Deliverable C2.1, Part 5: Macroeconomic model

Documentation of Methods and Models for Climate Mitigation Mid-century Strategy Scenario Analysis

Final report

LIFE ClimatePath2050 (LIFE16 GIC/SI/000043)

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Introduction

In the scope of LIFE ClimatePath2050[1] the **Deliverable C2.1: Documentation of Methods and Models for Climate Mitigation Mid-century Strategy Scenario Analysis**, **Part 5: Macroeconomic model** was prepared. The document presents the information on the models developed or updated in the scope of the project along with some basic results.

The composite deliverable C2.1: Documentation of Methods and Models for Climate Mitigation Mid-century Strategy Scenario Analysis consists of several parts, namely:

- **Part 1: Summary report on methods and models for scenario analysis**, condense summary report on methods and models for scenario analysis;
- **Part 2: Energy sector models**, includes the detailed information on sectoral models used for climate mitigation scenario analysis, the report enlightens general approach and presents final energy demand and supply models including households, services and agriculture energy use, energy use in transport and industry, models for district heating expansion analysis and CHP cross sectorial impact, distributed electricity production assessment and optimisation of power sector operation;
- **Part 3: LULUCF model**, includes the detailed information on Carbon Budget Model (CBM-CFS3) that is used for simulating the dynamics of forest carbon pools, considering various assumptions such as the type of forest management, land use changes, the occurrence of natural disturbances and timber harvesting;
- **Part 4: Other IPCC sectors agriculture, sector process emissions, IPCC sector waste**, includes information on the models used for assessing agriculture sector, process emissions and waste in accordance with IPCC;
- **Part 5: Macroeconomic model**, includes the detailed information on the newly developed multi-sectoral Computable General Equilibrium model (CGE) of the Slovenian economy (GreenMod Slovenia) that was developed and used specifically for the analysis of energy and environmental issues, considering the quantitative results of the energy sector models.

The deliverable **Part 5: Macroeconomic model**, includes the detailed information on the newly developed multi-sectoral Computable General Equilibrium model (CGE) of the Slovenian economy (GreenMod Slovenia) that was developed and used specifically for the analysis of energy and environmental issues, considering the quantitative results of the energy sector models. The model has been developed and revised in the scope of LIFE ClimatePath2050 project.

1 LIFE ClimatePath2050 (Slovenian Path Towards the Mid-Century Climate Target)

1 Purpose of the model

Any responsible national government seeking to contribute to climate change mitigation must ensure that a comprehensive decision-making support system is implemented on time. This allows existing and future climate change mitigation measures to be targeted appropriately and designed in the medium term, by 2030, and further in line with the ambitions to reduce greenhouse gases by the middle of the century. Energy savings in all sectors by all economic agents (households, firms, the government) is one of the key elements in reducing greenhouse gas emissions when thinking about the short term. However, in the long term, for example, by 2050, it will also be necessary to consider switching to less carbon-intensive resources, especially in the energy sector (Russ, et al., 2007). To achieve the ambitions regarding greenhouse gas reduction, it is necessary first to assess the effects of different energy and climate scenarios, which could lead to the desired goals, on macroeconomic and sectoral aggregates. The purpose of the model is thus to examine the macroeconomic effects of a moderate scenario (additional measures scenario that reduces emissions by 80% by 2050 compared to 1986 emissions; WAM(DU) scenario) and an ambitious scenario (additional measures scenario that reduces emissions between 90% and 95% by 2050 compared to 1986 emissions; WAMa(DUA) scenario).

The developed model is a dynamic, multi-sectoral Computable General Equilibrium model (CGE) of the Slovenian economy (GreenMod Slovenia) based on the year 2015. It was developed and used specifically for the analysis of energy and environmental issues, considering the quantitative results of the reference energy ecological model called REES-SLO. At the same time, the outputs of the CGE model may represent necessary input assumptions for the REES-SLO model. The connectivity of the models in both directions ensures the technical-economic coherence of the analysis.

2 Model Inputs

2.1 External influence factors

The most important external influence factors considered in the CGE model are energy use and the structure of energy inputs, anticipated energy efficiency improvement, and investments in energy efficiency.

Energy use

Energy use data was appropriately disaggregated according to the disaggregation of activities in the social accounting matrix (SAM) using the data and projections of the REES-SLO model. Below we show growth rates for the period from 2015 to 2050 for each activity (Tab. 1). To appropriately account for the changes in the structure of energy inputs in each activity, 5-year interval changes were calculated for each scenario (an example for the manufacturing-other industries activity is presented in Tab. 2).

Tab. 1: Change in energy use (calculated from GJ) in the period 2015-2050 by activities

Activity	Reference scenario WEM(OU)	Moderate scenario WAM(DU)		Ambitious scenario WAMa(DUA)	
		Nuclear option	Synthetic gas option	Nuclear option	Synthetic gas option
Agriculture	1.13	1.02	1.02	0.77	0.77
Mining	1.09	1.09	1.09	1.09	1.09
Paper industry	0.99	1.10	1.10	1.06	1.06
Chemical industry	1.10	1.18	1.18	1.24	1.24
Industry of non-metallic mineral products	1.24	1.16	1.16	1.11	1.11
Metals industry	1.16	0.91	0.91	0.85	0.85
Manufacturing-other industries	1.42	1.36	1.36	1.31	1.31
Electricity, gas and steam supply	0.72	1.34	0.87	1.30	0.82
Land transport	1.58	1.19	1.19	0.81	0.81
Water transport	1.19	1.19	1.19	0.81	0.81
Air transport	2.52	2.52	2.52	2.52	2.52
Commercial services	1.45	1.42	1.42	1.38	1.38
Construction	1.38	0.94	0.94	0.75	0.75
Public services	1.16	1.11	1.11	1.06	1.06
Households	0.67	0.49	0.49	0.39	0.39

Source: REES-SLO data and own calculations.

Tab. 2: Example of model inputs: Changes in the structure of energy inputs in the manufacturing-other industries activity - index

		2015	2020	2025	2030	2035	2040	2045	2050
Reference scenario WEM(OU)									
Logging	Manufacturing-other industries	100	79	77	77	49	48	47	46
Coal	Manufacturing-other industries	100	134	93	50	0	0	0	0
Natural gas	Manufacturing-other industries	100	106	115	127	143	158	175	191
Coke	Manufacturing-other industries	100	0	0	0	0	0	0	0
Refined petroleum	Manufacturing-other industries	100	86	76	67	56	43	28	15
Nuclear	Manufacturing-other industries	0	0	0	0	0	0	0	0
Electricity	Manufacturing-other industries	100	110	115	123	133	140	149	157
Gas	Manufacturing-other industries	0	0	0	0	0	0	0	0
Steam	Manufacturing-other industries	100	116	125	138	136	131	126	122
Moderate scenario WAM(DU) - Nuclear option									
Logging	Manufacturing-other industries	100	89	97	114	107	107	108	109
Coal	Manufacturing-other industries	100	135	91	47	0	0	0	0
Natural gas	Manufacturing-other industries	100	109	118	130	130	127	109	60
Coke	Manufacturing-other industries	100	0	0	0	0	0	0	0
Refined petroleum	Manufacturing-other industries	100	75	44	12	12	12	13	13
Nuclear	Manufacturing-other industries	0	0	0	0	0	0	0	0
Electricity	Manufacturing-other industries	100	109	114	121	129	135	142	149
Gas	Manufacturing-other industries	0	0	0	0	0	0	0	0
Steam	Manufacturing-other industries	100	115	118	122	129	134	140	145
Moderate scenario WAM(DU) - Synthetic gas option									
Logging	Manufacturing-other industries	100	89	97	114	107	107	108	109
Coal	Manufacturing-other industries	100	135	91	47	0	0	0	0
Natural gas	Manufacturing-other industries	100	109	118	130	130	127	109	60
Coke	Manufacturing-other industries	100	0	0	0	0	0	0	0
Refined petroleum	Manufacturing-other industries	100	75	44	12	12	12	13	13
Nuclear	Manufacturing-other industries	0	0	0	0	0	0	0	0
Electricity	Manufacturing-other industries	100	109	114	121	129	135	142	149
Gas	Manufacturing-other industries	0	0	0	0	0	0	0	0
Steam	Manufacturing-other industries	100	115	118	122	129	134	140	145
Ambitious scenario WAM(DU) - Nuclear option									
Logging	Manufacturing-other industries	100	97	116	151	161	163	167	170
Coal	Manufacturing-other industries	100	131	87	44	0	0	0	0
Natural gas	Manufacturing-other industries	100	103	106	99	96	86	47	1
Coke	Manufacturing-other industries	100	0	0	0	0	0	0	0
Refined petroleum	Manufacturing-other industries	100	73	42	11	11	11	11	12
Nuclear	Manufacturing-other industries	0	0	0	0	0	0	0	0
Electricity	Manufacturing-other industries	100	109	113	118	125	130	135	141
Gas	Manufacturing-other industries	0	0	0	0	0	0	0	0

Steam	Manufacturing-other industries	100	121	137	153	156	153	151	157
Ambitious scenario WAM(DU) - Synthetic gas option									
Logging	Manufacturing-other industries	100	97	116	151	161	163	167	170
Coal	Manufacturing-other industries	100	131	87	44	0	0	0	0
Natural gas	Manufacturing-other industries	100	103	106	99	96	86	47	1
Coke	Manufacturing-other industries	100	0	0	0	0	0	0	0
Refined petroleum	Manufacturing-other industries	100	73	42	11	11	11	11	12
Nuclear	Manufacturing-other industries	0	0	0	0	0	0	0	0
Electricity	Manufacturing-other industries	100	109	113	118	125	130	135	141
Gas	Manufacturing-other industries	0	0	0	0	0	0	0	0
Steam	Manufacturing-other industries	100	121	137	153	156	153	151	157

Source: REES-SLO data and own calculations.

Energy efficiency

Energy efficiency is measured by energy consumption in GJ per million € of production. Energy consumption data were recalculated to the appropriate levels from the data and projections of the REES-SLO model. Regarding the production, we first aggregated the disaggregated quantitative data following the SAM activities, then calculated the growth rates compared to the base year 2015 and applied these rates to the baseline data from the SAM for 2015. Below, we show the change in energy efficiency, where numbers above one indicate growth, i.e., more energy consumed per output unit (Tab. 3). A lower growth rate is therefore desirable.

Tab. 3: Change in energy efficiency (calculated from GJ/€ million) in the period 2015-2050 by activities

Activity	Reference scenario WEM(OU)	Moderate scenario WAM(DU)		Ambitious scenario WAMa(DUA)	
		Nuclear option	Synthetic gas option	Nuclear option	Synthetic gas option
Agriculture	1.03	0.94	0.94	0.70	0.70
Mining	1.09	1.09	1.09	1.09	1.09
Paper industry	0.86	0.95	0.95	0.92	0.92
Chemical industry	0.90	0.96	0.96	1.01	1.01
Industry of non-metallic mineral products	0.90	0.84	0.84	0.81	0.81
Metals industry	0.98	0.77	0.77	0.71	0.71
Manufacturing-other industries	0.83	0.79	0.79	0.76	0.76
Electricity, gas and steam supply	0.66	0.84	0.63	0.72	0.75
Land transport	0.60	0.45	0.45	0.31	0.31
Water transport	0.45	0.45	0.45	0.31	0.31
Air transport	0.99	0.99	0.99	0.99	0.99
Commercial services	0.77	0.76	0.76	0.73	0.73
Construction	0.87	0.59	0.59	0.47	0.47
Public services	0.73	0.70	0.70	0.66	0.66
Households	0.37	0.27	0.27	0.22	0.22

Source: REES-SLO data and own calculations.

Investments

At this point, we present the projected energy-related investments in the reference scenario (WEM(OU) scenario) derived from the RES-SLO model, which also include investments in energy efficiency (Tab. 4). Namely, investments in energy efficiency cannot be made without a more comprehensive investment. An example is an investment in the perimeter of a building, which also includes thermal insulation.

Tab. 4: Energy investments (including investments in energy efficiency) in € million in five-year periods by activities, reference scenario WEM(OU)

	2015	2020	2025	2030	2035	2040	2045	2050	All
Paper industry	0.50	14.33	15.04	21.41	32.22	30.93	13.55	12.57	141
Chemicals industry	6.62	80.88	92.58	93.97	95.95	95.79	98.71	101.71	666
Industry of non-metallic mineral products	25.50	25.59	19.03	19.79	20.48	19.28	20.61	22.20	172
Metals industry	10.33	33.94	36.99	38.67	40.67	40.23	43.00	50.06	294
Manufacturing-other industries	20.54	128.65	143.67	160.85	170.72	179.63	216.20	248.84	1269
Electricity, gas and steam supply	279.99	1117.85	2076.40	2426.49	2026.21	2748.21	2026.21	2105.21	14807
Commercial services	338.64	1686.35	1093.09	1471.65	1514.81	1531.92	1575.55	1630.14	10842
Public services	128.67	645.66	643.26	769.40	819.21	888.27	972.23	1061.47	5928
Households	661.58	3941.66	4155.88	3992.62	3345.00	3059.52	2897.97	2859.74	24914
Total	**1472**	**7675**	**8276**	**8995**	**8065**	**8594**	**7864**	**8092**	**59033**

Source: IJS CEU calculations using REES-SLO.

2.2 Internal Input Parameters

The crucial input data system for calculating the reference solution of the CGE model is the social accounting matrix (SAM), which embodies a comprehensive data framework for the national economy. Technically, the SAM is a square matrix (with the same number of rows and columns) representing the circular economic flow of income and expenditure. Each entry in row *i* and column *j* represents income for account *i* and expenditure for account *j*. The SAM summarises the economy's structure, including its internal and external links and the roles of different actors and sectors. In addition, it brings other data (including input-output tables, household surveys, producer surveys, trade statistics, national accounts data, the balance of payments and state budget information) into a single framework and provides a basic conceptual framework for the national accounts system. The preparation of the SAM requires the implementation of three steps: (i) disaggregation of products/activities in the SAM, (ii) preparation of a balanced SAM for the base year 2015, and (iii) harmonisation of the reference scenario (OU scenario).

According to the obtained data, and with the help of the Statistical Office of the Republic of Slovenia and leading experts in the field, a final decision was made regarding the disaggregation of the SAM. The SAM was disaggregated into 21 products and 17 activities (Table 5, Table 6). Each product/activity includes categories from two classifications: Standard classification of activities (https://www.stat.si/doc/pub/skd.pdf); and Classifications of products by activity (https: //www.stat .si /dokument/3658 /CPA_2008.pdf).

Tab. 5: Disaggregation of products in the SAM

	Products	*Code*
1	Products of agriculture, forestry, and fishing, except logging	A 01 + 03 + 02.1+ 02.3 +02.4
2	Logging and related services	A 02.2
3	Coal and lignite	B 05
4	Natural gas	B 06.2
5	Ores (other)	B 07+08+09
6	Paper	C 17
7	Coke	C 19.1
8	Refined petroleum products	C 19.2
9	Chemicals	C 20
10	Other non-metallic mineral products	C 23
11	Basic metals	C 24
12	Other manufacturing products	C 10-16, 18, 22, 25-33, 21
13	Electricity	D 35.1
14	Synthetic gas	D 35.2
15	Steam	D 35.3
16	Land transport services	H 49
17	Water transport services	H 50
18	Air transport services	H 51
19	Commercial services	36, 37, 39, 45-47, 52-53, 55-56, 58-66, 68-75, 77-80, 82, 90, 92-99
20	Construction	41-43
21	Public services	84-88

Source: Classification of products by activity, 2008.

Tab. 6: Disaggregation of activities in the SAM

	Activities	*Code*
1	Agriculture	A 01-03
2	Mining	B 05-09
3	Paper industry	C 17
4	Production of coke and refined petroleum products	C 19
5	Chemical industry	C 20
6	Industry of non-metallic mineral products	C 23
7	Metals industry	C 24
8	Manufacturing – other industries	C 10-16, 18, 22, 25-33, 21
9	Electricity supply	D 35.1
10	Gas supply	D 35.2
11	Steam and hot water supply	D 35.3
12	Land transport	H 49
13	Water transport	H 50
14	Air transport	H 51
15	Provision of commercial services	36, 37, 39, 45-47, 52-53, 55-56, 58-66, 68-75, 77-80, 82, 90, 92-99
16	Other manufacturing industries	41-43
17	Provision of public services	84-88

Source: Standard classification of activities, 2008.

2.3 Key assumptions, scenarios and border conditions

The analyzed scenarios are based on the target values - the GHG emission reduction target in the EU for 2050 between 80-95%. The first of the scenarios with additional measures (WAM(DU), moderate scenario) simulates an 80% reduction in CO2 emissions relative to baseline emissions (CO2 emissions in 1986), while the second scenario (WAMa(DUA), ambitious scenario) reduces CO2 emissions by 90%-95% relative to baseline emissions. With the consideration of emission sinks, the second forms the scenario for achieving net-zero GHG emissions in 2050.

In 1986, GHG emissions in Slovenia amounted to 20 million tons (exactly 20,414,536 Gg), of which CO2 emissions were 16 million tons (exactly 16,668,971 Gg) - does not include LULUCF. It follows that an 80% reduction in emissions by 2050 means that CO2 emissions should be reduced to 3.3 million tones. A 90% reduction means that CO2 emissions amount to 1.7 million tones and a 95% reduction to 0.8 million tons of CO2. An 80% reduction in emissions by 2050 represents a level of 4,071 kt CO2 equivalents of greenhouse gas emissions. A 90% reduction means an achieved level of 2,035 kt CO2 equivalents, and a 95% reduction implies 1,018 kt CO2 equivalents.

The analysis, therefore, considers the following three scenarios:

1. The **WEM(OU)** scenario: a scenario with existing measures - a reference scenario,
2. The **WAM(DU)** scenario: scenario with additional measures - a moderate scenario that achieves a reduction of GHG emissions by 80% compared to baseline emissions,
3. The **WAMa(DUA)** scenario: scenario with additional measures - an ambitious scenario that achieves a reduction of GHG emissions by 90% to 95% compared to baseline emissions,

whereas in the case of scenarios with additional measures, we also analyse two options that differ according to the prevailing technology, namely the use of synthetic gas or nuclear energy. These two options become relevant after 2030.

The WEM(OU) scenario (reference scenario with existing measures) analyses the development in the case of continued implementation of all measures that have already been adopted or derived. The measure is implemented if financial resources have been allocated or other necessary resources (human, established legislation, etc.). However, for the measures taken by the government, there must be a clear intention on the part of the government to continue implementing the measures. The cut-off date for the analysis is October 1, 2018. In addition to the existing measures, the scenario with additional measures also considers measures still in the design phase with a realistic possibility of their implementation (Urbančič et al., 2018).

3 Model structure

3.1 Methodology

The model (GreenMod Slovenia) is a dynamic multi-sectoral model of the Slovenian economy for energy and environmental analysis. It embodies considerable detail on the nature of production and demand in the economy. It is called a multi-sectoral model because it treats the economy as a system of inter-related industry sectors. The model captures the interdependencies between industries that arise from the purchase of each other's outputs of goods and services; competition for available resources, such as labor and capital; and other constraints that generally operate (e.g. the balance of trade, budget constraints, etc.). The model incorporates considerable detail on individual industries within an economy-wide framework. Because of this, the model can be used to analyses a vast range of issues, either broad in scope or industry-specific. It provides information on the effects of energy policies and other changes on the economy generally, outputs of individual industries, imports and exports of different commodities, employment patterns, commodity prices, etc.

CGE models are based on microeconomic theories. They are designed to measure the direct, indirect and induced economic and environmental impacts of policy changes on the economy in the short, medium and long run. The input-output core enables the model to trace the extent and the channels of changes in policy and the international environment. The resulting price changes affect the demand for the sectoral outputs and alter the resource allocation of factors. The simulations explore the effects of external shocks (such as a change in the international prices, fluctuations in the real exchange rate, foreign demand, etc.) and domestic policy changes. Model simulations provide results regarding the impacts on several macroeconomic aggregates.

The main premise of the CGE models is that "structure" matters, and they explicitly consider the workings of a multi-sectoral, multi-market, general equilibrium system undergoing structural adjustment, i.e. CGE models simulate the transactions in a market economy. They capture the interaction of various actors in the economy including households, (as consumers, workers and savers); firms (as producers, consumers of intermediate goods, and investors); government (as consumer and transfer agent); and the rest of the world, (as consumers of exports, producers of imports and providers or recipients of international capital flows). Consistent with microeconomic theory, all agents are assumed to optimize within budget constraints as well as the constraints imposed by regulatory frameworks. CGE models are unique in their ability to present the trade-offs of a given policy decision, especially when the policy has economy-wide repercussions as in the case of corporate, sales and individual income taxes. Even the sign of an affected variable may change when an analysis is extended from partial to general equilibrium.

The GreenMod Slovenia model is calibrated on the Social Accounting Matrix for 2015. The model is solved using the general algebraic modelling system GAMS. It has a recursive dynamic structure composed of a sequence of several temporary equilibria, in which current savings determine future capital accumulation and the growth rate of the economy. The recursive sequence equilibrium approach assumes myopic expectations. In each time period, the model is solved for equilibrium, given the exogenous conditions assumed for that particular period. The endogenous determination of investment behavior is essential for the dynamic part of the model. Investment is not only a demand category but also depends on dynamic economic processes, as follows: a homogenous composite investment commodity is allocated between activities according to the current (year t) net rate of return on fixed capital in particular activity. The current net rate of return on fixed capital is derived as the ratio of the rental rate for capital services in particular activity to the price of composite investment commodity in year t less the depreciation rate for particular activity. The model is solved dynamically with annual steps.

3.2 Technologies, sectors, processes

The production account

The CGE model does not model the behavior of individual firms, but of groups of similar ones aggregated into particular activities. Real output for each activity is determined from a nested production structure. Capital and labor are assumed to produce sectoral value added, according to a constant elasticity of substitution (CES) function. Value added is related to output through a Leontief production function, which assumes an optimal allocation of inputs. Firms receive income from sales of goods and subsidies and transfers from the government, they purchase intermediate inputs, make wage payments, pay taxes on capital use, labor use and taxes on income. The capital stock is sector specific during each period and is initially fixed. It changes every year depending on the initial capital stock, the depreciation rate and new investment.

The production account incorporates the intermediate inputs, the factors of production, the taxes on the factors, and the indirect taxes paid by the firms on their production on the one hand, and the payments received from the sales of their output on the other hand.

The production block is disaggregated into branches of activity. Therefore, each column of the production block represents a branch of activity. The column shows the expenditures of the firms of that branch, i.e. the inputs or intermediate consumption used for the production and the value added. The inputs include goods and services delivered by the other branches of activity as well as the auto-consumption of the branch of the activity itself. The value added by each branch of activity is composed of the capital (net capital, tax on capital and consumption of fixed capital) and the labor used during the production process.

The row of the corresponding column explains how domestic production is used. Some of the domestic production is used to satisfy the domestic demand, and some of it is sold abroad to meet the foreign demand.

The commodities account

The commodity account explains the flows of goods and services in the markets. It describes the supply of goods and services by the activities (producers) and the rest of the world (imports including tariffs on imported goods) on the one hand, and the sales of these commodities to activities (as intermediate inputs) and the final consumers (households, government, fixed capital formation, and the rest of the world) on the other hand.

Each column of the commodities block is composed of the goods and services at the basic prices, taxes and subsidies on products and imports. The column total is the value of the supply of the commodity in the market at the purchasers' price. The row of the corresponding column shows how the total supply is delivered to the domestic and foreign markets. The total supply is delivered to the firms as intermediate consumption, to the households as final consumption expenditure by the households, to the government as final consumption expenditure by the government and to the rest of the world as exports.

The factors of production account

We distinguish two factors of production in the SAM: labor and capital. The factors of production account show (in the row) the supply of labor and capital to the branches of activity, the government and the rest of the world on the one hand and the remunerations of the owner (households, firms, government and rest of the world) of these factors (in a column) on the other hand.

The institutional accounts

The institutional accounts incorporate the income received by each economic agent (firms, households and government) and their outlays. The outlays include the consumption of commodities, the transfers to the other agents, the taxes, and the savings.

The firms' account

The firms' expenditures are composed of transfers to the households, governments, and the rest of the world. It also includes the corporate taxes and the savings of the firms. Note that the intermediate consumption of the firms and corporate taxes are included in the production account.

The income of the firms is composed of the remunerations from the ownership of factors of production, i.e. the remuneration of capital, and the transfers from the other economic agents, i.e. households, government and the rest of the world.

The households account

The outlays of the households include the final consumption expenditure by the households, the tax on income and the savings. The income of the households includes the transfers received from the other economic agents and the remunerations of the factors of production. The households' savings is derived as the difference between the households' revenues and the households' expenditures.

The government account

The outlays of the government include the final consumption expenditure by the government, the transfers to the other agents and the savings. The income of the government includes the transfers received from the other economic agents, the taxes paid by the other agents and the remunerations of the government capital.

The capital account

The capital account is composed of the gross fixed capital formation (GFCF) and the changes in inventories. The column includes expenditures on goods and services for investment. The row is composed of the depreciation of capital, the domestic savings and the current external balances. The data on GFCF and the changes in inventories are derived from the 2015 input-output tables.

The rest of the world account

The specification of foreign trade is based on the small-country assumption, which means that the country is a price taker in both its imports and exports markets. As a result, both world import prices and world export prices are exogenously fixed. The assumption of limited substitution possibilities between domestically produced and imported goods, is now a standard feature of applied models and was also be adopted here. It indicates that domestic consumers use composite goods of imported and domestically produced goods, according to a CES function. A limited substitution is also assumed to exist between goods produced for the domestic market and for exports, as captured by a constant elasticity of transformation (CET) function.

The rest of the world account describes the interaction between the domestic economy and the rest of the world. In the column, we have the exports of goods and services to the rest of the world, the compensation of employees from the rest of the world, the capital transfers from the rest of the world, the property income and the net taxes on production from the rest of the world, the current transfers from the rest of the world and the current external balance.

In the row, we have the imports of goods and services from the rest of the world, the compensation of employees to the rest of the world, the capital transfers to the rest of the world, the property income, net taxes on products to the rest of the world, and the current transfers to the rest of the world.

The data on exports and imports is from the 2014 and 2015 input-output tables. The current external balance of the Rest of the World is derived as the difference of its revenues and its expenditures.

The other accounts

The other accounts are composed of all the taxes and subsidies received by the government mentioned in the commodities and activities sections.

3.3 Connections with other models

To prepare the reference scenario, data was coordinated with the REES-SLO model in order to ensure the connectivity of the two models in the following areas:

- projections of emission growth by activities,
- energy efficiency projections by activities,
- projections of energy use by activities,
- projections of emission coefficients for individual energy sources by activities and households,
- projections of emission permit price developments for the ETS sector,
- investment projections by activities.

Disaggregated quantitative data (projections from the REES-SLO model) were first appropriately aggregated in accordance with the products/activities of the SAM matrix. Furthermore, growth rates were calculated compared to the base year 2015, and these rates were applied to the baseline data from the SAM. This allowed us to ensure the coherence and connectivity of the two models in terms of assumptions about the development of key parameters in the reference scenario.

3.4 Future development of the model and research challenges

GreenMod Slovenia is the first energy CGE model specially designed for Slovenia. Its operation and the results are considered as a technical basis for adapting and upgrading the model in the future, especially in terms of replacing or introducing new energy sources and introducing economic instruments to achieve emission targets and to test different scenarios or evaluate specific projects. Specific and important challenge remains in the necessary improvement of the quality of data used for the construction of the SAM.

4 Model results

Further below are some examples of results that we would like to highlight at the macroeconomic level and the level of individual industries/products. Tab. 7 and Tab. 8 show the effects of additional measures in the WAM(DU) and WAMa(DUA) scenarios on macroeconomic aggregates. The results read as changes caused by additional climate-energy measures compared to the reference scenario (WEM(OU) scenario). The estimated values do not represent forecasts of the movement of individual macroeconomic aggregates in the period under review but estimate changes in the economy due to planned measures. In doing so, all other conditions are unchanged, and all the complex connections in the model are considered.

Additional energy investments increase energy efficiency and thus reduce the consumption of energy inputs per unit of production in an individual industry or reduce energy consumption in the final consumption of households. Lower input costs have a favorable effect on the growth of labor demand and the reduction of the unemployment rate, as well as the increase of production. The final impact on consumer prices is positive. Prices are expected to decrease slightly compared to the reference scenario (in the WAM(DU) scenario by 0.2% in 2030; in the WAMa(DUA) scenario by 0.3%). Increased disposable households' income is reflected in higher final private consumption. In the WAM(DU) scenario, private consumption is higher by 1.5% in 2030 compared to the reference scenario. In the WAMa(DUA) scenario, private consumption in 2030 is higher by 2.2% compared to private consumption in the reference scenario.

The positive consequences of additional measures are also reflected in increased savings of both firms and households, while at the same time reducing the current budget deficit of the government, which is increasing its revenues due to increased economic activity. Increased total savings are reflected in higher total gross investments, which are expected to be 1.1% higher in the WAM(DU) scenario in 2030, compared to the OU scenario; as well as 3.9% higher in the WAMa(DUA) scenario in 2030.

Increased economic activity is also followed by an increase in employment, which in the WAM(DU) scenario in 2030 is higher than employment in the OU scenario by 1.5%. In the WAMa(DUA) scenario, the increase is 1.4%. The changed structure of investments also affects the change in the production structure of the Slovenian economy, which will be more noticeable after 2030.

Increased energy efficiency and consequently lower consumption of energy inputs increase international competitiveness of domestic production and increase exports (DU scenario: by 0.6% in 2030 compared to the WEM(OU) scenario; WAMa(DUA) scenario: by 1.2% in 2030 compared to the WEM(OU) scenario) compared to imports. The positive consequences of the planned additional measures under both scenarios (WAM(DU) and WAM(DUA)) are finally reflected in GDP. In the WAM(DU) scenario, GDP is expected to be 1.1% higher in 2030 compared to the WEM(OU) scenario. In the WAMa(DUA) scenario, GDP is expected to be 2.1% higher in 2030 compared to GDP in the reference WEM(OU) scenario.

Tab. 7: Example of macroeconomic results: Changes in macroeconomic indicators for the scenario with additional measures - moderate (WAM(DU) scenario)

% difference compared to the reference scenario WEM(OU)															
Macroeconomic aggregates	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GDP	0.56	0.60	0.63	0.64	0.63	1.20	1.28	1.34	1.37	1.38	1.20	1.19	1.18	1.15	1,11
Employment	0.20	0.25	0.30	0.35	0.40	0.30	0.31	0.32	0.34	0.35	0.41	0.51	0.62	0.75	0,90
Private consumption	0.22	0.28	0.34	0.41	0.48	0.37	0.38	0.39	0.40	0.41	0.57	0.76	0.98	1.22	1,49
Investments	1,84	1.83	1.76	1.63	1.46	2.79	2.73	2.58	2.34	2.00	1.54	1.49	1.40	1.26	1.07
Households' disposable income	0,25	0.31	0.38	0.45	0.52	0.39	0.40	0.42	0.43	0.44	0.59	0.78	0.99	1.23	1.50
Export	0.22	0.26	0.32	0.38	0.44	0.37	0.41	0.44	0.47	0.50	0.45	0.45	0.47	0.50	0,56
Import	0.12	0.14	0.16	0.19	0.22	0.18	0.20	0.22	0.23	0.25	0.20	0.18	0.17	0.16	0,17
Real labour prices	0.14	0.18	0.21	0.25	0.29	0.21	0.22	0.23	0.24	0.25	0.29	0.36	0.44	0.53	0,63
Real consumer prices	-0,3	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1	0.0	0.1	0.0	0.0	-0.1	-0.1	-0.2

Source: Own calculations.

Tab. 8: Example of macroeconomic results: Changes in macroeconomic indicators for the scenario with additional measures - ambitious (WAMa(DUA) scenario)

% difference compared to the reference scenario WEM(OU)															
Macroeconomic aggregates	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GDP	0.93	1.03	1.13	1.21	1.29	1.81	1.96	2.08	2.18	2.25	2.00	2.05	2.09	2.12	2,12
Employment	0.41	0.51	0.62	0.73	0.84	0.72	0.76	0.80	0.84	0.88	0.89	1.00	1.12	1.25	1,39
Private consumption	0.45	0.58	0.72	0.85	1.00	0.88	0.94	1.00	1.06	1.12	1.23	1.45	1.69	1.94	2,21
Investments	2,76	2.92	3.03	3.09	3.11	4.47	4.59	4.64	4.61	4.48	3.93	4.02	4.06	4.05	3.97
Households' disposable income	0,51	0.64	0.78	0.92	1.07	0.92	0.99	1.05	1.11	1.18	1.28	1.50	1.73	1.99	2.26
Export	0.50	0.60	0.71	0.83	0.97	0.86	0.93	0.99	1.06	1.12	1.00	1.04	1.09	1.15	1,23
Import	0.27	0.32	0.37	0.43	0.50	0.43	0.46	0.49	0.52	0.55	0.46	0.46	0.46	0.47	0,48
Real labour price	0.29	0.36	0.44	0.52	0.60	0.51	0.54	0.57	0.59	0.62	0.63	0.71	0.79	0.88	0,98
Real consumer prices	-0,3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2	-0.1	0.0	-0.2	-0.2	-0.2	-0.3	-0.3

Source: Own calculations.

Among the results related to income quintile groups, we show household consumption. In terms of households' consumption, both scenarios with additional measures are more favorable compared to the scenario with existing measures. The real consumption of households is higher in both the moderate and ambitious scenario in all income quintile groups compared to consumption in the reference scenario. However, consumption increases more in the higher quintile groups (Tab. 9).

Tab. 9: Example of results by income quintiles: Change in real households' consumption by income quintile groups compared to real households' consumption in the reference scenario (%)

	1. quintile group		2. quintile group		3. quintile group		4. quintile group		5. quintile group	
Scenario	WAM(DU)	WAMa(DUA)	WAM(DU)	WAMa(DUA)	WAM(DU)	WAMa(DUA)	WAM(DU)	WAMa(DUA)	WAM(DU)	WAMa(DUA)
2016	0.03	0.07	0.14	0.30	0.21	0.43	0.25	0.51	0.30	0.60
2017	0.06	0.15	0.20	0.41	0.27	0.57	0.32	0.66	0.37	0.76
2018	0.09	0.21	0.25	0.52	0.34	0.71	0.39	0.81	0.45	0.91
2019	0.12	0.28	0.30	0.63	0.40	0.84	0.46	0.97	0.52	1.07
2020	0.14	0.35	0.36	0.74	0.47	0.99	0.54	1.13	0.60	1.24
2021	0.14	0.37	0.29	0.69	0.37	0.89	0.42	1.00	0.44	1.06
2022	0.14	0.39	0.30	0.74	0.39	0.95	0.43	1.06	0.46	1.13
2023	0.13	0.40	0.30	0.79	0.40	1.01	0.45	1.13	0.48	1.20
2024	0.13	0.42	0.31	0.84	0.41	1.07	0.46	1.19	0.49	1.28
2025	0.12	0.43	0.31	0.88	0.41	1.13	0.47	1.26	0.51	1.35
2026	0.30	0.61	0.48	1.04	0.58	1.26	0.62	1.36	0.65	1.43
2027	0.49	0.80	0.68	1.25	0.78	1.49	0.82	1.58	0.84	1.66
2028	0.70	1.00	0.90	1.48	1.01	1.73	1.03	1.81	1.05	1.90
2029	0.92	1.21	1.14	1.73	1.26	1.99	1.27	2.07	1.29	2.16
2030	1.16	1.43	1.40	1.99	1.54	2.27	1.55	2.34	1.56	2.45

Source: Own calculations.

The example of domestic consumption by products illustrates the results by product groups. Domestic demand for non-energy intensive products, chemical and metal products is higher in the WAMa(DUA) scenario compared to the scenario with existing measures (Figure 1). The most significant difference between the two scenarios is in 2025. After 2025 the difference between the two scenarios decreases again. However, in 2030 domestic demand for all three product groups is still higher in the WAMa(DUA) scenario compared to the reference level, i.e. by 2.6% for chemical products, by 0.1% for metal products and by 2.6% for other energy-intensive products. Domestic demand for non-metallic mineral products is also higher, with the largest difference between the scenarios in 2029. Domestic demand for refined petroleum products is lower in the WAMa(DUA) scenario from 2026 onwards compared to the WEM(OU) scenario (-3.0% in 2030).

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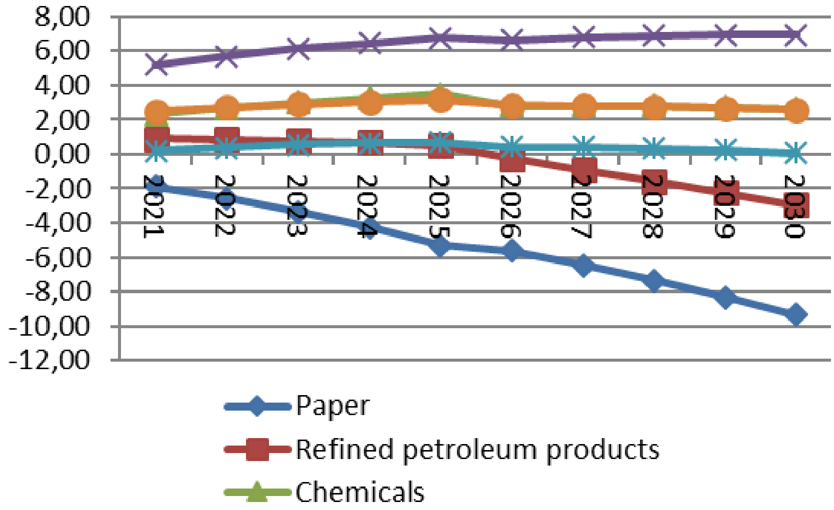
With the contribution of the LIFE Programme of the European Union and the Ministry of the Environment and Spatial Planning, Republic of Slovenia, the Climate Change Fund.

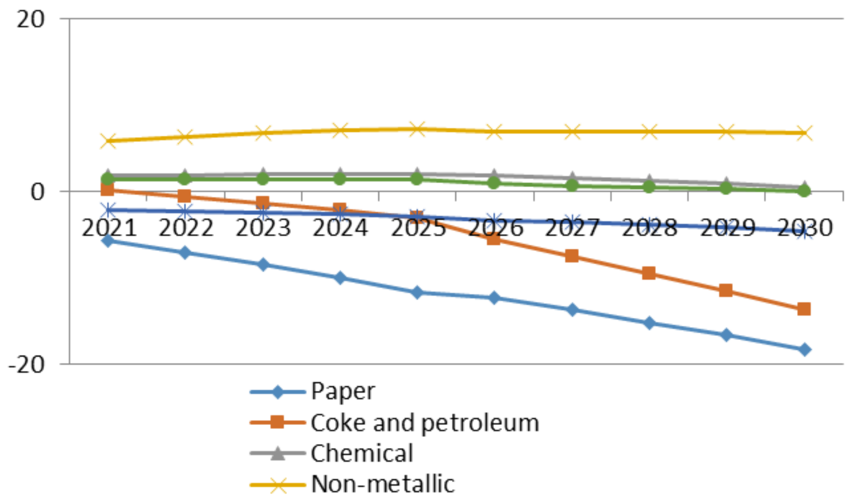
Figure 1: Example of results by product groups: Domestic consumption: WAMa(DUA) scenario vs. WEM(OU) scenario, %



Source: Own calculations.

The example of labour demand by different activities is illustrated in Figure 2. Labour demand in non-energy-intensive activities is slightly higher in the WAMa(DUA) scenario compared to the WEM(OU) scenario, ranging from 0.1% in 2030 to a maximum of 1.4% in 2021. The same applies to labour demand in the chemical activity. The largest difference in labor demand between the two scenarios is in the production of non-metallic mineral products activity, wherein 2030 demand is higher in the WAMa(DUA) scenario by 6.8% compared to the WEM(OU) scenario. In the WAMa(DUA) scenario, the paper activity, coke and refined petroleum activity, and the metal activity are at a disadvantage. In the paper activity, the demand for labor in 2030 is lower in the WAMa(DUA) scenario by 18.2% compared to the OU scenario and in the production of coke and petroleum products activity by 13.6%.

Figure 2: Example of results by activities: Labour demand in the DUA scenario vs OU scenario, %



Source: Own calculations.

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5 Abbreviations, figures and tables

5.1 List of abbreviations

CES	Constant elasticity of substitution
CET	Constant elasticity of transformation
CGE	Computable General Equilibrium
CGE	Computable General Equilibrium
ETS	EU Emissions Trading System
GAMS	General Algebraic Modelling System
GDP	Gross Domestic Product
GFCF	Gross fixed capital formation
GHG	Greenhouse Gas
LIFE	EU's funding instrument for the environment and climate action
LTS	Long Term Strategy
LULUCF	Land Use, Land-Use Change and Forestry
NECP	National Energy and Climate Plan
REES-SLO	Reference Energy and Emission System model for SLOvenia
SAM	Social Accounting Matrices
WAM	With Additional Measures
WAMa	With Additional Measures - ambitious
WEM	With Existing Measures

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