS sector and the non-ETS sector (2005 to 2015) based on the latest greenhouse gas inventory and the WM projection (up to 2030). The development of the total emissions without the LULUCF sector is also presented.

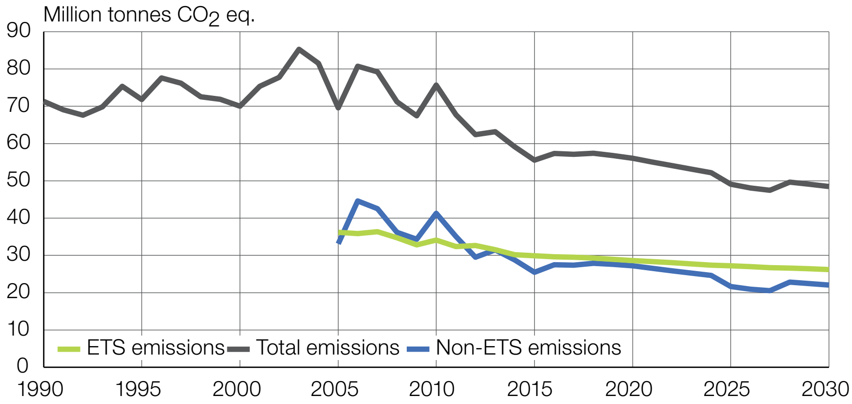
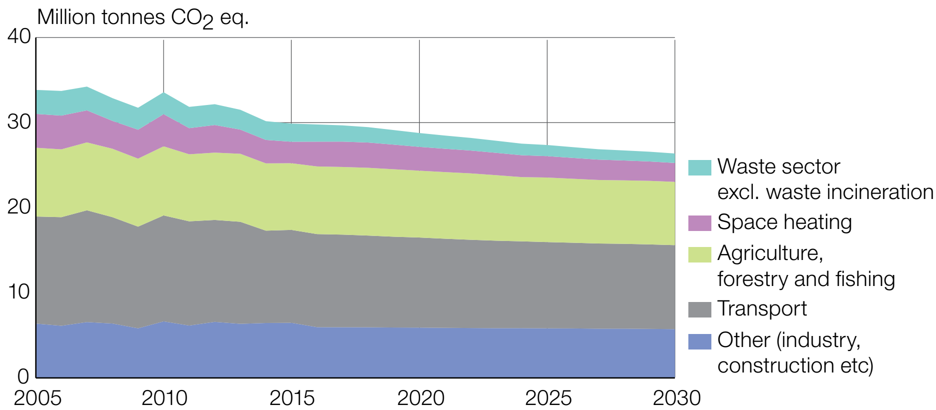


Figure 5.4
Emissions in the non-ETS sector (corresponding to EU ETS scope of 2013) by category (2005 to 2015) based on the latest greenhouse gas inventory and the WM projection (up to 2030)



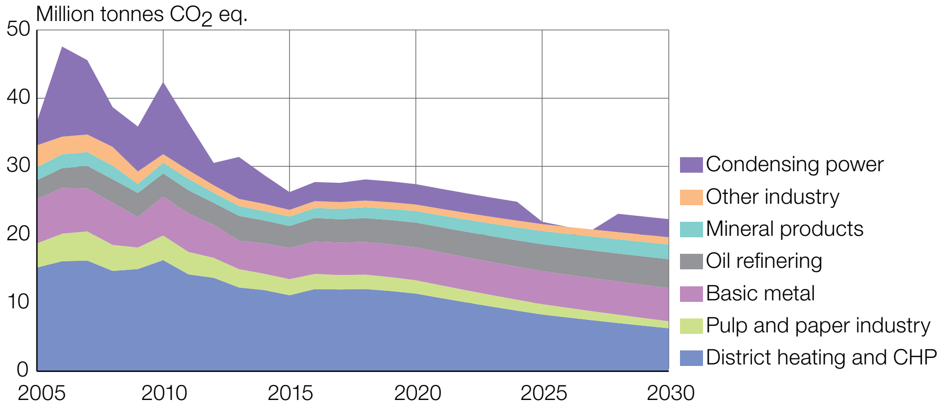
emissions by branch in the EU ETS sector for the years 2005 to 2030 is illustrated in Figure 5.5. The curves include both energy and process related emissions from sources included in the EU ETS in 2013.

The development of total emissions with regard to the number of inhabitants, primary energy use and economic development is presented in Table 5.3.

Table 5.3
Greenhouse gas emission intensity based on the latest greenhouse gas inventory for 2010 to 2015 and the WM projection for 2020 to 2030

	2010	2015	2020	2025	2030
Emissions per capita, tonnes CO_2 eq. /capita	14.1	10.1	10.0	8.5	8.3
Emissions per GDP, kg CO_2 eq./EUR	0.40	0.30	0.32	0.25	0.22
Emissions per primary energy, tonnes CO_2 eq./MWh	0.19	0.15	0.14	0.12	0.12

Figure 5.5
Emissions in the EU ETS (corresponding to EU ETS scope of 2013) sector according to the greenhouse gas inventory (2005 to 2015) and the WM projection (up to 2030)



5.2.2 Sectoral emissions

Energy

The energy sector is strongly affected by policy measures to reduce the emissions, to enhance energy efficiency and to increase the share of renewable energy sources. Both the supply and demand sides are facing significant changes, part of the changes results from policy measures, part from technological development and development of the energy and fuel markets. As many of the changes involve or concern investments like power plants, the effects are robust and long lasting.

In the WM projection, the most significant future changes in electricity and heat production are the startup in 2018 of a 1600 MW nuclear power plant unit currently under construction, one additional nuclear power plant unit in the mid-2020s and the increase in the use of renewable energy sources, mainly wind power and biomass in CHP plants. All these changes reduce emissions. In the WM projection, Finland remains a net importer of electricity during the projected period except for a few years right after mid-2020s when Finland can be self-sufficient in power supply. During that period the generation from the new nuclear and wind power plants is expected to replace some domestic conventional power generation resulting in a reduction of domestic greenhouse gas emissions.

Factors affecting the future energy demand are first of all energy efficiency measures, but also the economic development and structural changes within the industry. According to the WM projection, energy used for heating of residential and service sector buildings is decreasing even though the volume of buildings is expected to increase continuously. The emissions from space heating are decreasing even faster than the energy demand due to the increased use of renewable energy. District heat production from heat-only plants is expected slightly to increase its share at the expense of combined heat and power production, which is struggling with the feasibility due to low electricity prices.

The historical and projected emissions from the energy sector (excl. transport) in the WM projection are presented in Table 5.4. 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 belong to the EU Emission Trading Scheme (see Figure 5.5).

Table 5.4
Historical (1990 to 2015) and projected (2020 to 2030) 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
Total emissions, million tonnes CO_2 eq.	41.3	43.8	41.5	40.6	47.3	29.6	30.7	24.6	24.5
CO_2	40.7	43.2	40.8	39.9	46.5	28.9	29.8	23.7	23.6
CH_4	0.3	0.2	0.2	0.2	0.3	0.2	0.4	0.4	0.4
N_2O	0.4	0.4	0.5	0.5	0.6	0.5	0.5	0.5	0.5

Historically, district heating emissions have varied according to the heating demand (cold or warm winters). The emissions from condensing power have varied strongly depending on the hydro situation in the Nordic electricity market. Future years are in the projections assumed to be standard years (i.e. long-term average plus impact of climate change) with respect to heating demand and hydro levels. Full load hours equaling average historical figures are assumed for condensing power. In reality, the emissions will continue to vary from one year to another but to a lesser extent due to decreased specific emissions in both district heat and power generation. The CO_2 emissions from both district heating and industrial energy use are declining steadily in the WM projection.

The importance of CH_4 and N_2O emissions within the energy sector is quite 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 small.

The development of emissions outside the EU ETS is presented in Figure 5.4 above. 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 decline from 2 million tonnes CO_2 eq. to 1.4 million tonnes CO_2 eq. in 2030. The emissions from machinery are expected to remain approximately at their current level, i.e. 2.4 to 2.5 million tonnes CO_2 eq., even though the use of machinery is expected to increase over time. The reasons for this favourable development are more efficient equipment and a more efficient use of the equipment. Also the emissions from non-ETS industrial energy use stay around the current level of 0.6 million tonnes CO_2 eq. in the WM projection despite an increase in activity. The energy-related emissions from agriculture and forestry are today 1.4 million tonnes CO_2 out 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 1.1 million tonnes CO_2 eq. The expected energy savings from energy advice within agriculture are 24 GWh/a and the corresponding CO_2 emission reductions 6 kt/a in 2020. In 2030, the estimated energy savings impact is 40 GWh/a and emission reductions 10 kt/a assuming same activity levels beyond 2020.

Transport

The WM projection for the transport sector includes all of the measures that were already being used within the transport sector to cut down on emissions in June 2016 (see also Section 4.5.2).

According to the WM projection, even though the total vehicle mileage will increase, the emissions are expected to decline by 2020 (Table 5.5). The emission reductions will be achieved by domestic and EU-wide policy measures, including promoting of the use of biofuels, improving vehicle technology and renewing the vehicle fleet, as well as by improving energy efficiency and directing the growth in passenger traffic volumes to more environmentally friendly transport modes. It is assumed that the use of biofuels will increase to a total of at least 13.5 per cent of the road transport fuels sold in 2020 and that the growth in transport performances will remain at a moderate level, i.e. 0.5 to 1.5 per cent annually.

Table 5.5
Historical (1990 to 2015) and projected (2020 to 2030) 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
Total emissions, million tonnes CO_2 eq.	12.1	11.3	12.1	12.9	12.7	11.1	10.8	10.3	10.0
CO_2	11.8	11.1	11.9	12.8	12.6	11.0	10.6	10.2	9.9
CH_4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Industrial processes and other product use

The main factors affecting the development of emissions from industrial processes and product use include changes in industrial production and measures applied for reducing emissions. The global recession reduced the emissions from the sector in 2009, after which they have stayed at an approximately 20 per cent lower level compared to the peak year 2008.

In the WM projection the emissions are expected to increase slightly until mid-2020s as industrial production increases (Table 5.6). CO_2 emissions from industrial processes are mainly caused by the manufacturing of iron and steel, cement, lime and hydrogen. N_2O emissions will be small, only 0.2 million tonnes CO_2 eq. in 2020, and they will also slightly increase towards the year 2030.

Table 5.6
Historical (1990 to 2015) and projected (2020 to 2030) 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
Total emissions, million tonnes CO_2 eq.	5.4	4.9	5.8	6.5	6.3	6.1	6.3	6.5	6.5
CO_2	3.7	3.4	3.9	4.0	4.6	4.2	4.7	5.1	5.4
CH_4	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0
N_2O	1.7	1.5	1.4	1.6	0.2	0.3	0.2	0.2	0.3
	0.1	0.1	0.6	0.9	1.5	1.6	1.4	1.1	0.8

The WM projection for F-gases includes the impacts of the EU regulation on F-gases[3] and the EC directive relating to emissions from air-conditioning systems in motor vehicles[4]. Emissions from refrigeration and air-conditioning equipment are expected to decline as a result of these measures and technical changes leading to smaller charges and decreased leakage. Emissions from electricity distribution equipment have declined heavily as a result of voluntary actions of the industries. A slight increase of emissions is assumed in the future but the peak level of emissions in the 1990's will not be reached.

3 2014/517/EU
4 2006/40/EC

Restrictions forced by the EU regulation have a decreasing effect on emissions from foam blowing, aerosols and other sources. The emissions from foam blowing and aerosols are expected to decrease in the future. The emissions from other sources are expected to stay quite steady. Emissions from refrigeration and air-conditioning equipment account for more than 90 per cent of Finnish F-gas emissions, and therefore, the projected overall emission trend is declining.

Emissions from solvent and other product use are expected to remain at their present level according to the WM projection.

Agriculture

In recent years, the changes in the emissions from agriculture have been small. Under the WM projection, the emissions are expected to increase slightly (two per cent between 2005 and 2020), as nitrogen (N) and organic soils are estimated to be increasing sources (Table 5.7).The decline in livestock numbers and N fertilization will slightly lower the total emissions after 2020 and the total greenhouse gas emissions from agriculture will be one per cent lower in 2030 compared to 2005.

Energy-related emissions related to agriculture are reported in the energy sector and not included in Table 5.7.

Table 5.7
Historical (1990 to 2015) and projected (2020 to 2030) 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
Total emissions, million tonnes CO_2 eq.	7.5	6.8	6.5	6.5	6.6	6.5	6.6	6.4	6.4
CO_2	0.6	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2
CH_4	2.8	2.5	2.5	2.5	2.6	2.6	2.6	2.5	2.4
N_2O	4.1	3.9	3.6	3.6	3.7	3.7	3.8	3.7	3.7

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 5.8).

Table 5.8
Historical (1990 to 2015) and projected (2020 to 2030) 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
Total emissions and removals, million tonnes CO_2 eq.	–12.7	–12.4	–21.7	–27.1	–27.3	–26.0	–10.6	–4.3	–4.2
CO_2	–15.5	–15.1	–24.3	–29.6	–29.6	–28.2	–12.2	–5.7	–5.6
CH_4	1.5	1.5	1.3	1.2	1.0	0.9	0.3	0.1	0.1
N_2O	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3

The WM projection for forestry is based on the National Forest Strategy (NFS) 2025, which estimates that the carbon sink of forests (including trees and soil but excluding HWP) will remain at a level of at least 13.5 to 20 million tonnes CO_2 eq. per annum during the period 2025 to 2030. The estimate is based on the assumption that loggings will increase by 10 to 15 million cubic metres per year and that the use of wood for bioenergy will continue as defined in the national long-term climate and energy strategy and the NFS.

The government and stakeholders will continue to carry out joint initiatives to promote the use of wood as a renewable material that also contributes to climate change mitigation.

The impact of harvested wood products on emissions varies annually. In the most recent inventory, harvested wood products were estimated to be a sink of 2.3 million tonnes CO_2 eq in 2015.[5] In the WM projection, the HWP sink has been assumed to remain at the 2015 level during 2020 to 2030.

With regard to agricultural soils, CO_2 emissions and removals from croplands and grasslands are not expected to be subject to large changes by the year 2030 according to the WM projection.

Waste

Greenhouse gas emission projections for the waste sector include CH_4 from landfills, CH_4 and N_2O emissions from biological treatment of waste and CH_4 and N_2O emissions from wastewater treatment. Projections for the waste sector do not include emissions from waste incineration, which are reported in the energy sector. According to the WM projection, greenhouse gas emissions from the waste sector will decrease (Table 5.9). The main reason for this is the implementation of the Landfill Directive[6] and national legislation[7] and strategies aimed at reducing the amount of waste and minimising the amount of waste disposed at landfills.

Table 5.9
Historical (1990 to 2015) and projected (2020 to 2030) greenhouse gas emissions from the waste 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
Total emissions, million tonnes CO_2 eq.	4.7	4.6	3.9	2.8	2.6	2.1	1.6	1.3	1.1
CH_4	4.6	4.5	3.7	2.7	2.5	2.0	1.5	1.2	1.0
N_2O	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

CH_4 emissions will decline significantly in the WM projection: by the year 2020, they will be approximately one third the amount they were in the year 1990. This trend will also continue after 2020, and emissions in 2030 are projected to be about two thirds of the 2020 level.

N_2O emissions from biological treatment of waste were 0.04 million tonnes CO_2 eq. and from waste water treatment 0.08 million tonnes CO_2 eq. in 2015. In the WM projection these emissions are expected to remain at approximately the current level up to 2030.

International bunkers

According to the most recent greenhouse gas emission inventory, the fuel consumption for international aviation was 26,818 TJ and for international marine transportation 11,832 TJ in 2015. The annual growth rate by 2030 is estimated at 2 per cent for international marine transportation and 3 per cent for international aviation. Based on these assumptions and using the emissions in 2015 as the basis, the total greenhouse gas emissions from bunker fuels are projected to be 3.3 million tonnes CO_2 eq. in 2020 (1.0 million tonnes

5 HWP figure is presented here as according to the Convention reporting.
6 Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste
7 Government Decree on Landfills 331/2013

CO_2 eq. from marine and 2.3 million tonnes CO_2 eq. from aviation bunkers). The corresponding total estimate for 2030 is 4.3 million tonnes CO_2 eq. (1.2 million tonnes CO_2 eq. from marine and 3.1 million tonnes CO_2 eq. from aviation bunkers).

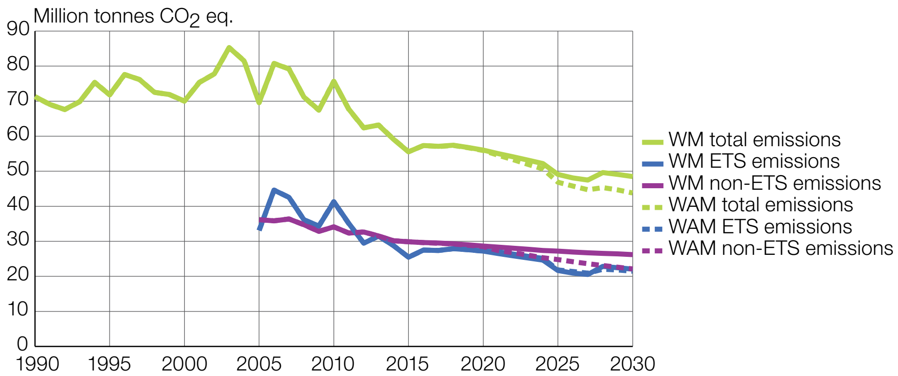
These projected emissions of marine and aviation bunkers do not take into account the impact of the measures presented in Table 4.6 which aim at improving energy efficiency and increasing the use of alternative fuels.

5.3 'With Additional Measures' projection

With the existing policy measures Finland is on track to meet its 2020 emission reduction and renewable energy targets. The effect of the additional measures is aimed at the 2020s and in full at the year 2030 at the latest. 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 is not known have not been included in the WAM projection. These are 1) phasing out oil heating in the public sector, 2) reducing emissions from machinery by improving energy efficiency and promoting the use of alternative fuels or power sources, and partly 3) promoting the use of biogas.

The effect of the policies and measures included in the WAM projection on the total greenhouse gas emissions is illustrated in Figure 5.6. Continuous lines portray the WM projection and dashed lines the WAM projection.

Figure 5.6
Greenhouse gas emissions in EU ETS and non-ETS sectors in the WAM projection (dashed lines) compared to the WM projection (solid lines) in the years 2016 to 2030 and historical emissions for 1990 to 2015 based on the most recent inventory



The total greenhouse gas emissions in 2030 are estimated to be 48 million tonnes CO_2 eq. in the WM projection and 44 million tonnes CO_2 eq. in the WAM projection. The additional emission reduction measures in the WAM projection will mainly affect the non-ETS sector.

Table 5.10 presents a summary of the WAM projection emissions and the difference between them and the emission levels in the WM projection.

In the building sector, additional measures are under preparation. Nearly zero-energy (NZEB) regulations for new buildings will come in force in 2018. According to the National Energy and Climate Strategy for 2030 is an obligation to blend 10 per cent of bioliquids into light fuel oil used for heating of buildings. A decision of the types of

Table 5.10
Greenhouse gas emissions on a gas-by-gas basis for the WAM projection and difference between them and the WM projection in 2020 to 2030, million tonnes CO_2 eq. (the greenhouse gas emissions in 2010 and 2015 are based on the most recent inventory and shown for comparison)

	2010	2015	2020	2025	2030
CO_2	64.1	44.4	45.3	37.2	34.8
CH_4	5.4	4.9	4.5	4.1	3.8
N_2O	4.7	4.7	4.8	4.7	4.7
F-gases	1.5	1.6	1.4	0.9	0.5
Total	75.7	55.6	55.9	46.8	43.8
difference to WM			–0.1	–2.3	–4.7

policy instruments which are going to be applied to fulfil this PAM have not been made yet and these measures are therefore not yet included in the WAM projection.

In the transport sector, the estimated additional total emission reductions in the WAM projection are 2.8 million tonnes CO_2 in 2030. The potential emission reduction impact of promoting the use of biofuels (additional measure) in the WAM projection is 1.5 million tonnes CO_2 eq. in 2030 compared to the WM projection. The emission reduction effects of improving the energy-efficiency of vehicles (additional measures), should total some 1.0 million tonnes CO_2 eq. in 2030. The potential emission reduction impact of improving the energy-efficiency of the transport system (additional measure) is 0.3 million tonnes CO_2 eq. in 2030.

The WAM projection for F-gases is based on additional measures that are expected to promote the alternative low-GWP non-HFC technologies in the refrigeration and air conditioning equipment sector in addition to the F-gas regulation. These additional measures include criteria for public procurement related to F-gases and information and education campaigns. It is estimated that the emission reductions achieved by these additional measures will be 0.3 million tonnes CO_2 eq. in 2030.

In the waste sector, no significant additional measures are planned. The implementation of the existing measures will push the emissions to a very low level.

In the agricultural sector the estimated additional total emission reductions in the WAM projection are 0.5 million tonnes CO_2 eq. in 2030. The main reductions are based on activities planned to be put into practice on organic soils, for example by intensifying long-term grass cultivation and afforestation. The potential emission reduction impact concerning N_2O emissions is 0.45 million tonnes CO_2 eq. in 2030. Use of biogas produced in the agriculture sector to replace fossil fuels is a new measure which will reduce CH_4 emissions in the agriculture sector in 2030 by 0.05 million tonnes CO_2 eq and in the energy sector in 2030 by 0.3 million tonnes CO_2 eq.

Measures identified to reduce N_2O emissions from organic soils will have effects also on the CO_2 emissions from the LULUCF-sector.

5.4 Total effect of policies and measures

The aggregated estimates for the greenhouse gas reduction impacts of already implemented individual policies and measures presented in Chapter 4 are 12, 20, 34 and 42 million tonnes CO_2 eq. for 2010, 2015, 2020 and 2030 (without LULUCF), respectively. The planned measures will reduce greenhouse gas emissions increasingly in the 2020s reaching an additional annual reduction of 6.3 million tonnes CO_2 eq. in 2030. The total effect of the policies and measures by gas is shown in Table 5.11.

Table 5.11
The total effect of the policies and measures (PaMs) calculated based on estimated impact of PaMs (see Tables 4.3–4.11, excluding Table 4.7 and Table 4.10) for the year 2015, 2020 and 2030 (million tonnes CO_2 eq). The total emissions in 2015 based on the most recent inventory are also given for comparison.

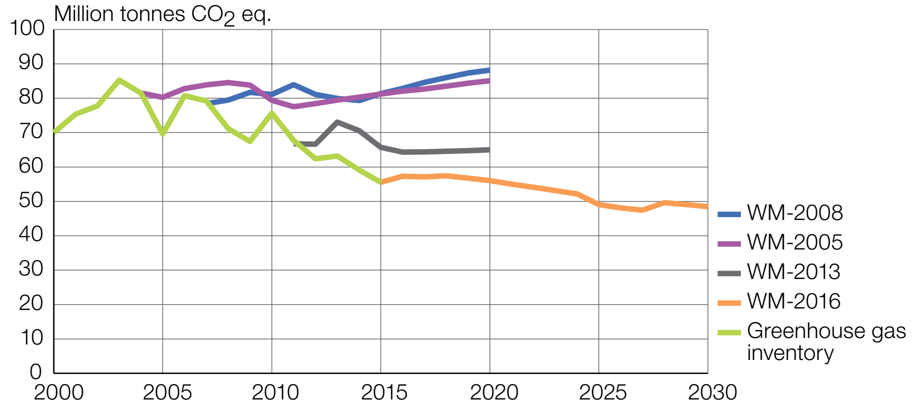
	Total emissions in 2015	Implemented measures			Planned measures		
		Total effect of PaMs in 2015	Total effect of PaMs in 2020	Total effect of PaMs in 2030	Total effect of PaMs in 2015	Total effect of PaMs in 2020	Total effect of PaMs in 2030
CO_2	44.4	18.8	28.9	36.2	0	0	5.5
CH_4	4.9	0	2.9	3.4	0	0.0	0.05
N_2O	4.7	0	0	0	0	0.0	0.5
F-gases	1.6	1.4	1.8	2.8	0.0	0.0	0.3
Total	55.6	20.2	33.6	42.4	0.0	0.0	6.3

The total effect of policies and measures contains noticeable uncertainties. The impact estimates of individual policies and measures are not 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 to for example in the case of simultaneous increase of biofuel content and energy efficiency in the transport sector and in heating. The mitigation impact has, however, not been estimated for all policies and measures. Consequently, the total emission reduction can be larger than the reported total effect.

Figure 5.7 shows Finland's greenhouse gas emissions in the WM projections in the last four national climate and energy strategies, i.e. strategies from the years 2005, 2008, 2013 and 2016. The WM projections in the previous national climate and energy strategies projected significantly higher emissions for 2015 than those reported in the latest greenhouse gas inventory. This suggests that the additional measures implemented in the 2010s have had a substantial impact on the total emissions.

The main difference between the projections shown in Figure 5.7 is that in the newest projection, many measures from previous WAM projections have been implemented and then included in the WM projection. Major additional measures that have been implemented since the Sixth National Communication concern energy efficiency improvements in the existing building stock and reduced deposition of biodegradable waste in landfills. The projections differ mostly compared to the previous National Communication in terms of waste treatment, road transport, space heating of buildings, and electricity supply. In

Figure 5.7
Greenhouse gas emissions according to the most recent inventory for 2000 to 2015 and in the WM projections of the climate and energy strategies published in 2005, 2008, 2013 and 2016 up to 2020 and 2030 respectively.



addition, the global recession and the structural adjustment of the Finnish forest industry have been taken into consideration in the 2013 and 2016 strategy but not in the previous ones. Finland is not, according to the energy and climate strategy from 2016, any longer aiming at self-sufficiency of electricity supply as there is no rational for it in a power market that is rapidly integrated regionally as well as on a European-wide level. Part of the condensing power assumed in the projections of earlier years is in reality substituted with electricity import. The current WM and WAM projections try to reflect the international electricity exchange in a realistic manner. Without an aim of self-sufficiency the domestic greenhouse gas emissions in electricity supply are somewhat lower and have smaller yearly variations.

The total effect of implementing additional measures can be seen in the emission development trend after 2015, which has levelled off in the 2013 and 2016 projections, whereas it continued to increase in the projections from 2005 and 2008.

In the current WM projection, the emissions in 2020 are projected to be about 35 per cent below the projected levels in 2005 and 2008 WM projections and 14 per cent below the 2013 WM projection.

5.5 Economic impacts

VTT Technical Research Centre of Finland Ltd has assessed the impacts of the policy measures[8] of the National Energy and Climate Strategy for 2030 on the energy system and national economy.

The impact assessment compares the impacts of the new policy measures of the WAM scenario to the development in the WM scenario. For the economic impact assessment, a dynamic applied general equilibrium model that describes the economy from the perspective of decisions made by households, companies and the public sector is used.

In the WAM scenario, reductions in greenhouse gas emissions will mainly be achieved by means of energy system and non-ETS sector measures. The impacts of emissions trading are already taken into account in the WM scenario. However, the structure of both the production and consumption change in the WAM scenario, which has an impact on the budgetary position of the public sector. In addition, the support required by biorefineries increases public expenditure, while the growing share of biofuels and a slower transport performance reduces the fuel tax accrual. In the modelling, it is assumed that budget neutrality is achieved by a small increase in commodity tax (for example, through value added taxation).

In addition to the impacts associated with central government finances, increasing the share of biofuels by means of the distribution obligation will also push transport costs up, as the price of renewable diesel is higher by some 33 cents/l than the price of fossil fuels. As an estimate, this would mean that with a blending ratio of 30 per cent, diesel users would incur an annual additional cost of EUR 200 million compared to the current prices. Similarly, replacing light fuel oil with bioliquids in heating and machinery will increase the users' costs. A blending ratio of 10 per cent in light fuel oil will increase the fuel oil price by some 6 cents/l, or 8 per cent. If the oil consumption of an oil-heated low-rise building is 3 000 l a year, the annual cost impacts will be approx. EUR 180 million. As regards machinery, the cost increase ensuing from the blending obligation would primarily affect businesses and agriculture. The increase in fuel oil costs will be approx. 8 per cent, or similar to the cost increase of oil heating. The absolute effects will, however, depend on company size and machinery use.

The impact of the WAM measures on the national economy in 2030 is shown in Table 5.12.

8 http://tietokayttoon.fi/julkaisu?pubid=16902

Table 5.12
The impact of the WAM measures on the national economy

	Change compared to the WM scenario, per cent	Impact on the domestic product compared to the WM scenario, percentage points
Domestic product	–0.59	
Private consumption	–0.40	–0.23
Investments	–0.85	–0.10
Public consumption	0.00	0.00
Exports	–1.75	–0.76
Imports	–1.33	0.49

The domestic product in 2030 is in the WAM scenario approx. 0.6 per cent smaller than in the WM scenario. This is caused by lower private consumption and investments than in the WM scenario and a slowing down of foreign trade. The decline in exports affects the domestic product most. On the other hand, imports also decline, which increases the domestic product.

While the change in employment in the national economy as a whole is put at -0.15 per cent, it is expected that primary production and energy supply sectors preserve their current employment levels.

More employment is created especially in the production of biofuels and bioenergy. The increase in the biorefining of forest raw materials (300 ktoe) increases employment by 2,000 person-years. In other biorefining sectors, the increase (300 ktoe) is estimated to be 150 person-years. It is expected that the 2 TWh increase in wind power capacity will create 400 person-years' worth of employment.

As coal use is phased out, chip and pellet boilers and heat pumps will replace coal in the heat production. The quantitative impact on employment is, however, difficult to estimate.

VTT has also assessed the economic impacts of the Medium-term Climate Change Policy Plan for 2030. The results on macroeconomic level are very similar to those of National Energy and Climate Strategy for 2030.

5.6 Sensitivity analysis of the projections

Energy use and hence the greenhouse gas emissions are sensitive for the assumptions made on economic growth. Sensitivity analysis has therefore been carried out for the WM projection varying the economic growth of industry and service branches as well as the building sector. No sensitivity analysis on the transport sector was made, but generally, a lower economic growth would have both a reducing and an increasing impact on the energy use for transport. On one hand, the need for transport is likely to be lower, but on the other hand, the renewal of the transport fleet slower. In the sensitivity analysis, the energy use in the transport sector is kept unchanged.

The manufacturing industry uses about 45 per cent of the country's final energy consumption and 47 per cent of the electricity. The forest industry has a significant impact on the energy sector, including renewable energy production, energy consumption and production. Iron and steel production is another energy-intensive branch, the development of which influences the projections noticeably. The energy balances projections of these branches are based on product group specific volume estimates. Both branches develop generally positively in the WM projection, even though some product groups continue to decrease (e.g. manufacturing of paper).

In the sensitivity analysis the annual growth of the volumes in forest industry and metal industry is 1 percentage point less than in the WM scenario from 2017 onwards.

This lower growth reduces the energy consumption in the forest and metal industry with 4 TWh in 2020 and 12 TWh in 2030 compared to the WM scenario. Corresponding values for electricity consumption reduction is 1 TWh in 2020 and 3 TWh in 2030. Both branches produce a part of their power themselves, so the net effect on the country's electricity balance is somewhat smaller.

A lower economic growth projection for the building sector has also been formed. The effect of a lower economic growth on construction and on the use of heating sources was assessed. The analysis is presented in a report published by the Finnish Environment Institute. Economic growth has a considerable influence on two factors, namely on renovation of existing buildings and on construction of new buildings. Economic growth affects indirectly also the demolition of buildings. In times with low economic growth there are less energy efficiency improvements done in existing buildings. On the other hand, the total building stock increases slower due to less construction activity, but at the same time fewer old and less energy efficient buildings are replaced. All in all, the energy demand of the building sector decreases slower in the projection with low economic growth than in the WM projection.

In addition to the branches and sectors mentioned above, the development of the other industry and service branches was varied by lowering the annual growths with 1 percentage point from the WM assumptions. No dynamic effects were taken into account. The overall effect of a lower economic growth results in a cease of the final energy consumption increase already after 2018. In 2030 the final energy consumption would be only 290 TWh and the total energy consumption 387 TWh. The greenhouse gas emissions would be 4 Mt CO_2 eq. lower than in the WM projection. Most of the emission reduction would, however, take place in the ETS sector, only 0.4 Mt CO_2 eq. in the non-ETS sector.

The main results of the sensitivity analysis are presented in Table 5.13.

Table 5.13
Main results from the sensitivity analysis on how the economic growth rate affects the overall energy balance and greenhouse gas emission

	2015	2020		2030	
	Historical	WM	Lower growth	WM	Lower growth
Primary energy consumption, TWh	363	407	398	418	387
Final energy consumption, TWh	294	311	303	313	290
Electricity consumption, TWh	82	88	85	91	85
Share of renewables in final energy consumption, %	39.3	43	43	47	47
GHG emissions, million tonnes CO_2 eq.	55.6	56	55	48	44
of which non-ETS emissions, Mt CO_2 eq.	29.9	29	29	26	26

5.7 Supplementarity relating to the Kyoto Protocol mechanisms

Finland's total greenhouse gas emissions in the 2008–2012 commitment period were 338,353,531 t CO_2 eq, approximately 5 per cent lower than the assigned amount, which was 355,017,545 tonnes CO_2 eq. Finland met its commitment by retiring 338,353,531 Kyoto Protocol units at the end of commitment period.

Of the total amount, 12,273,471 were CERs and 4,088,755 were ERUs. These Kyoto Protocol mechanisms units were units acquired by Finnish ETS operators which, according to EU ETS legislation, were entitled to cover a part of their EU ETS obligations through Kyoto Protocol mechanisms.

Finland did not retire any Kyoto Protocol mechanisms units to cover its emissions from non-ETS sector. The CERs and ERUs acquired through the Government purchase programme were carried over to the second commitment period of the Kyoto Protocol.

Finland has requested 14,018,572 AAUs, 6,798,242 CERs and 2,917,220 ERUs to be carried over to the second commitment period of the Kyoto Protocol. The AAU amount includes 10,000,000 AAUs transferred by the European Union from the Union Registry to Finland's holding account[9]. The transfer was made for the purpose of enabling Finland's compliance with its commitments in the second commitment period under the Kyoto Protocol after international LULUCF accounting rules were changed by Decision 2/CMP.7.

The estimated total effects of the policies and measures for 2020 mentioned in the Section 5.4 indicate that the Kyoto target for the second commitment period will be met entirely by domestic actions, and the possible use of Kyoto Mechanisms would be supplemental to domestic actions.

5.8 Methodology

5.8.1 Approach and responsibilities

The reported WM and WAM projections are integrated energy and climate projections that were originally compiled in 2016 for the preparation of the National Energy and Climate Strategy for 2030.The preparation of the strategy was coordinated by the Ministry of Economic Affairs and Employment under the Ministerial Working Group on Bioeconomy and Clean Solutions.

The basis for the projections is a projection framework describing the future development of central factors and circumstances affecting the projections. The framework as well as sector-specific key assumptions and policy measures are described in the background report to the National Energy and Climate Strategy. The ministries most involved in preparing the framework and projections were the Ministry of Economic Affairs and Employment, the Ministry of the Environment, the Ministry of Transport and Communications, the Ministry of Agriculture and Forestry, and the Ministry of Finance.

The sectoral projections and calculations were made by various experts within the contact network set up by the main ministries involved in drafting the climate policy. The ministries have consulted expert organisations for acquiring data, assessments of policies and measures and modeling of sector-specific projections. Following authorities and expert organisations contributed to the reporting in 2017: the Energy Authority, Finnish Environment Institute (SYKE), VTT Technical Research Centre of Finland Ltd, Motiva Ltd, Tampere University of Technology, Natural Resources Institute Finland, Finnish Transport Safety Agency, VATT Institute for Economic Research, Benviroc Ltd and Statistics Finland.

The main models and methods used in the work are briefly described in Section 5.8.3. 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 regarding fuel and carbon dioxide emissions in the energy production sectors as a whole; it was also responsible for coordinating the calculations. The Ministry of the Environment was responsible for the projection regarding space heating, for the analysis of the regional and urban structure, and for emission projections and calculations for waste and machinery. The duty of the Ministry of Transport and Communications included making

9 Commission Implementing Decision 2014/224/EU

projections for fuel and electricity usage as well as emissions from the transport sector. 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.

5.8.2 Assumptions underlying calculations

A summary of key variables and assumptions is presented in Table 5.14.

Finland's population will increase from the current 5.5 million to about 5.9 million by the year 2035. The age structure of the population will change significantly over the next couple of decades as the share of older age groups increases. The number of households is expected to increase from the current 2.6 million to approximately 3.0 million by 2035. At the same time, however, the average size of households will decrease. The number, structure and location of households will have an impact on the energy demand.

The GDP is assumed to increase in the coming years. In the projections the annual growth during 2016 to 2020 is on average 1.6 per cent. In the 2020s the growth will be higher, 2.6 per cent per annum on average, as the Government's reforms are starting to pay off and the competitiveness of the Finnish economy increases.

The activities that will sustain most growth in production in the 2020s are expected to be machinery and equipment manufacturing, forest industry, and financial and insurance business.

The international fuel price estimates are taken from the IEA's World Energy Outlook publication (IEA 2015). The price of crude oil is assumed to be USD 80/barrel in 2020 and USD 113/barrel in 2030. The price of natural gas is the corresponding years assumed to be USD 27/MWh and USD 38/MWh, respectively. Emission allowance prices are expected to rise in 2020 to EUR 15/ t CO_2 and in 2030 to EUR 30/t CO_2. The primary energy by source, the energy sources for district heat and combined heat and power production, the electricity supply and the energy sources in the transport sector are presented in Tables 5.15–5.18.

Table 5.14
Key variables and assumptions used in the projections analysis for 1990 to 2030

		Historical						Projected		
	Unit	1990	1995	2000	2005	2010	2015	2020	2025	2030
Population	Million inhabitants	4.99	5.11	5.18	5.25	5.38	5.50	5.63	5.75	5.85
Gross Domestic Product	Million EUR, 2010 prices	126,000	123,000	158,000	180,000	187,000	187,000	201,000	229,000	260,000

Table 5.15
Primary energy by energy source and gross final energy in 2010, 2015 and in the WM projection for 2020 to 2030, TWh

	2010	2015	2020	2025	2030
Oil, incl. bio-fraction	97	86	81	78	77
Hard coal	40	17	15	11	7
Coke, blast furnace and coke oven gas	12	11	15	16	17
Natural gas	41	23	27	25	22
Nuclear energy	66	68	106	114	123
Net imports of electricity	11	16	2	2	1
Hydropower	13	17	14	15	15
Wind and solar power	0	2	5	6	7
Peat	27	16	20	17	15
Wood fuels	90	92	104	111	118
Others	10	15	15	16	17
Total energy consumption	407	363	407	411	418
Final energy consumption	319	294	311	312	313

Table 5.16
Energy sources for district heat and combined heat and power production in 2010, 2015 and in the WM projection for 2020 to 2030, TWh

	2010	2015	2020	2025	2030
Hard coal	14	12	10	5	2
Oil	3	1	1	1	1
Natural gas	23	11	12	10	8
Peat	12	9	12	9	8
Wood fuels	12	16	20	25	29
Other renewables	1	2	4	4	4
Other	2	3	3	4	5
Total	66	54	63	59	57

Table 5.17
Electricity supply in 2010, 2015 and in the WM projection for 2020 to 2030, TWh

	2010	2015	2020	2025	2030
Hydro power	13	17	14	15	15
Wind and solar power	0	2	5	6	7
Nuclear energy	22	22	35	43	40
CHP, district heat	18	13	15	13	12
CHP, industry	10	8	11	12	12
Condensing power	14	4	tot. 7	tot. 1	tot. 6
Net imports	11	16			
Total supply	88	82	88	89	91

Table 5.18
Energy sources in transport in 2010, 2015 and in the WM projection for 2020 to 2030, TWh

	2010	2015	2020	2025	2030
Motor gasoline, fossil	18	16	14	12	11
Diesel fuel, fossil	27	24	24	24	24
Liquid biofuels	2	6	6	6	5
Electricity	0.7	0.7	0.8	1.0	1.2
Other	4	3	3	3	3
Total	51	49	48	46	45

In the transport sector, greenhouse gas emissions are influenced by a decline in specific energy consumption and, in particular, by an increased share of biofuels. It is estimated that the share of bio-based road transport fuels will increase to 13.5 per cent in 2020 and remain at this level thereafter.

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. Several new waste incineration plants have been constructed in recent years and in 2015 the incinerated amount was already more than 900,000 tonnes. The WM projection estimates that from 2020 onwards, the amount of municipal waste incinerated at waste incineration plants will be more than 1,240,000 tonnes per annum. In addition, co-incineration plants are expected to use 420,000 tonnes of waste-based fuels annually. Currently waste co-incineration is included in the emissions trading sector. The transfer of all waste incineration to the emission trading sector will be explored.

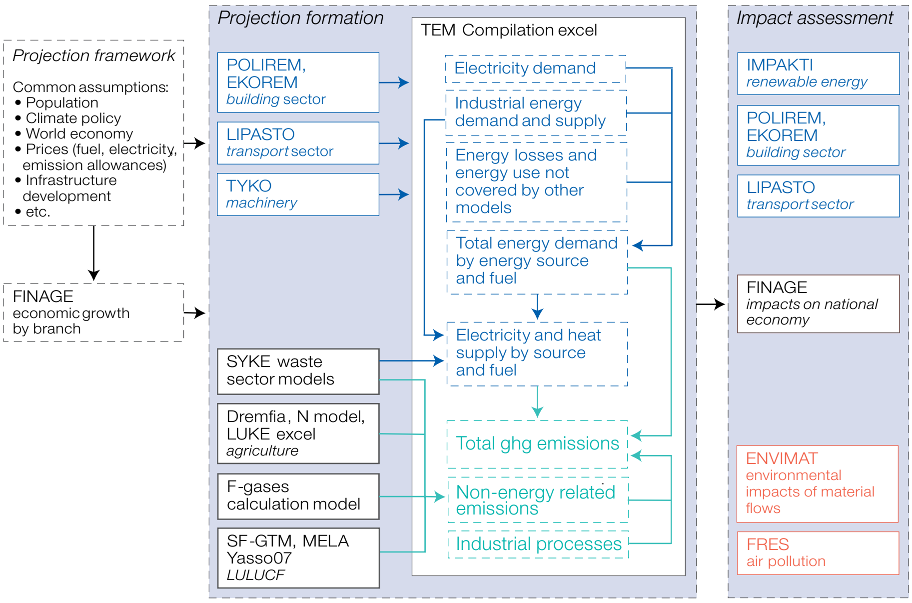
Assumptions and data sources for the different sectors are presented in more detail in the background report that was prepared for the National Energy and Climate Strategy for 2030.

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 for impact assessment of policy measures. 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 5.8. Data from sector specific models are compiled by the Ministry of Economic Affairs and Employment in the module named 'TEM Compilation excel' in Figure 5.8 The same excel is used for calculating 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 heading 'Energy demand and production'.

In addition to using advanced sector-specific models, the quality of the projections, including correct treatment of overlapping emission reduction measures, is ensured to the largest possible extent by the methodology used. Firstly, the projection results from all sector specific models are brought together to the TEM Compilation excel together with the most recent inventory data which enables direct comparison of historical and projected emissions. Secondly, the energy related CO2 emissions are not calculated until the final stage in the compilation excel from fuel-specific energy amounts forming the energy balance time series of the whole country. By this, double-counting of emission reductions can be efficiently avoided.

Figure 5.8
Schematic diagram of the relationship and data flow between the different models applied in the projections and impact assessment of policy measures.



Buildings

The impacts of policies and measures in the WM projection were estimated using EKOREM and POLIREM models. The EKOREM model is a bottom-up building stock calculation model developed by the unit of Construction Management and Economics at Tampere University of Technology and Technical Research Centre of Finland VTT Ltd (VTT). The calculation model is based on part D5 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 also to analyse the energy savings and greenhouse gas emission reduction potentials achieved by different 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 visualization approach for energy use and greenhouse gas emissions is presented.

In the EKOREM model, the building stock is divided into building type categories, which are similar to 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[10] 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 takes into account 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 well suited to analysing the impacts of policy measures on emissions, the use of renewable energy resources and the division of impacts between the ETS and non-ETS sectors. These two modelling tools have been used for previous National Communications

Energy demand and production

The Ministry of Economic Affairs and Employment prepares the projections for energy production using demand projections for each consumption sector as a basis. With the exception 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 and the extensive surveys made by Adato Energy on electricity use in different households. The demand projection assumptions are based on statistics, expert judgements and surveys by consultants, research organisations and branch organisations.

The energy needed from power and heat generation plants (main activity producer plants) is based on the total electricity and heat demand, the calculated electricity and heat generated by the industry itself (auto producer plants), as well as on assumptions about electricity net imports. Information on existing and planned power plants and their possible dismantling and construction schedule, respectively, is used. Studies including extensive market simulations performed by Pöyry Management Consulting Oy in 2016 have been used for the projections of electricity and district heat supply.

CO_2 emission projections are obtained by multiplying fuel consumption by the emission factors. Historical emissions and amounts of fuel are used for calculating CH_4 and N_2O emissions.

10 U-values (sometimes referred to as heat transfer coefficients or thermal transmittances) are used to measure how effective elements of a buildings fabric are as insulators. That is, how effective they are at preventing heat from transmitting between the inside and the outside of a building

The IMPAKTI calculation tool is used for calculating the emission mitigation impact of measures promoting the use of renewable energy (presented in Chapter 4). The IMPAKTI calculation tool is based on the assumption that forest chips, wind power and biogas from digesters will not be used without existing policies and measures. Therefore, the aggregated impact of policies and measures promoting the use of these energy sources is estimated based on the energy production (wind power and biogas plants) or fuel use (forest chips) and the assumptions about 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, to a small extent, other fuels. 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 for 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 can also replace other electricity generation modes or electricity imports. Therefore, the emission factor used for replaced electricity (600 t CO_2/GWh) is smaller than the emission factor used for electricity production in condensing power plants that use fossil fuels or peat (on average 850 t CO_2/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 energy efficiency measures presented in Chapter 4.

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 includes four submodels: LIISA for road transportation, RAILI for railways, MEERI for waterborne transport and ILMI for air traffic. LIPASTO is compiled and updated by VTT Technical Research Centre of Finland. The ILMI submodel is compiled and updated by the Finnish Aviation Administration. Since 2015, the road traffic submodel LIISA includes also a more detailed template for calculating the projections and implications of alternative powertrain and energy options called ALIISA. The LIPASTO model covers emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), particles (PM), methane (CH_4), nitrous oxide (N_2O), sulphur dioxide (SO_2) and carbon dioxide (CO_2). The mileage projections for road transport are based on the Finnish Transport Agency's base forecast, but re-adjusted by VTT in 2015, as described in Section 4.8. With this re-adjustment, the fuel consumption was assumed to decrease by 3.5 per cent in vehicles using both petrol and diesel yearly. The changes in the vehicle fleet are taken into account based on the estimated annual sales of new vehicles and the scrappage rate, being for cars about 7 per cent of the fleet size and corresponding to an average vehicle age of 11 to 12.5 years. In rail transportation, the mileage 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 regarding future emissions from aviation is based on assumptions about the growth in the number of commercial flights and improvement rates for the energy efficiency of aircraft engines. 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 TYKO-model which is part of the LIPASTO model. 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 (NOx), Particles (PM), methane (CH_4), nitrous oxide (N_2O), sulphur oxide (SO_2), carbon dioxide (CO_2). The time period of the calculations is 1980-2040 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). The method is widely used, for example, in the Non-Road model used by US EPA (Environmental Protection Agency) and in the CORINAIR Off-Road Vehicle and Machines model. It has been adjusted to Finnish circumstances, e.g. for age and attrition of the machinery. The method is in compliance with 2006 IPCC Guidelines for National Greenhouse Gas Inventories and EMEP/EEA Emission Inventory Guidebook.

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 as follows: refrigeration and air conditioning equipment, foam blowing and use of foam products, aerosols, electrical equipment and grouped emission sources (e.g. fixed firefighting systems and semiconductor manufacturing). A completely new calculation model for F-gas emissions and emission projections in the refrigeration and air conditioning equipment sector was built during 2016. The model covers the years 1990 to 2050 and is divided into fifteen different subsectors (equipment types). The emissions estimation methodology in the model is the Tier 2 emission factor approach of the 2006 IPCC Guidelines (Volume 3, Section 7.5).

Agriculture

An economic model and several greenhouse gas calculation models were used to compile the projections for the agriculture sector (CH_4, N_2O) and croplands and grasslands in the LULUCF sector (CO_2).

Future agricultural production intensity was estimated using the agricultural sector model Dremfia, which takes into account the prices of agricultural inputs and outputs and agricultural policy. The model has been frequently used in evaluating impacts of agricultural and agri-environmental policies. For this reason the model has also been continuously updated and re-validated based on available statistical information on, e.g., input and output prices, food consumption, use of inputs, production, land use and productivity in agriculture. Parameters and principles of agricultural policy have been updated annually as well when necessary. The results from Dremfia were fed into the calculation models (Luke excel in Figure 5.8), which are used for the greenhouse gas emission inventory (see the most recent National Inventory Report for details). Dremfia produces most of the input data for the greenhouse gas projections modelling: the area of cultivated soils, the use of mineral fertilizers and the numbers for the most important animal species. In addition, the development of some variables (not included as such in the Dremfia model) in the future were estimated using expert judgments: the area of organic soils, the spread of manure management systems, the number of horses (slightly increasing population), sheep, fur animals, reindeer and turkeys (stable population), and developments in the weight of cattle and N excretion of animals.

The method and assumptions were done in the same way in previous National Communications. The method makes it possible to take into account 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 projections are based on statistics and modelling following IPCC guidelines. The scenario tool is thus primarily an emissions calculation model, which is complemented with expert judgments on how rapidly the measures will affect the waste sector. The same basic modelling tool has been used in previous National Communications.

The projection calculations are based on assumptions concerning developments in the amount of waste related to standard population projections and the rate at which new waste treatment facilities are introduced, in particular their incineration capacity, which will reduce the stream of waste to landfills. 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 taken into account. CH_4 and N_2O emissions are treated separately.

The modelling builds on aggregating information for the waste sector, and thus, there are only limited opportunities to project the detailed effects of individual policy measures in terms of emission reductions. So far, there has been only limited information on 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 development of the tree stock and drain (m^3) for the LULUCF sector projection is estimated using the MELA model[11]. MELA is a forestry model consisting of two parts: 1) a forest simulator based on individual tree growth and development models, and 2) a linear optimisation package. The information on forest resources, which is based on the national forest inventory, is used as a basis for MELA. The model utilises the roundwood demand and information on stump prices produced by the SF-GTM model. The SF-GTM model is a partial equilibrium model depicting Finland's forestry sector: forestry, the forest industry and the forest product market. The MELA model also provides the input data for the Yasso07 model, which is used to project the changes in carbon stocks in mineral forest soils.

The projections for croplands and grasslands were compiled using the Dremfia model (see the section on agriculture above). Yasso07 model and methods of the greenhouse gas inventory were used to estimate carbon stock changes also for cropland and grassland.

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. In Europe, models based on MONASH have

11 The MELA model is described in the document on forest management reference level calculations for Finland: http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_finland_2011.pdf

been developed for Denmark, Finland, and the Netherlands. VATTAGE, a precursor of FINAGE, is described in detail in in Finland's sixth National Communication[12].

Several factors explain the popularity of MONASH. The main ones are the advanced and user-friendly software packages that facilitate data handling and the set-up 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 time frames. In forward-looking policy analysis, MONASH-type models offer a disciplined way to forecast the baseline development of the economy. They also allow the user to replicate and explain the historical development of an economy in great 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) accumulation of fixed capital; (2) 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 that 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. Some of the industries, however, gain from the subsidies granted to renewable energy, and even in energy-intensive industries, the 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 expected equilibrium wage growth, with the result that in the short run, adjustments will occur partly through increased levels of unemployment. In the long run, wages will adjust fully to one-off shocks, and full employment will be restored. In the case of gradually tightening emission targets, however, the shocks are not one-off, implying sustained, above-equilibrium unemployment rates.

Literature

Dixon P.B. & Rimmer, M.T. (2012). Dynamic General Equilibrium Modelling for Forecasting and Policy: A Practical Guide and Documentation of MONASH. Contributions to economic analysis/256, North-Holland/Elsevier, 2002.

Heljo, J., Nippala, E., and Nuuttila, H. (2005) Energy consumption and CO2 eq. emissions of buildings in Finland (in Finnish with an English summary). Tampereen teknillinen yliopisto. Rakentamistalouden laitos. Raportti 2005:4.

Honkatukia, J. and Lehmus, M. (2016) Suomen talous 2015–2030: Laskelmia politiikkatoimien vaikutuksista (in Finnish with an English Abstract). VATT Tutkimukset 183/2016. The Government Institute for Economic Research (VATT), Helsinki 2016.

http://vatt.fi/suomen-talous-2015-2030-laskelmia-politiikkatoimien-vaikutuksista

Honkatukia, J. (2009). VATTAGE – A dynamic, applied general equilibrium model of the Finnish economy. VATT Tutkimuksia 150. The Government Institute for Economic Research (VATT), Helsinki 2009.

IEA (2015) World Energy Outlook 2015. http://www.worldenergyoutlook.org/publications/weo-2015/

Koljonen, T., Soimakallio, S., Asikainen, A., Lanki, T., Anttila, P., Hildén, M., Honkatukia, J., Karvosenoja, N., Lehtilä, A., Lehtonen, H., Lindroos, T.J., Regina, K., Salminen, O., Savolahti, M., Siljander, R. & Tiittanen, P. (2017) Energia- ja ilmastostrategian vaikutusarviot: Yhteenvetoraportti (in Finnish with an English description). Publications of the Govenrment's analysis, assessment and research activities 21/2017. http://tietokayttoon.fi/julkaisu?pubid=16902

12 http://unfccc.int/files/national_reports/annex_i_natcom/submitted_natcom/application/pdf/fi_nc6[1].pdf

Lehtonen, H. (2001) Principles, structure and application of dynamic regional sector model of Finnish agriculture. Academic dissertation. Systems Analysis Laboratory, Helsinki University of Technology. Publications 98. Agrifood Research Finland, Economic Research (MTTL). Helsinki. 265 pages. http://lib.tkk.fi/Diss/2001/isbn9512256894/isbn9512256894.pdf

Lehtonen, H. & Rankinen, K. (2015). Impacts of agri-environmental policy on land use and nitrogen leaching in Finland. Environmental Science and Policy, Volume 50, June 2015, p. 130–144. doi:10.1016/j.envsci.2015.02.001

Lindroos, T.J., Monni, S., Honkatukia, J., Soimakallio, S., and Savolainen, I. (2012) Estimations of greenhouse reductions and economical effects of renewable energy in Finland. VTT Technology 11 (in Finnish with English summary). http://www.vtt.fi/inf/pdf/technology/2012/T11.pdf

Maija K. Mattinen, Juhani Heljo, Jaakko Vihola, Antti Kurvinen, Suvi Lehtoranta, Ari Nissinen (2014), Modeling and visualization of residential sector energy consumption and greenhouse gas emissions, Journal of Cleaner Production, 2014, 81: pp. 70-80. DOI: 10.1016/j.jclepro.2014.05.054. http://www.sciencedirect.com/science/article/pii/S0959652614005319

Mattinen, M., Heljo, J. & Savolahti, M. (2016) Rakennusten energiankulutuksen perusskenaario Suomessa 2015-2050 (in Finnish, with English Abstract). Suomen ympäristökeskuksen raportteja 35/2016. https://helda.helsinki.fi/handle/10138/166673

Mattinen, Maija, Hildén, M. and Petäjä, J. (2012) Calculations of greenhouse gas emissions of waste sector and F-gases for policy scenarios in Finland. Finnish Environment Institute, Finnish Environment 18, Helsinki. http://hdl.handle.net/10138/38772

Ministry of Economic Affairs and Employment (2016) Government report on the National Energy and Climate Strategy for 2030. Publications of the Ministry of Economic Affairs and Employment 12/2017. http://julkaisut.valtioneuvosto.fi/handle/10024/79247

Ministry of Employment and the Economy (2013) National Energy and Climate Strategy. Government Report to Parliament on 20 March 2013. http://tem.fi/en/energy-and-climate-strategy

Ministry of Employment and the Economy (2014) Energy and Climate Roadmap 2050. Report of the Parliamentary Committee on Energy and Climate Issues on 16 October 2014. Publications of the Ministry of Employment and the Economy. Energy and the climate 50/2014. http://tem.fi/documents/1410877/2769658/Energy+and+Climate+Roadmap+2050/9fd1b4ca-346d-4d05-914a-2e20e5d33074

Ministry of the Environment (2017) Government Report on Medium-term Climate Change Plan for 2030 – Towards Climate-Smart Day-to-Day Living. Reports of the Ministry of the Environment 21en | 2017, Helsinki, Finland. http://julkaisut.valtioneuvosto.fi/handle/10024/80769

Prime Minister's Office (2015) Finland, a land of solutions - Strategic Programme of Prime Minister Juha Sipilä's Government. Helsinki, 29 May 2015, Government Publications 12/2015. http://valtioneuvosto.fi/en/sipila/government-programme

Pöyry Management Consulting Oy (2016) EU:n 2030 ilmasto- ja energiapolitiikan linjausten toteutusvaihtoehdot ja Suomen omien energia- ja ilmastotavoitteiden toteutuminen (in Finnish with an English description). Publications of the Govenrment´s analysis, assessment and research activities 28/2016. http://tietokayttoon.fi/julkaisu?pubid=12101

Sievänen, R., Salminen, O., Lehtonen, A., Ojanen, P., Liski, J., Ruosteenoja, K and Tuomi, M. (2013) Carbon stock changes of forest land in Finland under different levels of wood use and climate change. Annals of Forest Science. DOI 10.1007/s13595-013-0295-7.

Internet links

LIPASTO calculation system, http://lipasto.vtt.fi/en/index.htm

YASSO model, http://en.ilmatieteenlaitos.fi/yasso