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MAINTAINING MODELS AND UPDATING PARAMETERS. ANALYSIS OF DATA AVAILABILITY

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CONTENT

INTRODUCTION

The energy system is already undergoing significant changes, which will be further reinforced by the European Union (EU) Development Strategy "European Green Deal", endorsed at the end of 2019, and the comprehensive package of measures contained therein, with a long-term objective of achieving EU climate neutrality by 2050.

The European Union is a world leader in the context of the future challenges of energy and climate policy, both through its active dialogue on these issues and with ambitious objectives (the European Green Deal and the climate neutrality goal in 2050) and through the planned transformation of the entire economy towards sustainability. It is clear that Latvia is also facing these challenges, and we must already be able to refocus and find the most optimal course of action for our situation and a combination of measures covering all sectors of the economy and their mutual effects.

In order to give more discussion on modeling opportunities in the context of energy and climate policy, it is necessary to be able to find answers to the following questions: where is Latvia now and what does it give us? Where do we want and can get in 2030? And where in 2050? What could these development scenarios be? How to transform from the lure of short-term benefits to action that has long-term results? Do we need innovative policies, or will it be enough with only innovative technologies?

Currently, the long-term Latvian energy modelling system is being developed within the framework of the project, taking into account both the Latvian Energy and Climate Plan 2030 and the binding requirements of both medium and long-term EU strategies and regulatory enactments.

1. TIMES MODEL – UPDATE AND DATA AVAILABILITY ANALYSIS

TIMES model has been developed and improved to as closely and correctly as possible characterise all sectors and sub-sectors of economy, including all processes and sub-processes. The TIMES model structure was adopted to local circumstances and conditions.

Due to fact that there are not measured specific energy data in various sectors and subsectors, including processes and sub-processes, in-depth research and analytical studies have beeb caried out to solve those data gaps.

The new technology data base was updated and expanded.

1.1. Industrial sector

The industrial sector is the third largest energy consumer in Latvia compiling 21% of the total final energy used in 2017. The industrial sector in Latvia consists of 13 sub-sectors. To analyse the development of the industrial sector, the model structure has been prepared in accordance with the industrial sub-sectors given in the energy balance (see Figure **Error! Reference source not found.**).

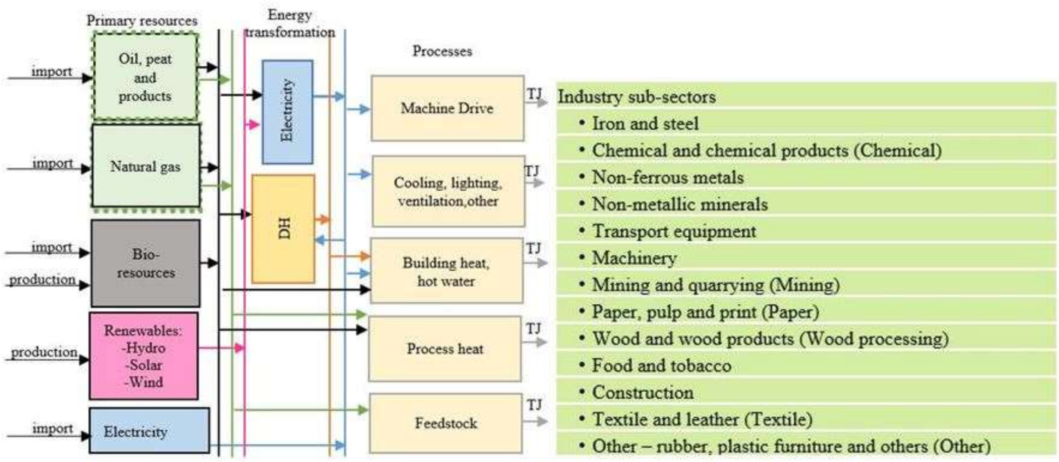


Fig. 1.1. Distribution of energy resources in industrial sub-sectors

In 2017 38% of the total final energy used were wood biomass, 18% electricity, 14% oil products and 13% natural gas. The distribution of primary energy resources consumed by sub-sector is shown in Figure **Error! Reference source not found.**.

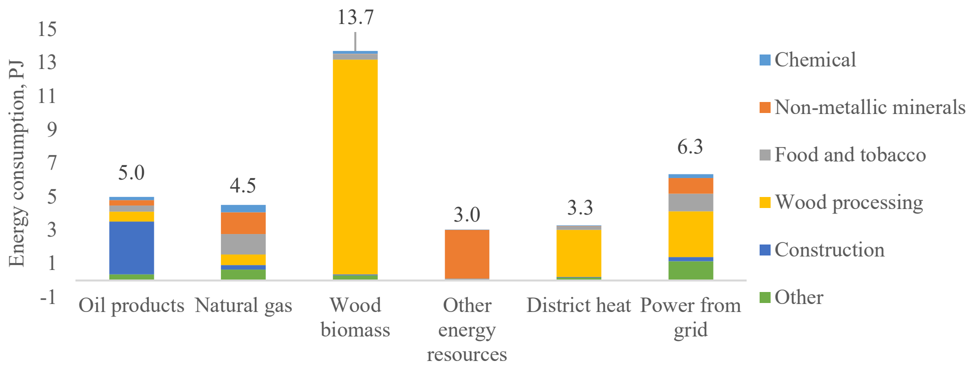


Fig. 1.2. Energy consumption in industry sub-sectors in 2017.

The second largest share of resources is electricity from the grid, representing 6.3 PJ or 18% of all energy resources used in the industrial sector. Electricity is mainly used in the manufacture of wood and wood products, representing 2.7 TJ or 43% of the total electricity consumed by industry. The third largest is the consumption of petroleum products, equal to 5 PJ or 14% of the total final consumption of energy resources. Natural gas is also widely used in the industrial sector, accounting for 4.5 PJ or 13% of all energy resources consumed by industry in 2017. Natural gas is mainly used in the manufacture of non-metallic mineral products and in the food and tobacco sub-sector.

Five different end-use processes have been analysed in the industry sector – feedstock, machine drive, process heat, building heat and hot water, and other processes including cooling, lighting and ventilation (see Table **Error! Reference source not found.**.).

Table 1.1.

Final processes analysed in the industry sector

	Legend of demand process						Legend of demand process				
	1	2	3	4	5		1	2	3	4	5
Iron and steel		v	v	v	v	Mining ETS			v	v	
Iron and steel ETS			v	v		Paper, pulp and print (Paper)		v	v	v	v
Chemical and chemical products (Chemical)	v	v	v	v	v	Wood and wood products (Wood processing)	v	v	v	v	v
Chemical ETS			v	v		Wood processing ETS			v	v	
Non-ferrous metals		v	v	v	v	Food and tobacco	v	v	v	v	v
Non-metallic minerals		v	v	v	v	Food and tobacco ETS			v	v	
Non-metallic minerals ETS			v	v		Construction	v	v	v	v	v
Transport equipment	v	v	v	v	v	Construction ETS			v	v	
Transport equipment ETS			v			Textile and leather (Textile)		v	v	v	v
Machinery		v	v	v	v	Textile ETS			v	v	
Mining and quarrying (Mining)		v	v	v	v	Other – rubber, plastic furniture and others (Other)	v	v	v	v	v

1 – feedstock, 2 – machine drive, 3 – process heat, 4 – building heat, hot water, 5 – cooling, lighting, ventilation, other

For some sectors (chemical production, transport equipment) all processes have been analysed but for sectors included in ETS only two processes (process heat, building heat and hot water) have been included due to specific plants.

In order to determine the proportion of energy sources used for each process, the authors used data from an industrial energy audits carried out between 2016 and 2018 and compiled during the project "The Pathway to energy efficient future for Latvia" (EnergyPath) [1]. The energy balance of 122 different companies was analysed to determine the distribution of different energy sources.

Power consumption in the industrial sector in the TIMES model has been divided into two major parts – electricity used for machine drive, to ensure manufacturing processes, and auxiliary processes – cooling, lighting, ventilation and other power consuming processes. In most of the industry sub-sectors, around 77% to 81% of power is used for machine drive (see Fig. **Error! Reference source not found.**.). Higher share of electricity consumption for machine drive is in the sub-sectors of non-metallic minerals and wood processing industries. In contrast, the lower share of electricity for machine drive is in food and tobacco production – only 54%.

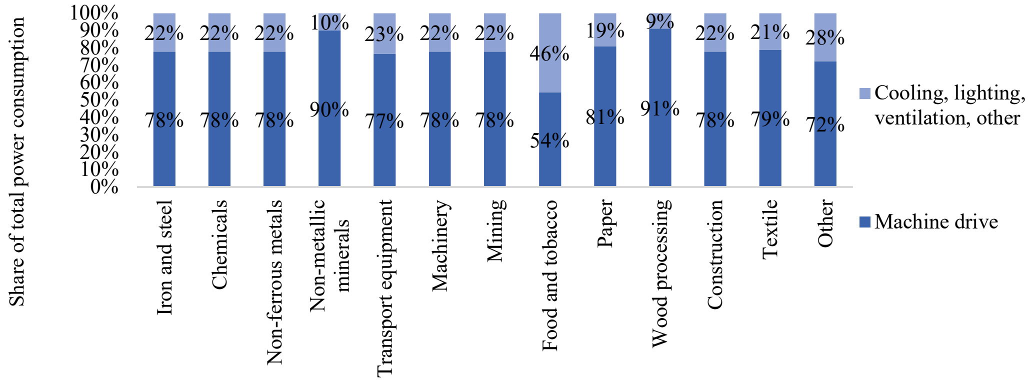


Fig.1.3. Power consumption structure in industry sub-sectors

Heat consumption in the TIMES model has been divided into thermal energy used for space heating and hot water preparation, and process heat that is used for manufacturing processes. Differences in heat consumption division in sub-sectors are more significant compared to power consumption (see Fig. **Error! Reference source not found.**.). In some sub-sectors, less than half of the heat is used for process heat (transport equipment production). Nevertheless, there are sub-sectors where even more than 90% of heat have been used for production processes – non-metallic minerals production and mining.

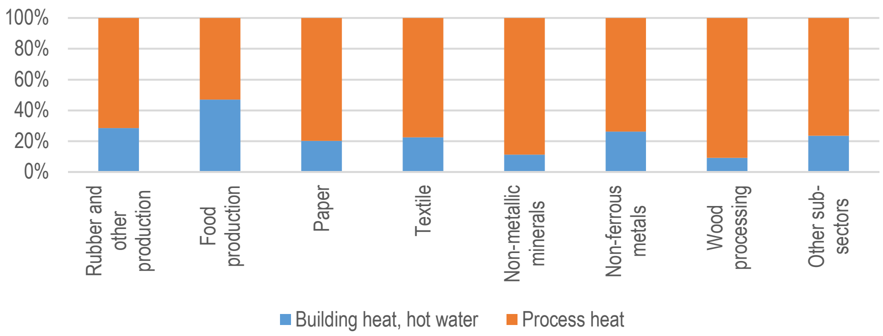


Fig.1.4. Heat consumption structure in industry sub-sectors.

It is assumed in the model that the distribution of final consumption for all energy resources used is the same. The aggregated energy audit balances did not cover part of the sub-sectors analysed. In the manufacture of chemicals, other metals, mining, construction, metals production and vehicle production, the distribution of electricity and thermal energy consumption is determined as the average value between the other sectors.

1.2. Commercial sector

The commercial sector used 15% of the total final energy in 2017, equal to 25 PJ. Power is the main resource used in the commercial sector reaching almost 10 PJ and 43% of the total final electricity consumed in 2017. The commercial sector used 6 PJ of district heat or 24% of final heat consumption and 27% of total natural gas consumption (3.7 PJ).

The commercial and public sector includes the private and public service sectors. There are different buildings and different levels of energy consumption in the commercial sector. Therefore, it has been divided into seven sub-sectors based on the building classification and floor areas available in the report by the Ministry of Economics “Long-Term Strategy for Renovation of Buildings” [2] (see Table **Error! Reference source not found.**.).

Table 1.2.

Commercial sub-sectors in Latvia.

Sector	Total energy consumption in 2017		Total area in 2017	
	TJ	%	m^2	%
Wholesale and retail buildings (Retail)	4085	16.04	4920	15.90
Office buildings (Offices)	4893	19.21	6510	21.03
Hotel buildings (Hotels)	2511	9.86	2310	7.46
Schools, universities and research buildings (Educational)	5144	20.20	6940	22.42
Buildings for medical or health care facilities (Medical)	2281	8.96	2020	6.53
Entertainment event, sports buildings, museums, cultural buildings, cultural and historical sites (Entertainment)	2506	9.84	3320	10.73
Other – garages, communication centres, stations, terminals etc. (Other)	3344	13.13	4930	15.93
COM ETS	704	2.76	-	-
Total	25468	100.00	30950	100.00

Resource consumption for almost all commercial sub-sectors has been divided into ten processes – heating, cooling, cooking, lighting, public lighting, refrigeration, ventilation, water heating, office equipment and other. New process of heating and cooling demand was created – heating and cooling area (m^2) to add more precise policy measures directly to energy efficiency of specific buildings (see. Figure **Error! Reference source not found.**.). Like other demand processes, demand for heating and cooling area (m^2) has been affected by demand drivers like GDP growth and elasticity for evolution with GDP.

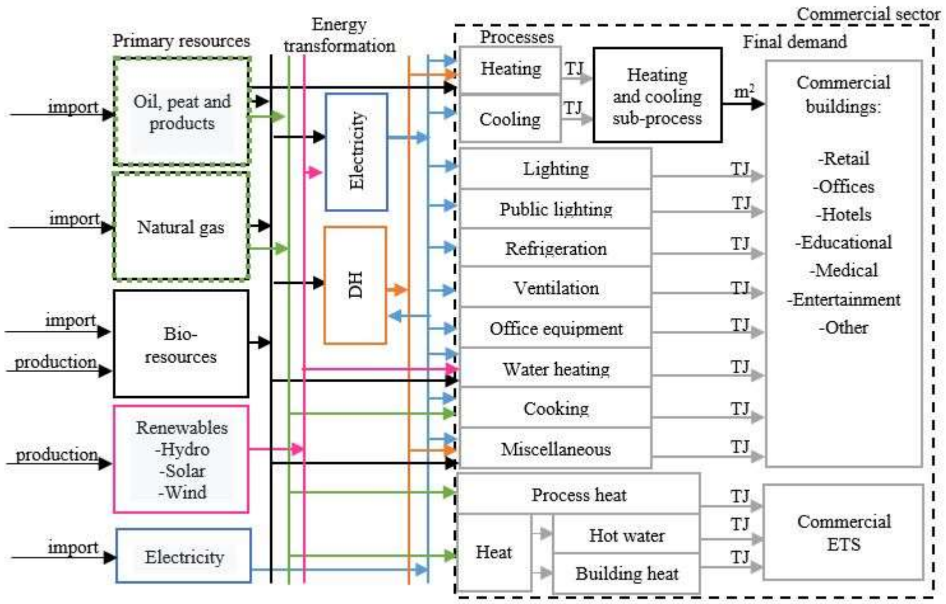


Fig.1.5. Process scheme of commercial sector.

Specific plants appear in commercial sector as ETS participants. Those mainly ensure different manufacturing processes. In TIMES model, they have been divided separately with similar processes to industrial sector – process heat and building heat and hot water.

The available statistical data only presents the total consumption of primary energy sources, heat and power consumption in overall commercial sector. Therefore, the specific consumption for different end use purposes (see Table **Error! Reference source not found.**.) has been determined through several assumptions and calculations.

The main input data for calculations is the total floor area of different types of buildings – offices, hotels and restaurants, schools, universities and research buildings (education), hospitals and buildings for health care facilities (medical), buildings for entertainment events and sports, museums, cultural and historical sites (entertainment) and other not previously classified buildings. Table **Error! Reference source not found.**. summarizes the main assumptions related to energy consumption distribution.

Heat consumption for the space heating has been calculated by assuming different levels of building efficiencies (specific heat consumption for space heating) according to available data sources [2]–[4]. The renovated and newly built buildings have been separated as those are subject to the specified standards [5]. As it is not necessary to maintain a certain indoor temperature throughout all the buildings, authors assume that only part of the total area is heated.

It can be seen in Table **Error! Reference source not found.**. that the specific consumption for domestic hot water has been estimated to be greater in hotels and hospitals [6], as there are high washing and cleaning standards applicable. Some of the buildings are mechanically ventilated to provide the necessary air exchange. Mechanical ventilation is assumed to be more widespread in the new and renovated buildings than in the existing buildings. Power consumption for the ventilation has been calculated similarly as space heating consumption by assuming the share of mechanically ventilated area and the average power consumption for ventilation [7]. Higher values have been assumed for medical and entertainment buildings as these buildings have higher requirements for air exchange rate.

Table 1.3.

Assumptions for energy distribution in commercial sector.

Parameter	Retail	Offices	Hotels	Education	Medical	Entertainment	Other
Share of heated area	85%	80%	75%	80%	80%	70%	30%
Specific heat consumption for space heating, kWh/m²							
existing buildings	130	140	135	160	160	150	120
renovated buildings				110			
newly built buildings				100			
Specific heat consumption for hot water heating, kWh/m²	10	10	35	21	24	10	5
Share of mechanically ventilated area							
existing buildings	60%	50%	50%	30%	50%	30%	30%
renovated buildings	70%	70%	70%	50%	70%	60%	40%
newly built buildings	80%	80%	80%	60%	80%	70%	50%
Power consumption for ventilation, kWh/m²	20	20	20	20	30	30	20
Share of building area with space cooling							
existing buildings	40%	50%	60%	40%	40%	20%	5%
renovated buildings	60%	70%	70%	50%	70%	60%	5%
newly built buildings	80%	80%	80%	60%	80%	70%	20%
Specific cooling consumption, kWh/m²	53	53	40	40	53	40	20
Average minimum level of illumination, lux	369	383	314	352	457	325	291
Specific power consumption for lighting, kWh/m²	29	14	12	10	34	13	20

Power consumption for space cooling has been determined according to the methodology presented by Werner [8]. Similar to previous estimations, authors assume the share of the total area, which is cooled during the warmer periods, and the specific cooling consumption of the particular type of building. Higher cooling demands have been assumed in the retail, office and medical buildings [9].

The specific power consumption for lighting has been determined through the minimum level of illumination requirements for different types of buildings [10].

$$SPC_{apg} = \sum \frac{Il_i \cdot \beta_{i,j}}{\eta_j} \quad (1)$$

where
Ili – illumination requirements in building type i, lm/m2;
βi,j –share of specific luminaries j used in buildings i;
η_j- efficiency of luminaries j, lm/W.

Authors assume that three different types of luminaries are used in commercial sector buildings – LED lighting (average share 44%; average efficiency 100 lm/W), efficient luminaries including luminescent and halogen lamps (average share 43%; average efficiency 56 lm/W) and inefficient luminaries (average share 13%; average efficiency 15 lm/W) [11].

In addition, power consumption for public lighting has been estimated through the correlation analyses (see Fig. **Error! Reference source not found.**). Authors have identified power consumption for the public lighting in several cities and towns, mainly presented in the sustainable energy action plans of municipalities. As it can be seen there is a good correlation between power consumption for the public lighting and the city or town area. Application of the regression equation allows estimating the total power consumption for public lighting in all populated areas and includes it in the overall energy balance of the commercial sector.

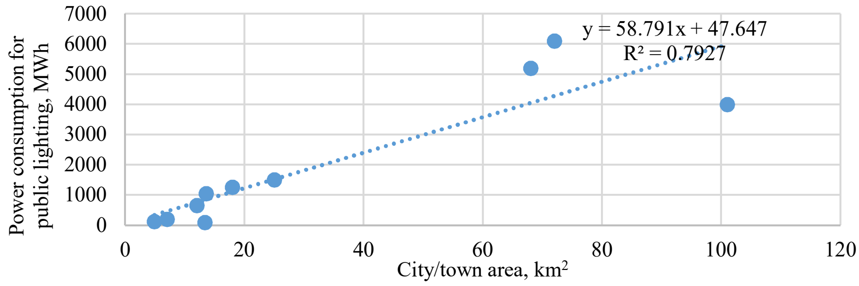


Fig.1.6. Regression analyses of power consumption for public lighting depending on the populated area.

Electricity consumption structure differs in commercial sector sub-sectors (see Fig. **Error! Reference source not found.**). In retail buildings as well in buildings for medical facilities and entertainment, most of the electricity is spent for lighting. In office buildings, the office equipment consumes the most power but in hotel and educational buildings most of energy is used for water heating.

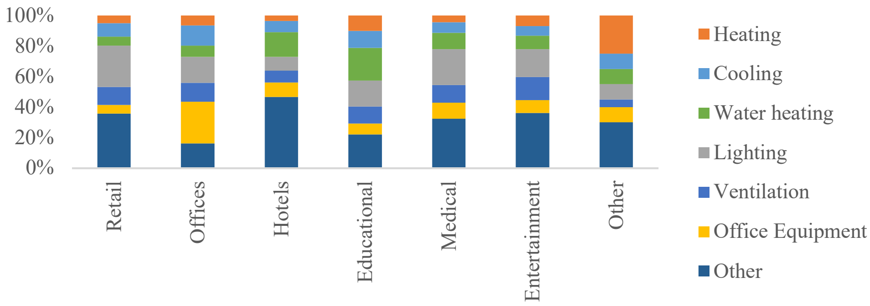


Fig. 1.7. Electricity consumption structure in commercial sector.

District heating and primary energy sources have been used for three processes – water heating, space heating and other processes like cooking.

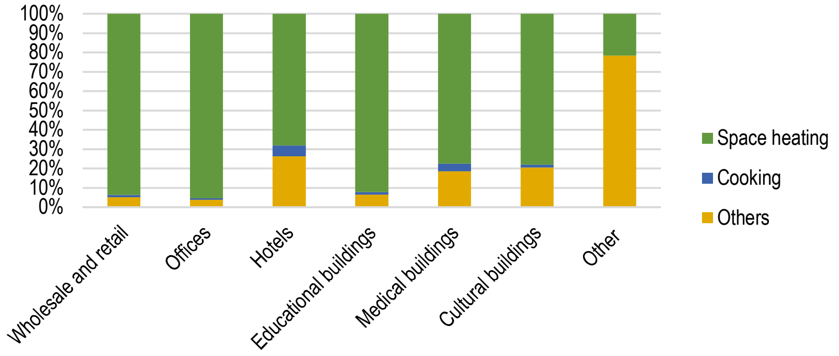


Fig.1.8. Distribution of heat and energy resources into commercial sub-sectors.

In almost all commercial sub-sectors, heating has mainly been used for space heating and only a small share for water heating (see Fig. **Error! Reference source not found.**.).

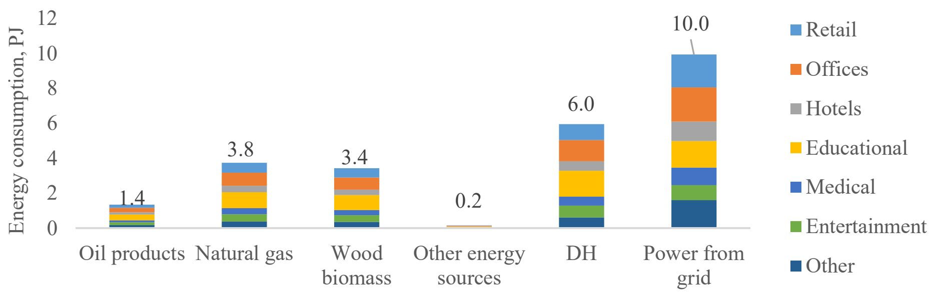


Fig. 1.9. Resource consumption structure in commercial sub-sectors in 2017.

Figure **Error! Reference source not found.**. gives the determined structure of consumed primary resources in 2017 using the methodology explained previously.

1.3. Residential sector

The second largest part reaching 29% of the final consumption is dedicated to the residential sector. Most of it was wood biomass consumption, equal to 21 PJ. In 2017 almost 6 PJ of power were consumed equal to 26% of total power consumption. Although natural gas consumption compile 9% of final residential energy consumption it is 34% of all consumed natural gas in Latvia.

The residential sector was divided into two sections – single-family houses and apartment buildings, as both use different energy resources and differ in their consumption. It is assumed that the single-family houses are not connected to the district heat (DH) network, but part of the apartment buildings are connected to centralised heat supply.

Processes analysed in TIMES model for residential sector are heating, cooling, water heating, refrigeration, lighting, cooking, electrical appliances and other applications (see Fig. **Error! Reference source not found.**.). New heating and cooling sub-processes are created similarly to the commercial sector. This allows to add policy measures related to energy efficiency of buildings more precisely.

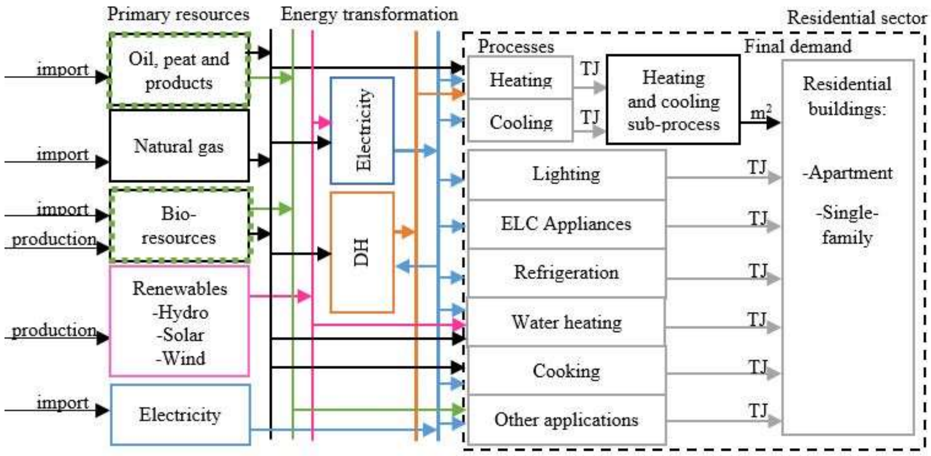


Fig.1.10. Process scheme of residential sector.

In addition, heating and cooling processes have been defined as pre-processes whereas the rest of the processes like cooking, lighting and others are marked as the final demand and will be analysed in different scenarios. There are also researches where surface area of the dwelling stock have been set as a demand driver for heating in the residential sector but it is not applied in the particular research [12].

The distribution of energy consumption is determined using available information on floorspace of single-family houses and buildings [2], as well as the total area of buildings connected to district heating [13]. The thermal energy consumption for buildings heating was calculated by adopting different levels of building efficiency in new, renovated, and existing buildings. The renovated and newly built buildings have been distributed on the assumption that their level of effectiveness complies with the required requirements for the base year [5]. Since it is not necessary to maintain a certain indoor temperature in all buildings, the authors have made the assumption that only part of the total area of buildings in Latvia is heated.

In order to determine the average heating consumption of buildings, the available data on the specific thermal energy consumption of more than 300 buildings connected to district heating is compiled. The average specific thermal energy consumption obtained for heating is 132 kWh/m^2 per year.

Some of the examined residential sector buildings have solar collectors installed mainly for hot water preparation during the summer period. Currently, information on the capacity installed by these technologies or the amount of thermal energy produced has not been compiled and is not included in the total Latvian energy balance. In order to reflect fully the current situation in Latvia's energy sector, the authors have included solar technologies for the preparation of hot water in the base year of the TIMES model, based on projects implemented under CCFI projects and technologies installed in 2011 and 2012. The authors have gathered publicly available information on more than 600 supported projects implemented in the “Usage of Renewable Energy in the Household Sector” programme, identifying the total installed capacity of solar collectors. It was established that an average of 1.6 MW of solar collector capacity was installed under this programme in each of the phases of the programme, provided that all projects submitted were realised and that all installations operate. Assuming that without co-financing solar thermal energy technology capacity installed each year is 50% less, the amount of solar energy produced in households was estimated to be around 20 TJ per year.

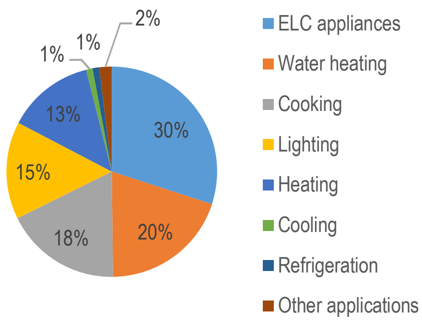


Fig.1.11. Structure of power consumption in residential sector in 2017.

The distribution of electricity consumption is similar in single-family houses and apartment buildings, since the behaviour of the consumer is similar in both type of building. The majority of power - 30% is consumed for different electrical appliances (TV, radio, mobile charging, etc.), 20% is used for heating water, 18% for cooking, 15% for lighting and 13% for heating (see Figure **Error! Reference source not found.**). The percentage distribution of energy resources and electricity usage is derived from the Odyssee [14] and Eurostat [15] database.

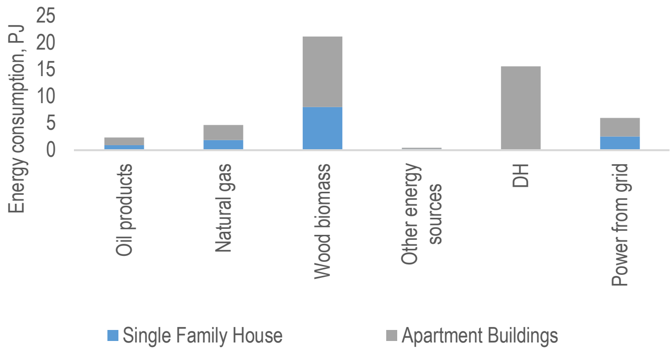


Fig.1.12. Resource consumption structure in residential sector un 2017.

Figure **Error! Reference source not found.** shows the distribution of energy resources in the residential sector. It appears that 38% of total wood consumption was used in single-family houses and 62% in multi-apartment buildings. Multi-apartment houses used nearly 16 PJ centralised heating energy in 2017.

1.4. Agriculture sector

The agricultural sector of the Times model is divided into three sub-sectors: agriculture, forestry and fishing. The fuel consumed in the sub-pipeline is determined according to the available data of Central Statistical Bureau of Latvia. In the forestry sub-sector it is assumed that only diesel fuel for wood harvesting and processing is consumed, and it has been determined on the basis of a specific indicator per one m^3 of forest developed [16] (see page Figure **Error! Reference source not found.**.).

The main final demand technologies in the agricultural sector are various types of tractors (machinery) and other devices (various electrical appliances, heating, hot water preparation, etc.).

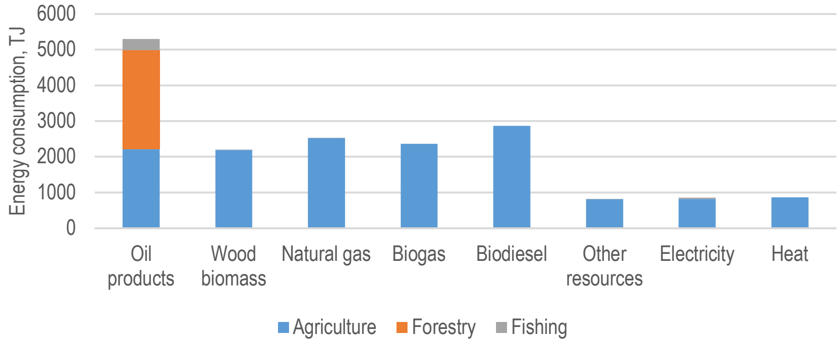


Fig.1.13. Distribution of energy consumption in the agricultural sector

Biogas is produced from raw materials available in the agricultural sector. The quantity of available raw materials is determined using the forecasts of the biogas sector system dynamics, based on the forecasts of the Latvian Ministry of Agriculture [17].

For the use of biogas in the transport sector, it is necessary to purify it. The cost of obtaining biomethane was taken from the BIOSURF study "Technical-economic analysis for determining the feasibility threshold for tradable biomethane certificates" [18]. Two technologies were considered for further transport of biomethane, connecting to the gas pipeline and transporting it in a compressed gas tank. The costs of connecting to the gas pipeline were accepted at tariffs determined by JSC "GASO" [19], while the costs of transporting a compressed gas tank from the scientific article "Biomethane in the transport sector—An appraisal of the forgotten option" [20].

1.5. Power sector

The power sector includes centralised electricity and heat production (see Fig. **Error! Reference source not found.**). In order to better model trends in the power sector, the power sector is divided into two sub-sectors – Riga and the rest of Latvia. For the distribution of the consumption of primary energy resources and the amount of heat produced, the available reports on air protection ("2-Gaiss" database [21]), the publicly available annual reports [22], [23] have been used. Data on the installed capacity installed of boiler houses, hydroelectric plants, wind plants, cogeneration plants are taken from Central Statistical Bureau of Latvia and from issued GHG permits [24].

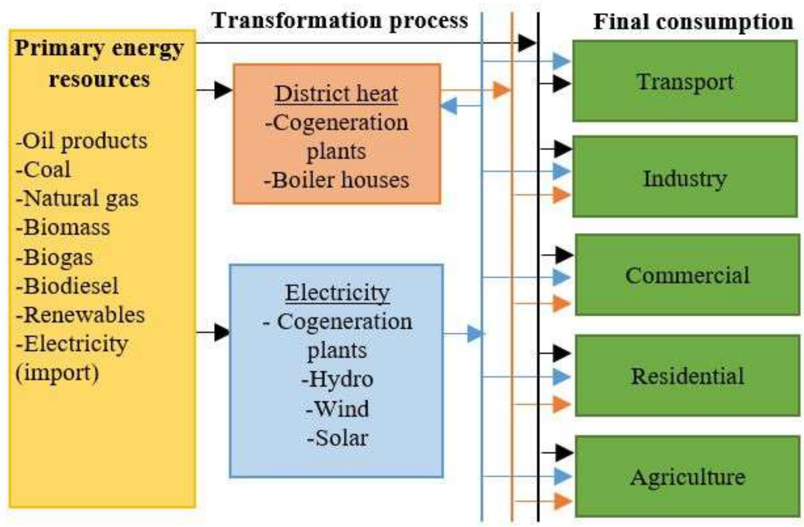


Fig. 1.14. Structure of power sector

The distribution of the total amount of heat and electricity produced is given in Figure **Error! Reference source not found.** with the additional breakdown consisting of ETS and non-ETS sub-sectors.

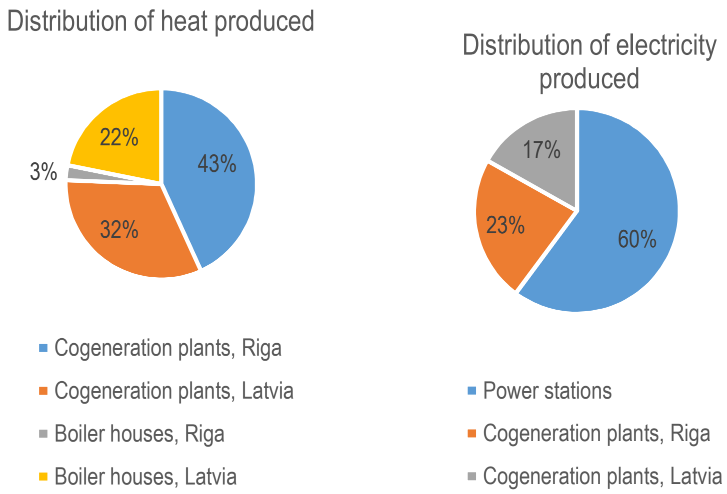


Fig.1.1.15. Distribution of produced heat and electricity

Although the amount of electricity produced by solar energy is not reported in the energy balance of Latvia in 2017, solar power plants are used by both households and the commercial sector and industrial sector mainly for self-consumption. Consequently, in the TIMES model, the authors included a certain proportion of electricity produced by solar panels in the power sector. In the absence of available data on solar electricity, which is not transferred to the electricity grid, the authors have used the available information regarding the permits issued by the Ministry of Economics for the introduction of new electricity generation plants [25]. The total amount of solar electricity produced in different sectors was estimated to be around 5,65 TJ in 2017.

1.6. Transport sector

Seven modes of transport have been implemented in the model structure for freight and for passenger transport by ship and air:

- Commercial truck light
- Commercial Truck Heavy
- Rail – Freigh
- Air Domestic
- Air International
- Shipping Domestic
- Pipeline network

Significant improvements have been made to road passenger transport in the model structure: distance, time parameter, comfort level, road infrastructure and service station infrastructure are applaid to model.

In order to ensure competition between different vehicles, 3 distances have been introduced in which different vehicles are able to move (see Figure **Error! Reference source not found.**.).

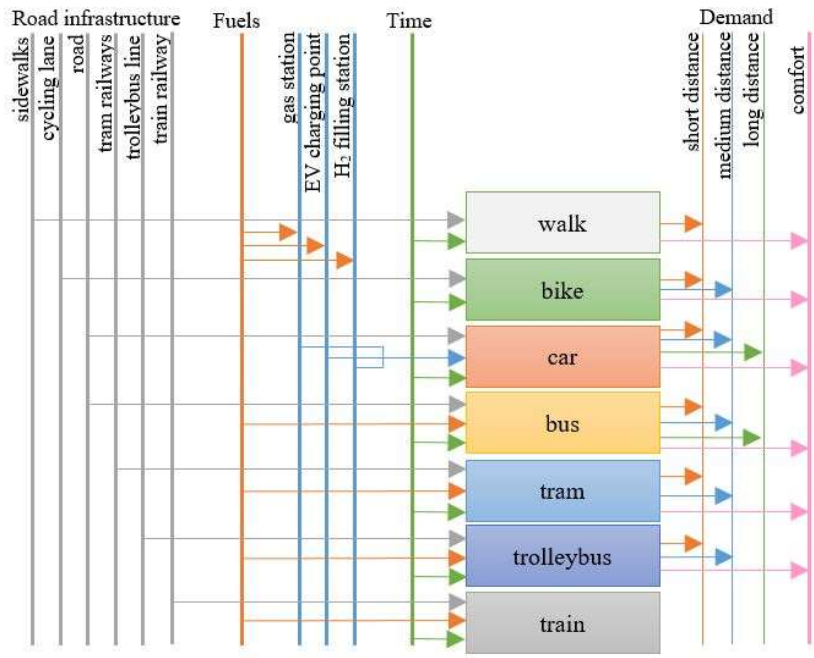


Fig.1.16. Transport sector structure of passenger travel on land

Road passenger distances, their lengths and means of transport which enable them to move within these distances are as follows:

- Short distances up to 5 km – walking, bikes, passenger cars, urban buses, trams, trolley buses
- Medium distances between 5 and 25 km – bikes, cars, urban buses, trams, trolley buses
- Long distances above 25 km – passenger cars, intercity buses and trains.

Table 1.4.

Assumptions for population mobility patterns

Transport mode	short distance (<5km)	medium distance (5-25km)	long distance (>25km)
Walking	100%	0%	0%
Bike	58%	42%	0%
Car	6%	30%	64%
Bus	19%	56%	25%
Trolleybus	20%	80%	0%
Tram	20%	80%	0%
Train	0%	0%	100%

The assumptions for the distribution of travel habits by distance were based on a study carried out in Denmark, adopting it to the situation in Latvia. For example, it was assumed that in the case of cycling, 58% of the cases take distances up to 5 km, while 42% of the cases travelled 5 km and more. On the other hand traveling by car, 6% of passengers travel distances up to 5 km, 30% of them take distances between 5 and 25 km and 64% more than 25 km (see Table **Error! Reference source not found.**.).

In addition, a *time* parameter is introduced. This parameter ensures that the model will not only switch to the most economically viable, which, for example, in the short distances would be a footing, but also takes into account the fact that there is a time limit.

Table 1.5.

Assumptions for vehicle speed (km/h) at each of the distances

Transport mode	short distance (<5km)	medium distance (5-25km)	long distance (>25km)
Walking	3		
Bike	12	12	
Car	26	42	63
Bus	21	21	52
Trolleybus	16	16	
Tram	16	16	
Train			36

Data on the speed of movement of vehicles in each of the distances were required to implement the time parameter. The average walking speed was estimated to be approximately 3 km/h, which is the slowest mode of movement. On the other hand, the quickest means of travelling any distance is the passenger car, where the average speed in the short distances reaches 26 km/h, at a mean distance 42 km/h, while in the long distances above 25 km the average speed of the car reaches 63 km/h (see Table **Error! Reference source not found.**.).

In addition, a new *comfort level* parameter has been introduced to ensure that the optimization of the model includes a criterion that prevents all transport flows from being switched to the most economically viable. The comfort level parameter requires a certain level of overall comfort and its development forecast is linked to the population growth. Moreover, this model implementation makes it possible to better integrate policy measures aimed to promote public transport usage by extending and optimizing routes, supporting the purchase of low-floor vehicles etc.

Table 1.6.

Rating description of the elements of comfort parameter

Nr.p.k.	Confort element	Rating description
1.	Security	1-insecure; 5-very safe
2.	Noise	1-big noise; 5- no noise
3.	Option to adjust indoor temperature	1- cannot be adjusted (outdoor air temparature); 5-can be easily adjusted
4.	Ability to travel with family	1-can only travel alone; 5- can travel with children (in own seat)
5.	Possibility to social distancing	1-no possibility (travel with many foreign others); 5-is possibility to travel alone
6.	Availability	1-needs to adapt to schedule, have to wait; 5-available anytime
7.	Non-barrier environment (ease of boarding)	1-cannot be travelled with wheelchairs etc.; 5-can easily move in a wheelchair (low floors, etc.)

The model used a multi-criteria analysis to determine the comfort level, evaluating 7 different elements, each on a 5-point scale (see Table **Error! Reference source not found.**.). The total maximum comfort level of each vehicle is 35 points (7 elements x 5 points). The average assessment of the comfort level of the baseline scenario is the highest for the passenger car, representing approximately 33 points, while the lowest overall average is for traveling by foot, which compiles 21 point (see Figure **Error! Reference source not found.**)

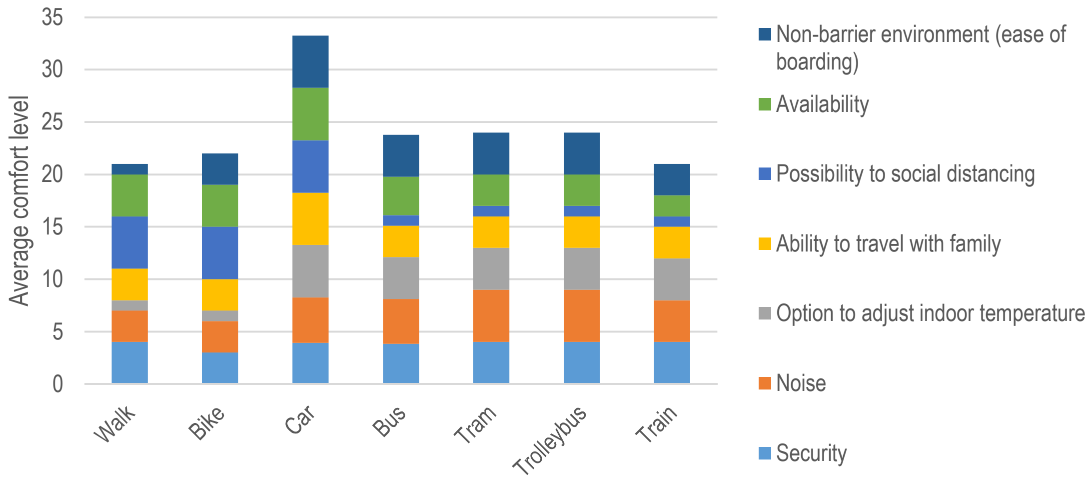


Fig.1.17. The average comfort level assumption for different modes of vehicle.

In addition, a road infrastructure parameter has been implemented, ensuring that transport flows cannot switch to vehicles without the necessary infrastructure. For example, trams whose tram line infrastructure is relatively limited.

Similarly, for light duty cars a required service station infrastructure has been introduced in the model. Without a sufficient number of service stations, it is not possible to develop a separate type of passenger vehicle, such as electric transport.

The consumption of total travel time for the reference year, the speed of vehicle travel in the distance and the distribution of population travel in the distance was calculated on the basis of data on the mobility of Latvian residents in 2017 [26] and assumptions from the modelling of the transport sector in Denmark [27], as well as the traffic data in Riga [28].

Data on the number of passenger vehicles by type of fuel consumed were derived from data of Central Statistical Bureau of Latvia (CSB) [29] and the Road Traffic Safety Directorate (CSDD) [30].

Data on the number of other vehicles were obtained from the Central Statistical Bureau of Latvia database [31], the Latvian Railways VAS [32].

Prices of new vehicles, depending on their fuel type, were adopted by reference to the US study "*Comparing resale prices and total cost of ownership for gasoline, hybrid and diesel passenger cars and trucks*" [33]. Prices of other public transport (trolleybus and tram) have been determined by investigating purchases made by Latvian local governments. Train prices are based on the adjustment of the 2015 US Department of Transportation Federal Railway Administration study entitled "*Cost-Benefit Analysis of Rail Electrification for Next Generation Freight and Passenger Rail Transportation*" [34].

CSB statistics were used to determine the length of the roads, while the "Cycling Development Plan for 2018-2020" was used to determine the length of the bicycle lanes [35].

Construction costs of new infrastructure were determined on the basis of the procurements of Latvian municipalities, as well as on the experience of other countries. The assumptions regarding the costs of bicycle lanes were based on available information on the procurement of Riga, Jurmala, Liepaja and Ventspils municipalities. The costs of construction of tramway and trolley-bus lines, as well as sidewalks, were also accepted on the basis of procurement by different municipalities. The cost of construction of roads is based on the formula for the construction season of 2018 of the Latvian Road Maintainer, where one million euro is one kilometre of road [36]. The costs of construction of railway tracks are determined by using the largest costs of the railway projects planned in Latvia ("Electrification of the Latvian railway network" and "Rail Baltica") [37].

Construction costs of fuel stations have been determined on the basis of available information on the construction of service stations in Latvia, as well as on the basis of experience from other countries.

1.7. Supply of energy resources

The SupplyData section of the *SUP* file lists prices for imported, local and export energy sources. Data on prices of imported coal, natural gas and crude oil were used according to EM data. Information on the annual and future prices of bioethanol, biodiesel and hydrogen was obtained on the basis of previous studies [38], [39]. Other energy prices are derived from the CSB database [40]. Data on energy consumption are taken from the 2017 energy balance available in the CSB database [41].

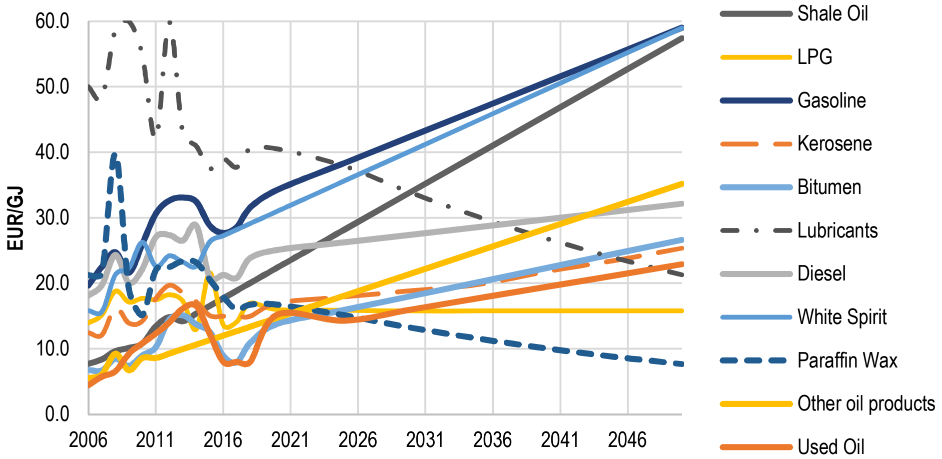


Fig. 1.18. Forecast of oil product prices

An analysis of historical data on the available period (from 2006 onwards) for each of the energy sources has been carried out to determine future price forecasts (see Fig. 1.18.) and volumes of exported/imported energy resources.

1.8. ETS un non-ETS sectors

The model uses an energy balance that includes a breakdown between the ETS and the non-ETS sectors for which data from the CSB was used [42], [43]. The ETS and non-ETS sectors are distributed in the industrial, commercial sector and transformation sector. The available data on GHG allowances issued and included plants have been used to determine more precisely the fuel consumption in these sub-sectors [24].

1.9. Demand for final processes

One of the most important input data in the TIMES model is the development of end-process demand during the modelling period. This demand is projected until 2050 and depends on several factors or demand drivers.

The main drivers in the TIMES model are GDP growth rate and population changes which are calculated based on forecasts developed by Ministry of Economics. For the demand processes of several sectors the EU Reference Scenario 2016 sectoral value added forecasts [44] have been used. These value added forecasts are used in transport, industry, commercial, agricultural sectors as well for energy sector self-consumption forecast, which ensures the operation of power sector. The TIMES model no longer predicts the amount of heat and space cooling, as these processes are embedded as intermediate processes required to provide space for household and commercial buildings. The required living space in the household sector is projected on the basis of GDP per capita, while the areas for commercial, office, educational, medical, cultural and other buildings are projected using the trend method including the population forecast.

2. TIMES MODEL SCENARIOS AND RESULTS

2.1. Description of scenarios

Four main scenarios – Baseline scenario, Baseline scenario with NECP2030 cumulative final consumption target, NECP scenario with National Energy and Climate Plan action policies and NECP scenario with cumulative final consumption savings target have been implemented in the model. Also reference scenario excluding existing taxes has been implemented in the model.

	Without NECP203 final energy goals	With NECP2030 final energy goals
Without NECP2030 activities	1st scenario *Baseline scenario*	3rd scenario
With NECP2030 activities and planned finance	2nd scenario	4th scenario

+

Towards Climate neutrality by 2050

Fig.2.1. Matrix of elaborated scenarios

2.1.1.Reference scenario

The Reference scenario does not include existing taxes, such as CO_2 and Natural resource tax (NRT), nor does it include a requirement to increase the amount of biofuels added to diesel and petrol starting from the year 2020. In the reference scenario biofuel share is applied at the level it was in 2017 and remains unchanged throughout the modelling period.

To run the reference scenario the following files must be selected in the Case manager window: SysSettings, BASE, NT-COM, NT-IND, NT-RSD, NT-PWR, NT_RSD, NT-AGR, NT-TRN_BASE, M2_BASE_UC-TRN, bound_TRN_BASE, bound_RES_BASE, NoFloShar_TNR_REF.

2.1.2.Baseline scenario

The Baseline scenario includes existing taxes, such as the NRT, CO_2 tax, excise duty on fossil fuels and a diversified excise duty for the industry and the transport sector natural gas, and also includes vehicle operating tax. As well as from 2020, the minimum share of added biofuels is 10% for petrol and 7% for diesel. The baseline scenario also includes an amount of insulation of residential buildings, which corresponds to 156 million euros of existing grants for the purpose of insulating buildings provided by EU funds. The amount of heating is derived from the System-dynamic model results and included as input data in the TIMES model.

To run the Baseline scenario, the following files must be selected in the Case manager window: SysSettings, BASE, NT-COM, NT-IND, NT-RSD, NT-PWR, NT_RSD, NT-AGR, NT-TRN_BASE, M2_BASE, UC-TRN, bound_TRN_BASE, bound_RES_BASE, CO2TAX, DRN_BASE, TRN_EksplNod.

2.1.3.NECP policy scenario

The NECP scenario includes the measures from Annex 4 of the National Energy and Climate Plan that are defined by a specific amount of funding. Similarly, non-financial measures, such as raising the comfort factor for public transport (the effect of improving public transport capabilities), restrictions on the installation of solid or liquid fossil fuels in heating, have been implemented. The measures incorporated directly or indirectly are the following:

- Promotion of the production of biogas and biomethane and the use of biomethane
- Promoting energy efficiency improvements of public buildings owned by the state and local governments
- Promotion of RES use and energy efficiency in local heating and individual heating
- Promoting the use of solar energy in electricity generation
- Promoting the use of RES and improving energy efficiency in industry and economic operators
- Promotion of RES use and energy efficiency improvements in district heating
- Limitations for the installation of new combustion plants that use only solid or liquid fossil fuels
- Construction of offshore wind park
- Promotion of energy efficiency in residential buildings
- Supporting sustainable infrastructure
- Promotion of the purchase of low-emission vehicles and low-emission vehicles by individuals or economic operators
- Promoting the use of the backbone of the rail as a modern and environmentally friendly public transport system
- Promotion of cycling, cycling infrastructure and sidewalk development

To run the NECP scenario the following files must be selected in the Case manager window: SysSettings, BASE, NT-COM, NT-IND, NT-RSD, NT-PWR, NT_RSD, NT-AGR, NT-TRN_NEKP, UC-TRN, bound_TRN_NEKP, bound_RES_NEKP, CO2TAX, DRN_NEKP, TRN_EksplNod and all files that start with 1NEKP.

2.1.4. Baseline scenario with cumulative energy end-use savings target

This scenario includes all baseline scenario conditions and an end-use energy saving target calculated on the basis of the final energy consumption value from the 2018 energy balance minus 1,34 PJ in the coming years till 2030. No cumulative savings target are set after the year 2030.

To run the Baseline scenario with cumulative energy end-use savings target, the following files must be selected in the Case manager window: All files from the Baseline scenario and the file TARGET.

2.1.5.NECP scenario with cumulative energy end-use savings target.

This scenario includes all the conditions of the NECP scenario and an end-use energy saving target calculated on the basis of the final energy consumption value from the 2018 energy balance minus 1,34 PJ in the coming years till 2030. No cumulative savings target are set after the year 2030.

To run the NECP-target, the following files must be selected in the Case manager window: All files of the NECP scenario and the file TARGET.

2.1.6.Adjustment and supplementation of scenarios

All scenarios could be supplemented and adjusted, taking into account the wide range of factors influencing the model inputs and results. There are uncertainty about tax rates in the future and currently unknown consequences of COVID-19, as well as the practicalities of the European Green Deal.

The nature and scope of possible adjustments will depend, firstly, on the information available and, secondly, on the speed how development policy documents will be designed and approved, and at last, on other factors, for example, macroeconomic conditions.

2.2. Results

2.2.1.Reference scenario

Final energy consumption by sectors in the Reference scenario for 2017-2050 is shown in Figure 2.2.1. The results show that total final consumption will increase to 180 PJ by 2050. In 2030, the total final consumption is 176 PJ. There is a growing trend in almost all final consumer sectors, with consumption declining only slightly in the residentiald sector.

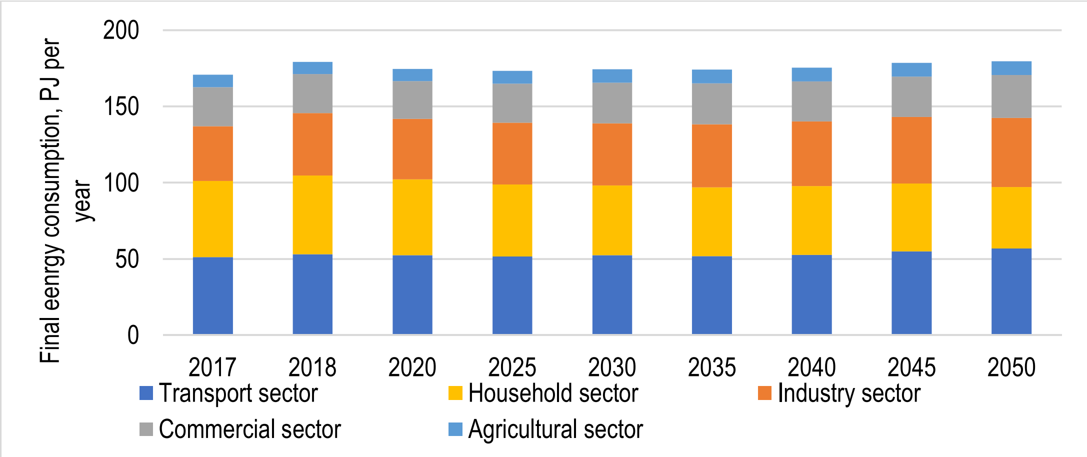


Fig. 2.2.1 Final energy consumption by sector in the reference scenario

Final energy consumption by used energy resources in the reference scenario in 2017-2050 is shown in Fig. 2.2.2.

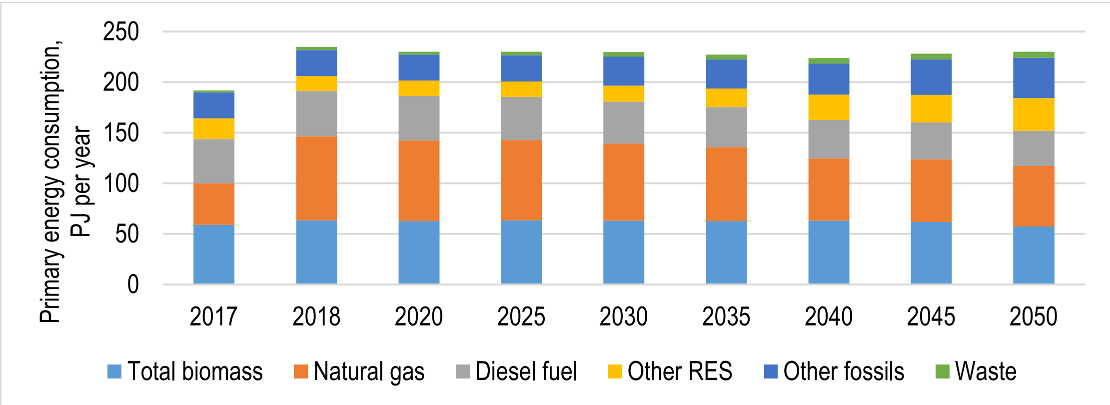


Figure 2.2.2. Consumption of main primary energy resources in the reference scenario

The results of final energy consumption in reference scenario shows that the projected use of other fossil fuels will increase by 2050, due to the wider use of coal in the residentiald and commercial sectors. It is due to low resource price growth and constant tax (eg CO_2 components) rates.

2.2.2. Baseline scenario

Final energy consumption by sector in the Baseline scenario for 2017-2050 is shown in Fig. 2.2.3. The results show that in 2030 the total final consumption will be 174 PJ, but in 2050 it will increase to 182 PJ. There is an growing consumption trend in the industrial, commercial and agricultural sectors, but consumption is declining only slightly in the residentiald sector.

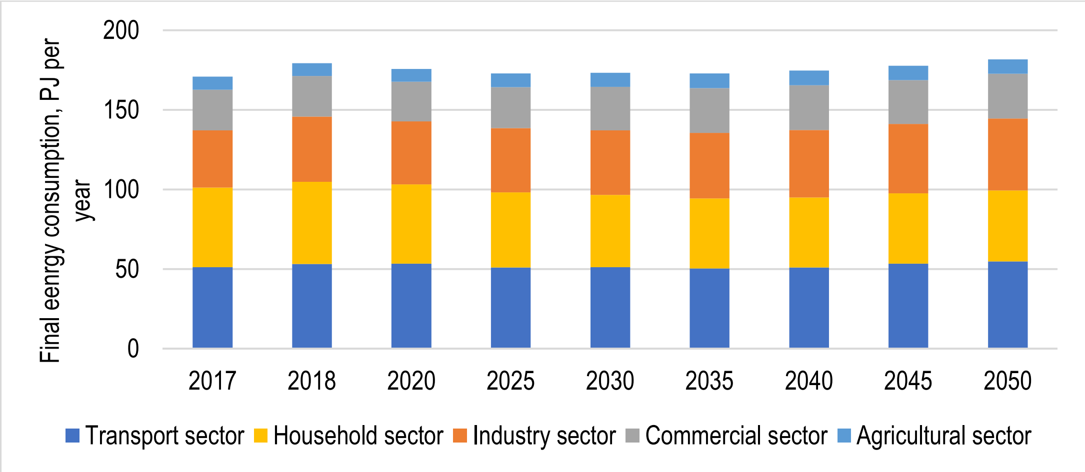


Fig. 2.2.3. Final energy consumption by sector in the Baseline scenario

Energy consumption by types of energy resources used in the Baseline scenario in 2017-2050 is shown in Figure 2.2.4. When analysing final consumption in terms of energy resources, it can be seen that by 2030 there will be a decrease in the use of natural gas and diesel fuel. After 2030, the projected use of RES will increase, which is related to the use of wind and solar energy in the power sector. However, in this scenario, the use of fossil fuels is also increasing, due to the wider use of coal in the industrial sector and the use of liquefied petroleum gas in the transport sector. The reason for this situation is the low growth rate of resource prices, as well as constant tax rates (eg especially the CO_2 component).

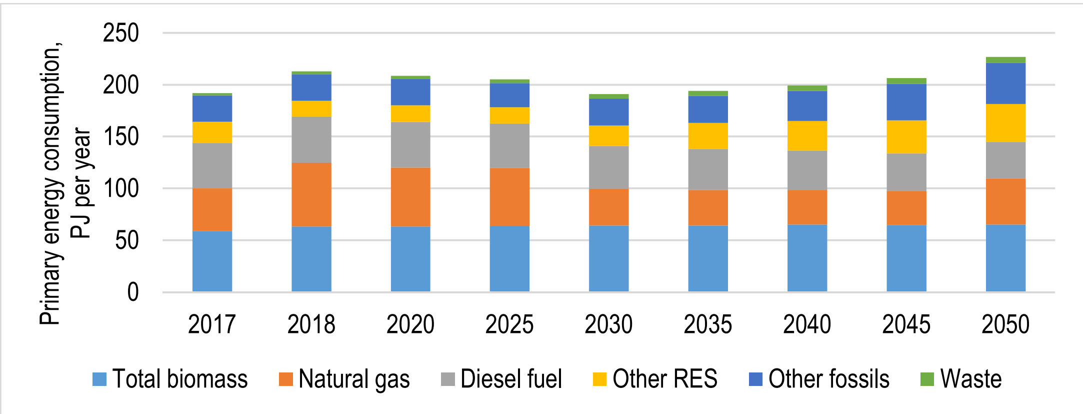


Figure 2.2.4. Consumption of main primary energy resources in the Baseline scenario

In the power sector, the use of solar and wind energy for heat and electricity generation is increasing in the Baseline scenario. The use of natural gas in the power sector is increasing during first years and then decreasing from 2030 onwards. The use of wood in the power sector decreases slightly in the Baseline scenario.

2.2.3.NECP2030 policy scenario

Final energy consumption by sectors in the NECP2030 policy scenario for 2017-2050 is shown in Fig. 2.2.5. The results show that in 2030, the total final consumption is 171 PJ, but in 2050 it is 172 PJ, which is a significant reduction compared to the Baseline scenario. The final energy consumption of sectors in the NECP2030 policy scenario will decrease by 4 PJ in 2030 and by 11 PJ in 2050. The cumulative savings comparing the NEKP2030 scenario and the Baseline scenario until 2050 is 22 PJ. There is still a growing consumption trend in the industrial, agricultural and commercial sectors, while a significant decrease in consumption is observed in the residential and transport sectors, which will increase after 2040.

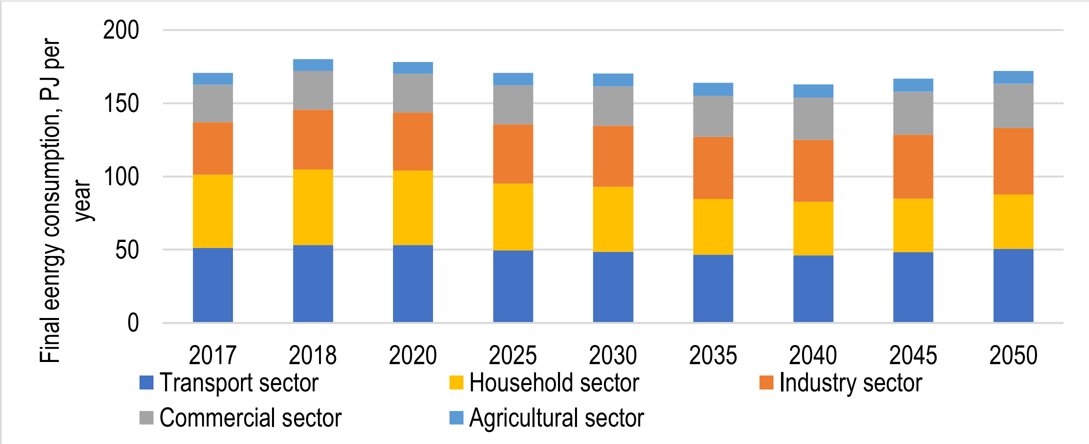


Fig. 2.2.5. Final energy consumption by sector in the NECP2030 policy scenario

Final energy consumption by types of energy resources in the NECP2030 policy scenario for 2017-2050 is shown in Fig. 2.2.6. The NECP2030 policy scenario, in contrast to the Baseline scenarios, shows a significant reduction in the use of diesel and natural gas. The decrease in oil resources can be explained by the development of electric transport, which replaces the existing cars with internal combustion engines, reducing the demand for fossil fuels. The main differences between the results of the Baseline Scenario and the NECP2030 Policy Scenario can be seen in the transport and residential sector.

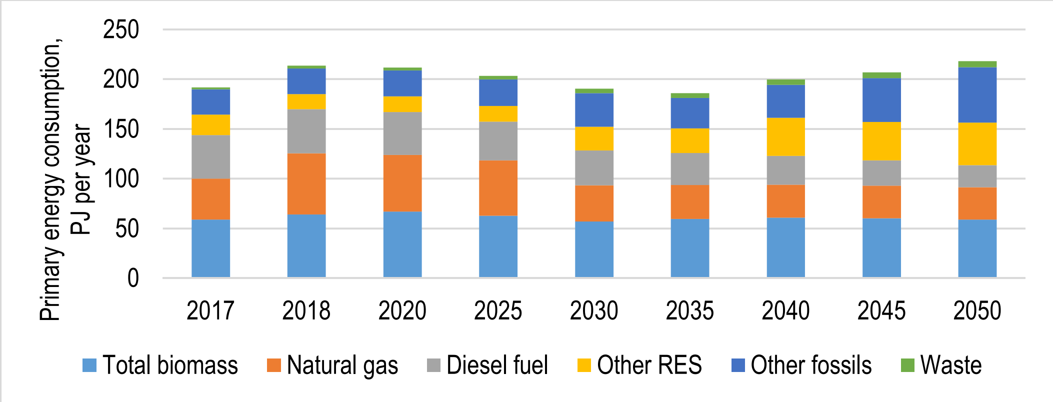


Figure 2.2.6. Primary energy consumption by type of energy in the NECP2030 policy scenario

As shown in Fig. 2.2.6. in the NECP2030 policy scenario, RES consumption and the share of RES increase faster, driven by, the increased use of solar and wind energy both at the microgeneration level (eg solar panels and solar collectors in households) and at the high capacity level (eg solar energy use in district heating systems, solar panels for self-consumption and wind farms).

Figure 2.2.7 shows that in the transport sector the consumption of diesel fuel and petrol is significantly decreasing and the use of RES bioethanol and electricity is slightly increasing. The use of biodiesel and advanced biofuels is not expected to grow rapidly as the total amount of diesel consumption decreases. However, the use of kerosene-type jet fuel in aviation remains relatively high in the transport sector, which will increase significantly until 2050. This is because there is no political measures planned to replace this fuel. After 2040, the use of liquefied petroleum gas will increase.

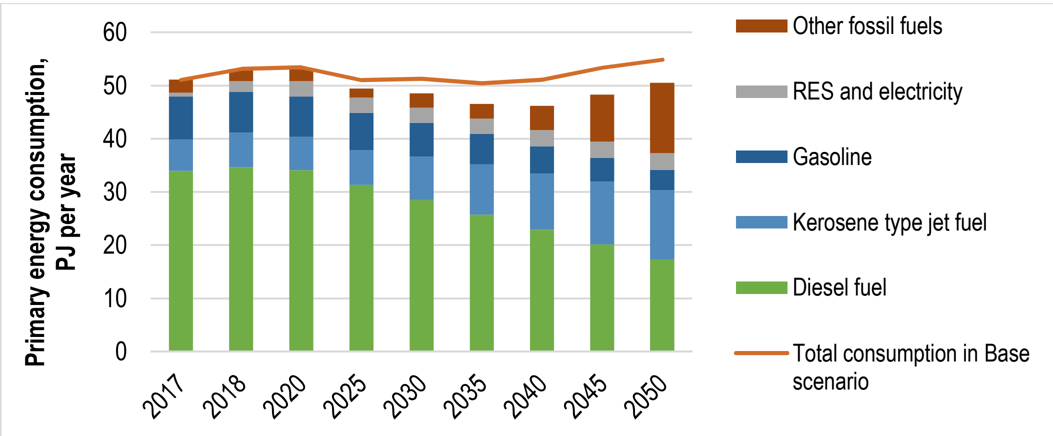


Fig. 2.2.7. Final consumption by type of energy resources in the transport sector in the NECP2030 policy scenario

Compared to the Baseline scenario, in the case of the NECP2030 policy scenario, the total final consumption of the transport sector will decrease by 4 PJ in 2030, but by 6 PJ in 2050. This is due to increased vehicle efficiency, the shift to lower-emission vehicles, the implementation of transport mobility and changes in economic activity (eg the possibility to work remotely, etc.).

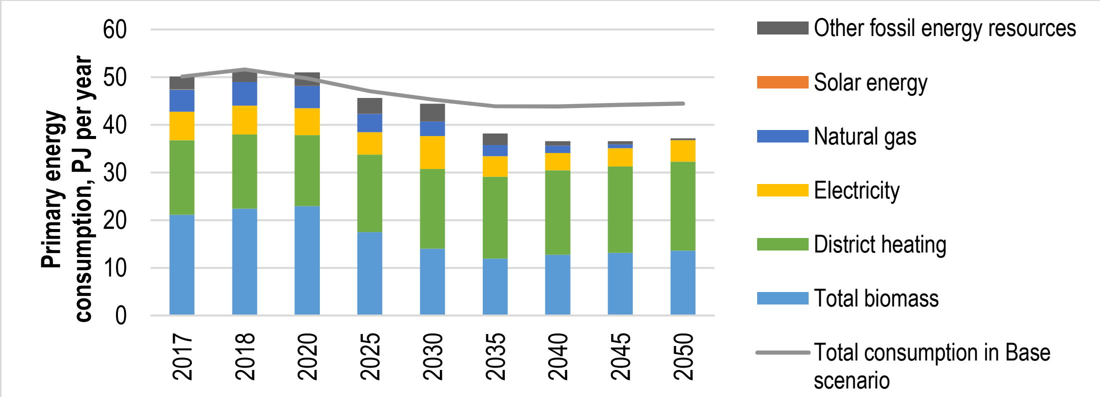


Fig. 2.2.8. Final consumption by type of energy resources in the residential sector in the NECP2030 policy scenario

In the residential sector, in the NECP2030 policy scenario, a significant contribution to the reduction of final consumption is provided by support of building renovations (see Figure 2.2.8).

Compared to the Baseline scenario, in the case of the NECP2030 policy scenario, the total final consumption of the residential sector will decrease by 1 PJ in 2030, but will decrease by 7 PJ in 2050. The modelled results show that the consumption of district heating in the residential sector is increasing and the use of biomass is decreasing. By 2050, natural gas consumption will be significantly reduced.

2.2.4.NECP2030 target scenario

By defining the achievable cumulative final consumption savings target for 2030, the results of the NECP2030 target scenario were obtained. Final energy consumption by sector in the NECP2030 target scenario for 2017-2050 is shown in Figure 2.2.9. The results show that in 2030, the total final consumption will be 162 PJ and will grow up to 172 PJ in 2050. Compared to the Baseline Scenario, sector consumption in the NECP2030 target scenario will decrease by 12 PJ in 2030 and by 10 PJ in 2050. Compared to the NECP2030 policy scenario, a much faster decline in final consumption is observed in the residential sector in 2030.

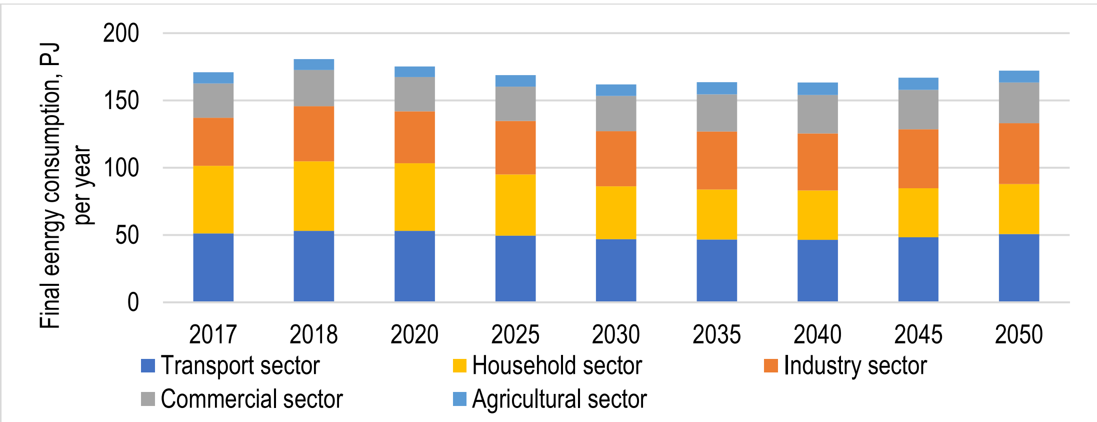


Fig. 2.2.9. Final energy consumption by sector in the NECP2030 target scenario

Final energy consumption by types of energy resources in the NECP2030 target scenario for 2017-2050 is shown in Fig. 2.2.10. Compared to the NECP2030 policy scenario, there is a slight increase in natural gas consumption, but the consumption of other fossil energy resources in 2030 will decrease by 5 PJ.

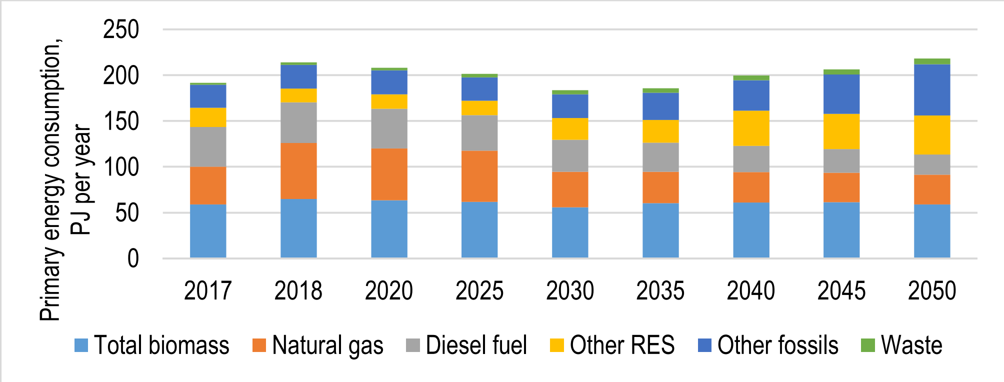


Fig. 2.2.10. Primary energy consumption by type of energy in the NECP2030 target scenario

In the residential sector a significant contribution to the reduction of final consumption is provided by support for building renovation and wider use of electricity in the NECP2030 target scenario (see Figure 2.2.11).

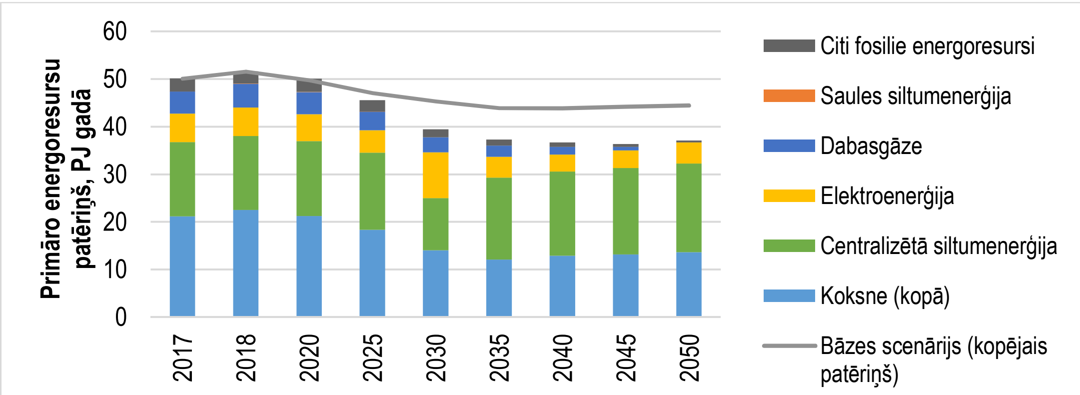


Fig. 2.2.11.Final consumption by type of energy in the residential sector in the NECP2030 target scenario

Comparing the NECP2030 policy and the NECP2030 target scenarios, the total final consumption of the residential sector will decrease by 5 PJ in 2030, but in 2050 it will be the same in both scenarios. The modeled results show that by 2030 the use of electricity will be significantly increased and the use of district heating and other fossil energy resources will decrease compared to the NECP2030 policy scenario.

2.2.5.Baseline target scenario

Final energy consumption by sector in the Baseline target scenario for 2017-2050 is shown in Fig. 2.2.12. The results show that in 2030 the total final consumption will be 162 PJ, but in 2050 it will be 182 PJ. Compared to the Baseline scenario, the consumption of sectors in the Baseline target scenario will decrease by 12 PJ in 2030, but in 2050 the final consumption of both scenarios will be the same. Compared to the NECP2030 target scenario, in 2030 a much faster decrease in final consumption is observed in the industry, commercial and residential sectors, but higher final consumption is in the transport sector.

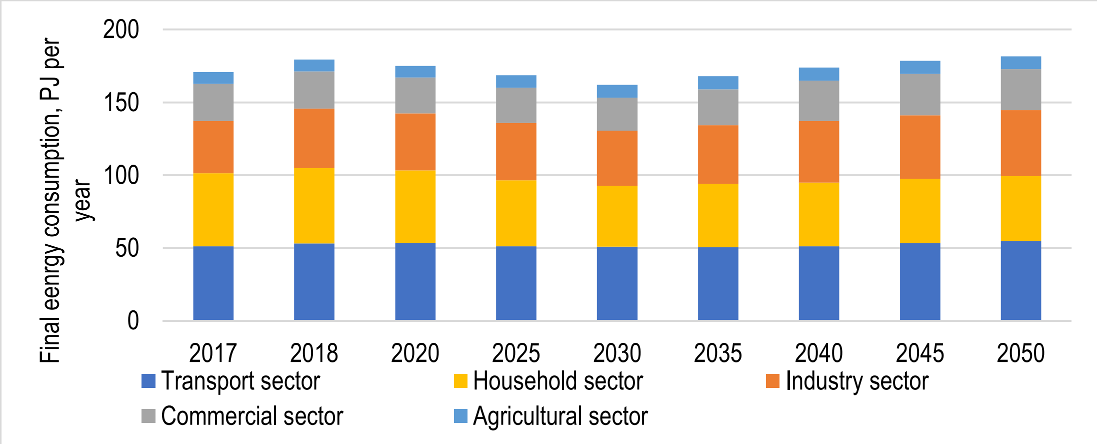


Fig. 2.2.12. Final energy consumption by sector in the Baseline scenario

Final energy consumption by types of energy resources in the Baseline target scenario for 2017-2050 is shown in Fig. 2.2.13.

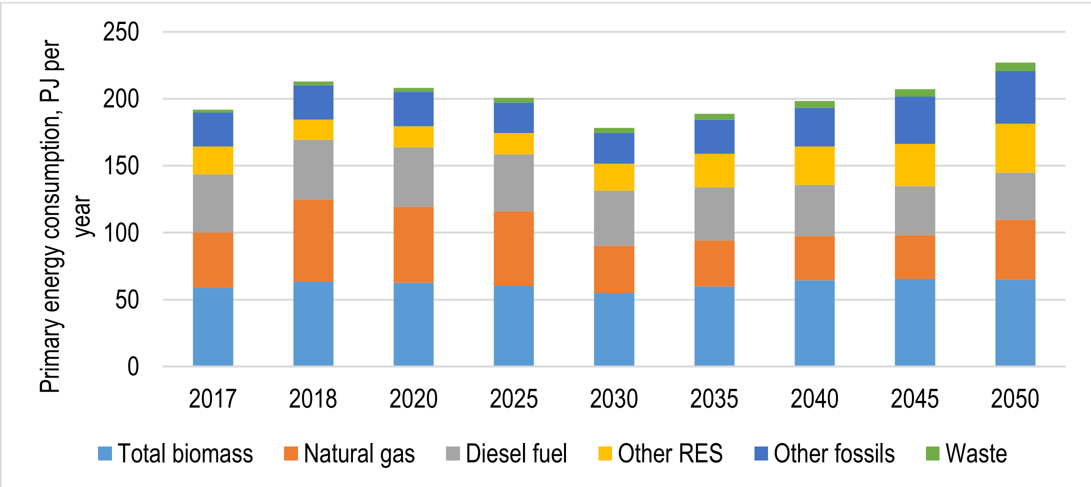


Fig. 2.2.13. Primary energy consumption by type of resource in the Baseline target scenario

Compared to the NECP2030 target scenario, in 2030 there is an increase in diesel fuel consumption by 6PJ, but natural gas consumption is decreasing. The Baseline target scenario also has lower consumption of biomass and other RES compared to the NECP2030 target scenario.

2.2.6. Comparison of scenarios

The figure below shows the comparison of the total final consumption of all analyzed scenarios from 2017 to 2050. It can be seen that in target scenarios, final consumption will decrease faster after 2020 than in the NECP2030 policy scenario. However, all scenarios show an increase in final consumption after 2030 (Baseline target scenario) or after 2040 (NECP2030 policy and NECP target scenario), which indicates the need to set long-term targets until 2050.

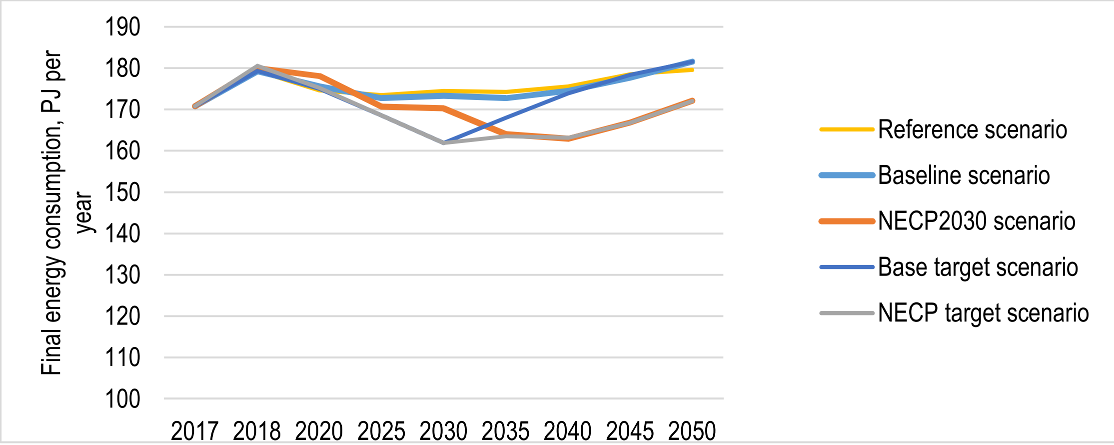


Fig. 2.2.14. Sectoral final consumption in the different scenarios analysed

The total consumption of primary resources in the various analyzed scenarios is shown in Figure 2.2.15. In all scenarios, there is a tendency for consumption to decrease by 2030 and further increase until 2050. A faster increase in the consumption of primary resources in 2050 is observed in the Baseline and Baseline target scenarios.

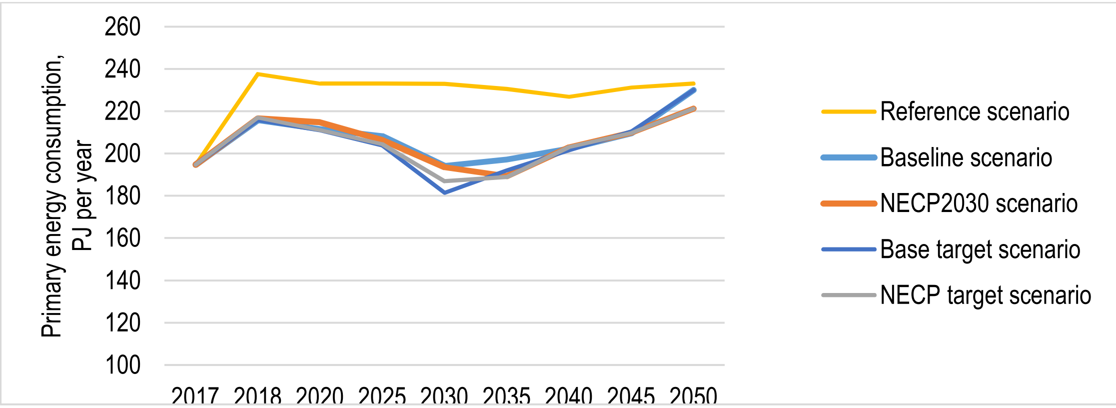


Fig. 2.2.15. Consumption of primary resources in different analyzed scenarios

The modeled share of RES in the total resource consumption is shown in Figure 2.2.16. It can be seen that in 2030, the highest share of RES achieved is in the Baseline and NECP2030 policy scenario (44%), but lower - in the scenarios of the defined final consumption savings target (41-42%). In the Baseline scenarios, the share of RES achieved in 2050 is 44%, but in the NECP scenarios 46% of the total consumption of primary resources.

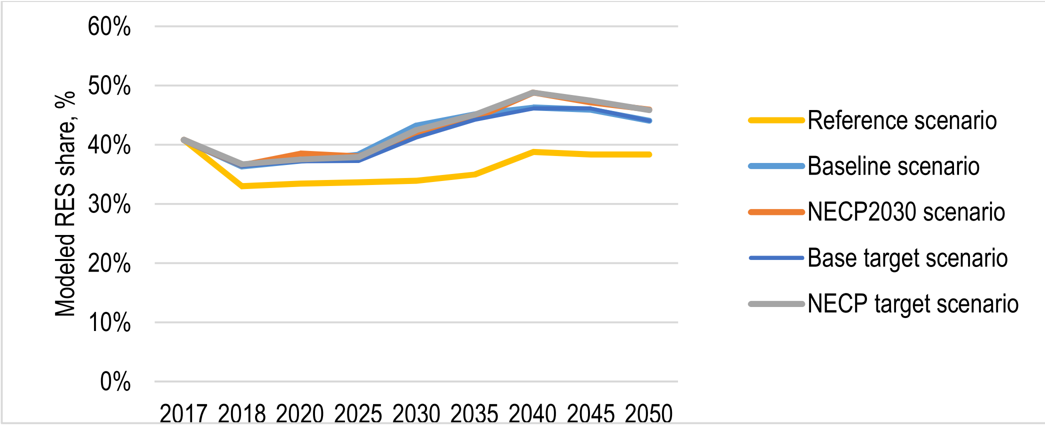


Fig. 2.2.16. The modeled share of RES in various analyzed scenarios

The results of the scenarios show that the policy measures included in the NECP allow to achieve resource consumption savings and a higher share of RES, but it is already necessary to set long-term goals until 2050 in order to more successfully implement energy system restructuring and climate neutrality goals.

3. UPDATING AND SUPPLEMENTING THE SYSTEM DYNAMICS MODEL

The Latvian National Energy and Climate Plan (NECP) system dynamics model that was developed during the first year of the project has been supplemented with a number of modules developed in other National Research Programm projects, manually transferred from the modeling software Powersim to Stella Architect, developed a user-friendly Internet-based model interface.

3.1. Transition from modeling tool “Powersim” to “Stella Architect”

In the first year of the project, the system dynamics model was created in the modeling software Powersim, but its ability to present the model in a user-friendly way is limited. Thus, the model was manually transferred to the modeling tool Stella Architect. It has a wide range of tools available to present and use the model in user-friendly way. Figure 2.1.att. shows print screen of the overall structure of the model as presented in Stella Architect, incl. energy consumption in different sectors (industrial sector, services sector, public sector, residential sector, energy consumption), the transport sector, the agricultural sector, energy production by each of consumption sectors, construction sector for heating of buildings, policy measures (energy efficiency and RES support fund, penalty-award mechanism, taxation, information, etc.) and policy scenarios (base scenario, municipality scenario, energy efficiency obligation scheme scenario, energy tax scenario) and results (RES share and cumulative savings).

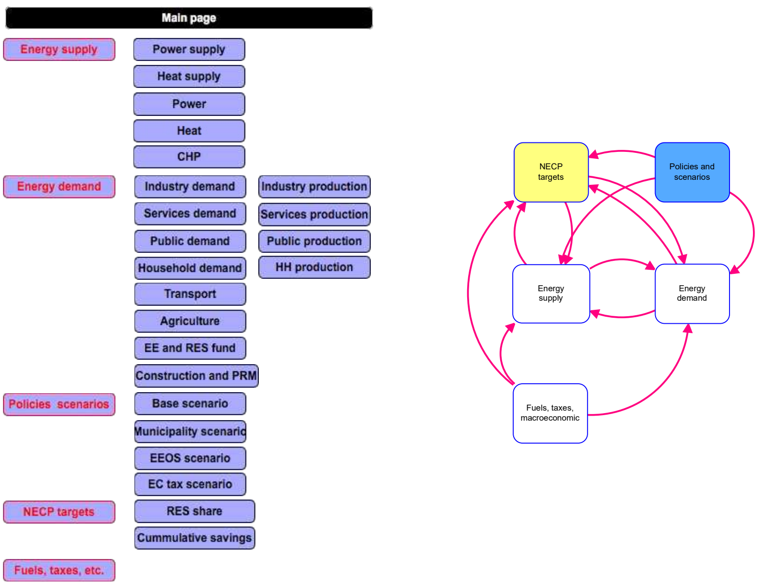


Figure 2.1. Screenshot of starting page of the transferred system dynamics model in Stella Architect software

3.2. Internet-based user interface

After the transfer of the system dynamics model from Powersim to Stella Architect, an Internet-based user interface was created. The interface is available to everyone.

Figure 2.2. shows screenshot of the Internet-based user interface start page of the model, which is available to anyone visiting assigned Internet page of the model.

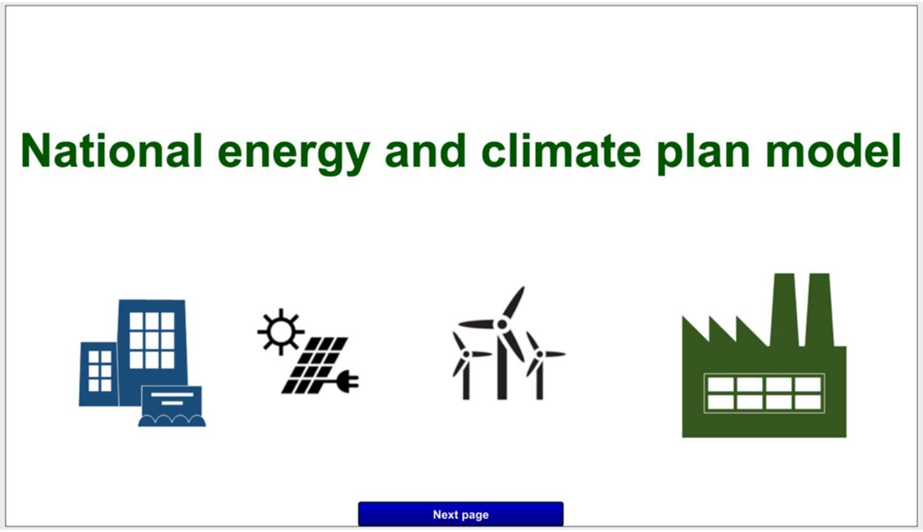


Figure 2.2. Screenshot of Internet-based user interface start page of the model

Figure 2.3.att. shows screenshot of user interface page where different policy tools can be selected. By changing their values, their impact on cumulative savings and the share of RES can be observed in relevant graphs. The interface provides policy measures that can be either switched on and off, or values can be changed within certain limits.

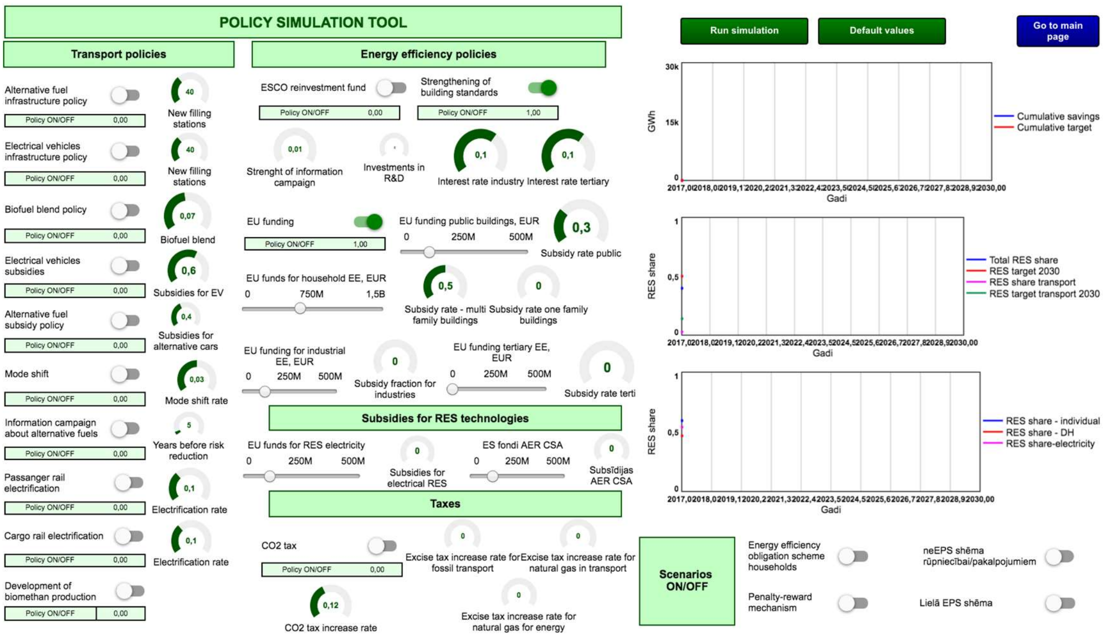


Figure 2.3. Screenshot of model user interface page where different policy tools can be selected

Figure 2.4.att. shows screenshot of the user interface page with achieved results for the selected policy tools. The interface provides control buttons for live mode simulation. It gives option to the user to monitor the impact of any policy tool on cumulative savings and the share of RES if their values during the simulation are changed.

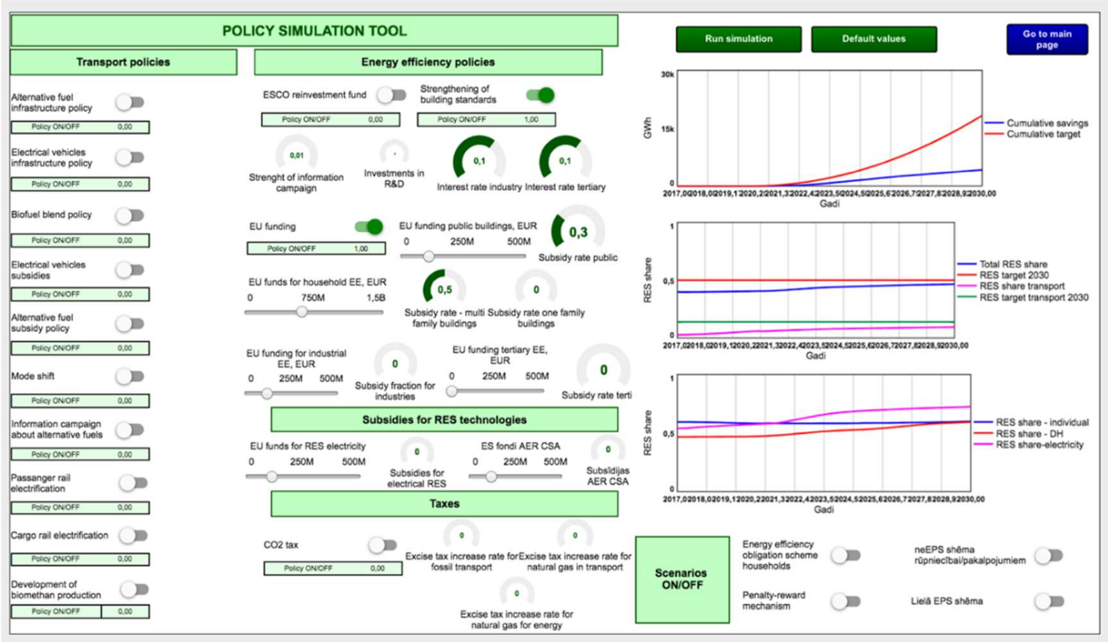


Figure 2.4. Screenshot of model user interface page with simulation results for different policy tools.

3.3. Supplementing the model with additional modules

The Latvian National Energy and Climate Plan (NECP) model developed in the first year of the project is complemented by a number of modules developed in other National Research Program (NRP) projects, e.g. energy community (developed in the NRP project Improving technological solutions for energy efficiency of buildings), energy efficiency obligations scheme (developed in the NRP project Assessment and analysis of energy efficiency policies), use of waste heat in the district heating system (developed in the NRP project Development of Latvian heating and cooling systems). They are integrated into the different sub-structures of the model as they relate to different sectors. Figure 2.5.att. shows the conceptual scheme of original NECP system dynamic model and new modules added to it. The waste heat utilization module is integrated into heat generation sector, industry, residentials, services and the public sector. The energy community module is integrated into all sectors, since it includes both energy production and energy consumption reduction. The energy efficiency obligations scheme module is integrated with all sectors since Ministry of Economy foresees introduction of energy efficiency obligations scheme in all sectors.

The structural integration of modules has been carried out during this reporting period. During coming months, the validation and simulation results of the new version of the model will be carried out.

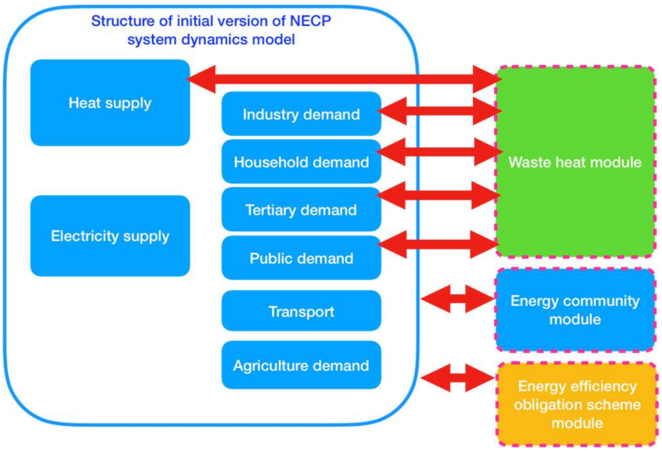


Figure 2.5. Conceptual scheme of the original NECP model and additional modules integrated into it

3.4. Energy Community sub-model

The NEKP model developed in the first year of the project integrates the energy community sub-model. The structure of this sub-model is developed by the NRP project Improvement of energy efficiency technological solutions for buildings to analyze the transition of the historic urban block to the positive energy balance block. This is a model of demand-supply energy flows. In the existing NECP system dynamics model, it is integrated into both energy consumption and energy production sub-models as prosumer. The main modules of the sub-model structure are shown in Figure 2.6., and are:

- demand for thermal energy;
- electricity demand;
- waste heat;
- renewable heating;
- supply of electricity from renewable energy sources;
- seasonal heat storage;
- storage of electricity.

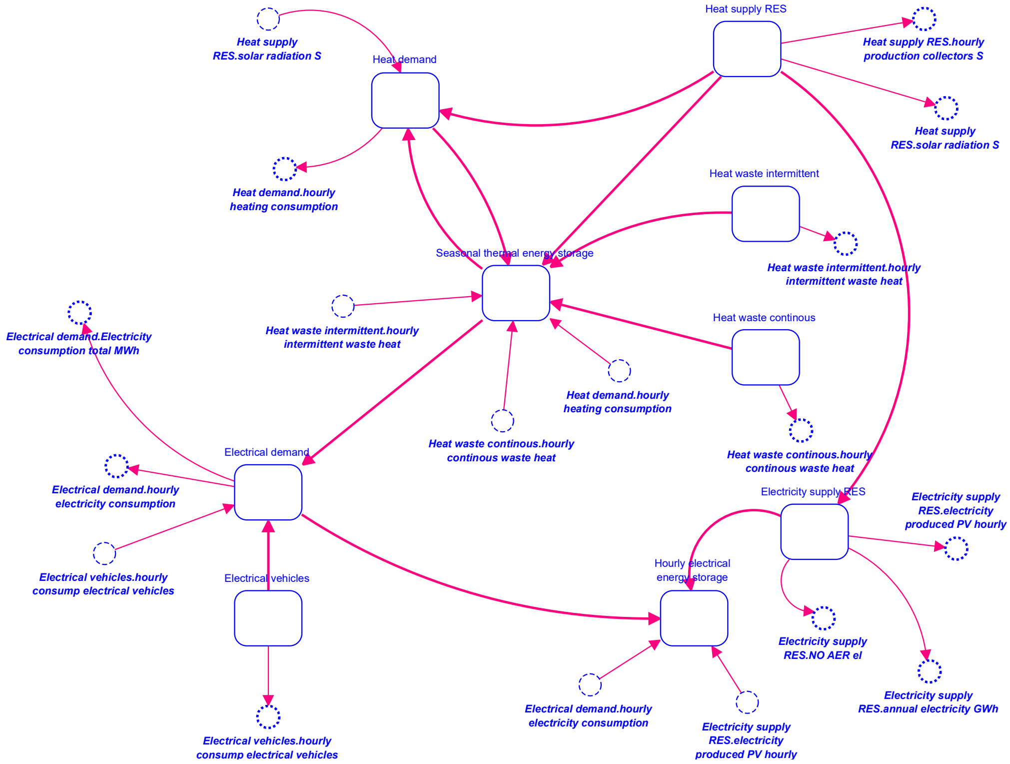


Figure 2.6. Module structure of supply-demand sub-model

In the heat demand module, the total hourly heat demand is calculated for heating and hot water preparation. The heat demand module (see Figure 2.7.att.) shows the main interconnections between buildings and their consumption. By adding them up, total amount of heat consumption in the block is calculated.

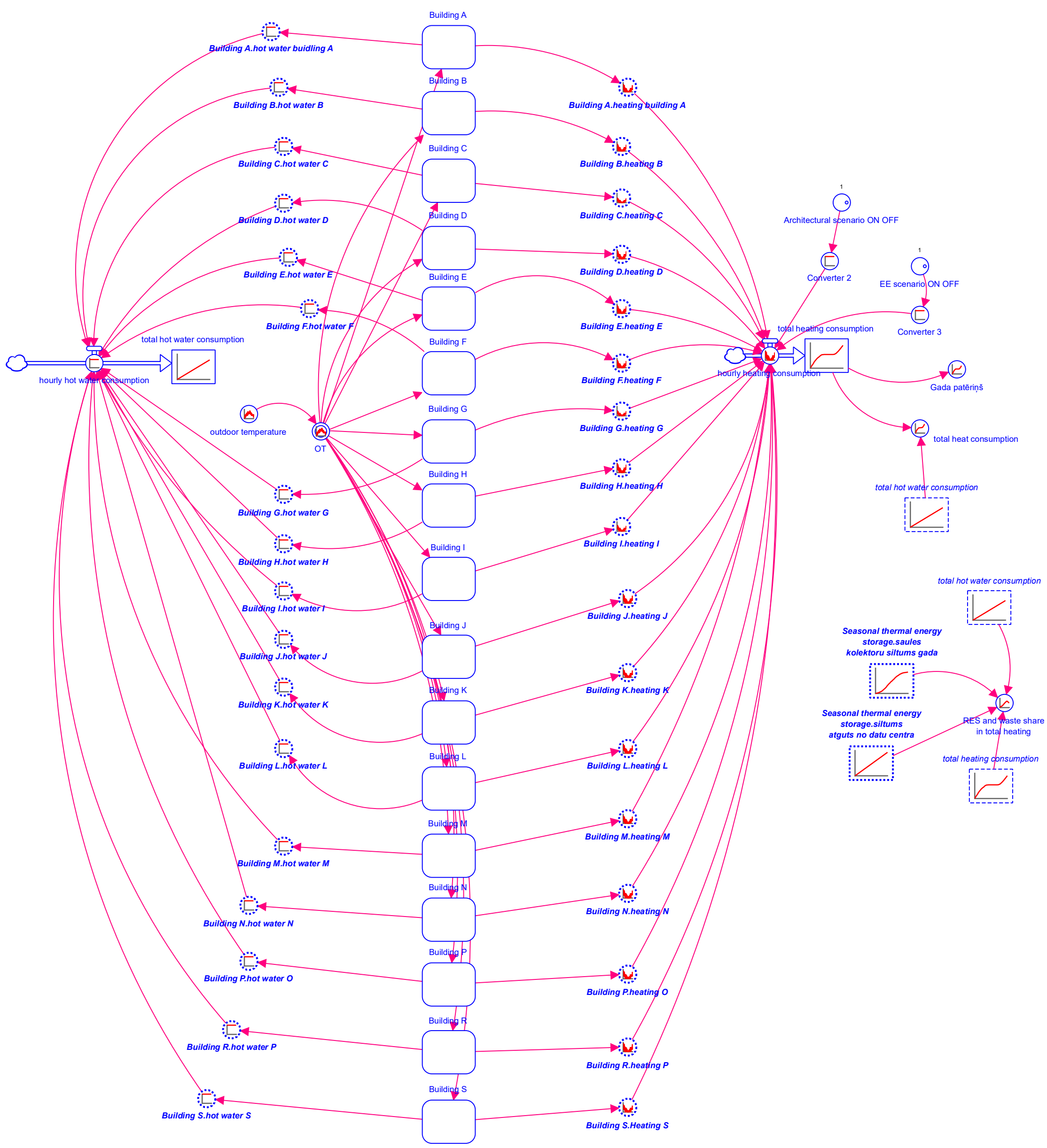


Figure 2.7. Heat demand module

The module includes calculations for all buildings in the block. The heat consumption of each building is calculated based on input data on the building envelope, ventilation, utilities, indoor temperature during the heating season, outdoor air temperature and hot water consumption. Figure 2.8. illustrates the structure of the heat calculation sub-module of one building.

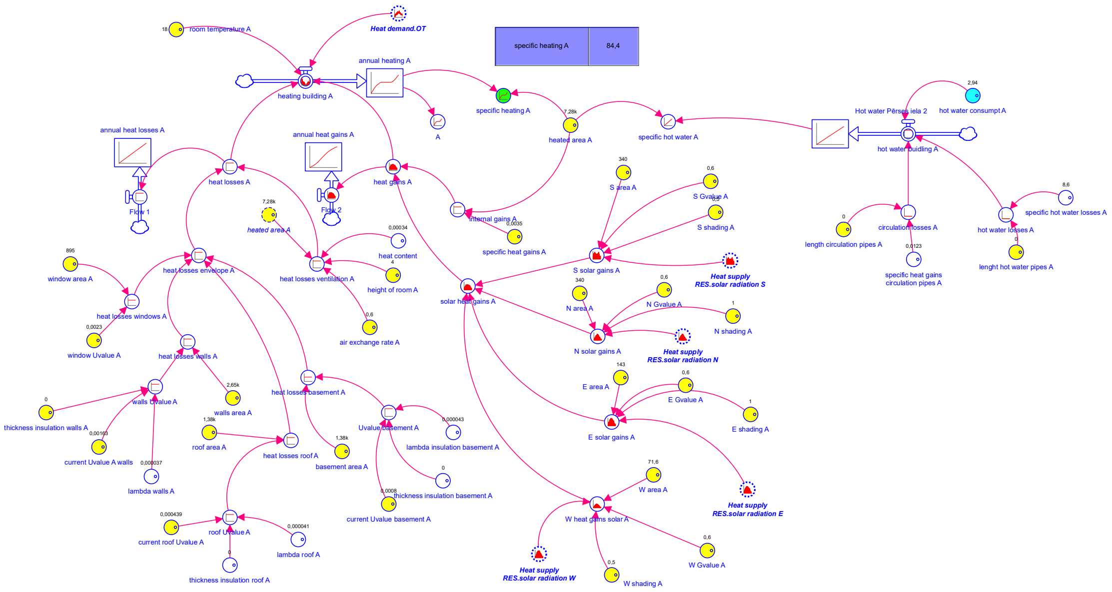


Figure 2.8. Sub-module of heat demand of the building

In the electricity demand module electricity consumption is either obtained from the data on the actual hourly electricity consumption or mathematical relationships are used. The choice of calculation method is determined by the availability of input data. Figure 2.9. shows that electricity consumption is distributed between office buildings, data center, residential sector, commercial sector, shops and production. In addition, the potential electricity consumption required to operate electric car charging stations and heat pumps is identified.

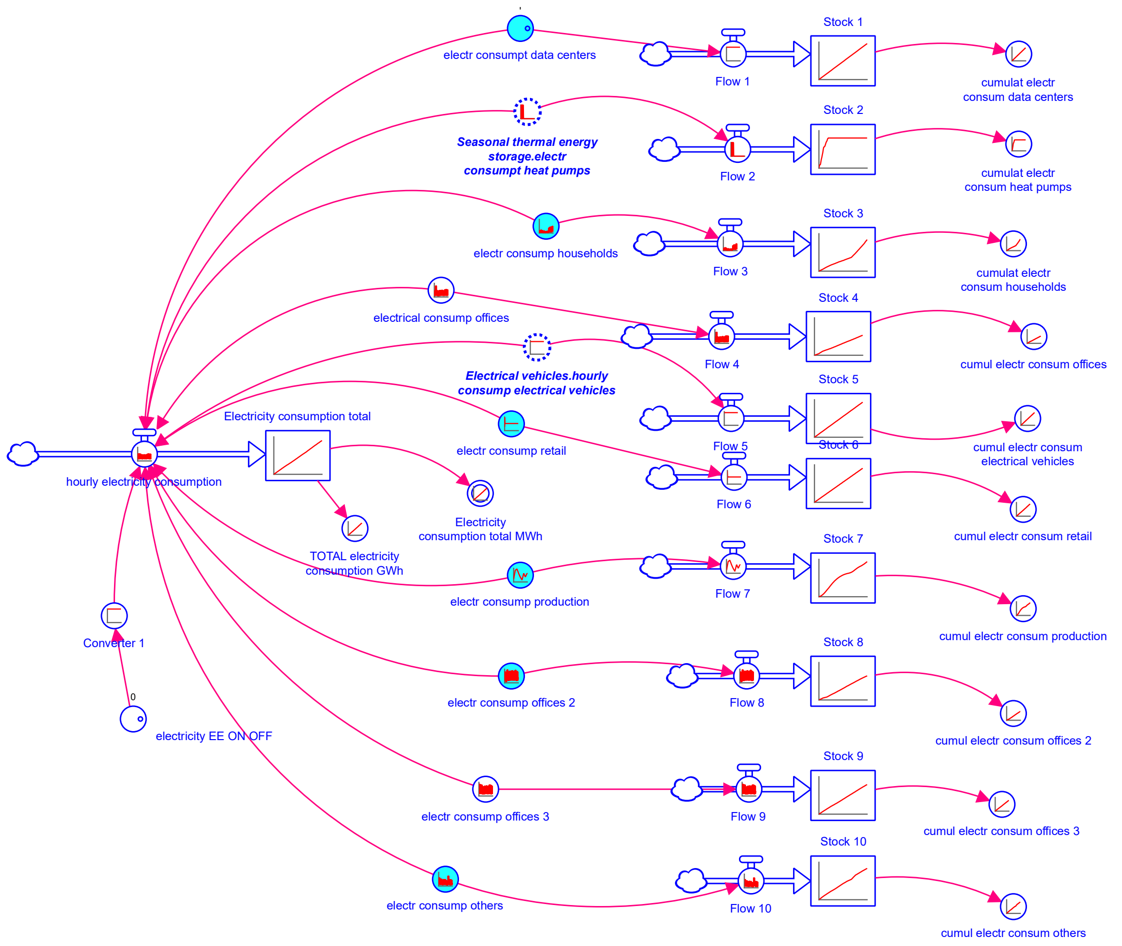


Figure 2.9. Structure of the electricity consumption module

Heat production from RES is carried out with combined solar collectors and PV panels (PVT). The structure of the module presented in Figure 2.10. This figure shows that the amount of heat depends on the positioning of the panels, their area, efficiency and hourly solar radiation.

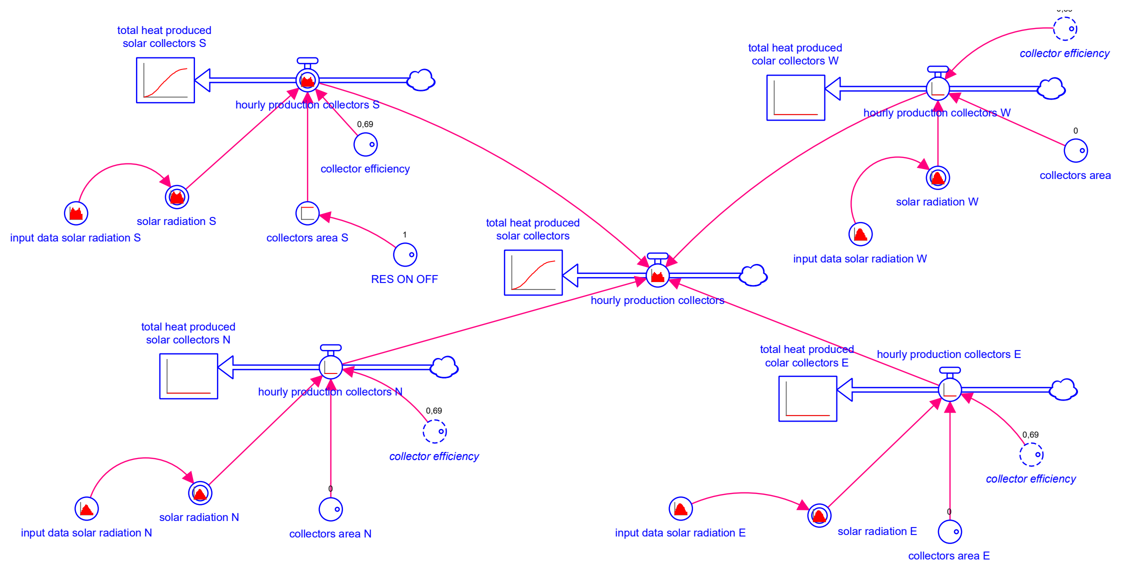


Figure 2.10. Production of thermal energy from renewable sources

The electricity supply from the RES module uses solar panels on the roof (PVT) and on the walls (PV). The parameters used in the calculations are shown in Figure 2.11.

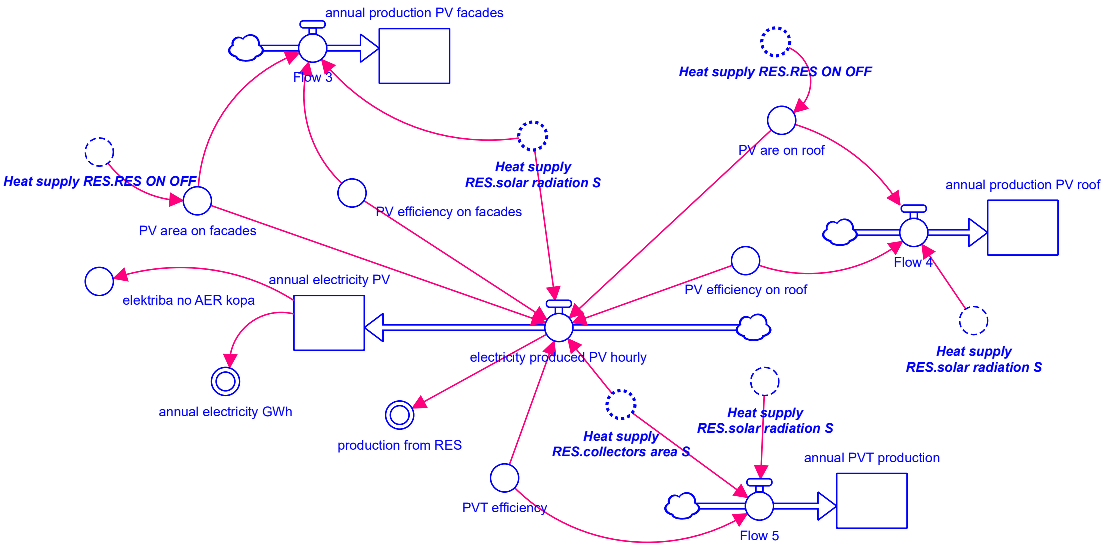


Figure 2.11. Electricity generation from renewable energy sources

The waste heat utilization module (see Figure 2.12.) includes all energy consumers who can provide heat as waste, which is generated as a by-product of technological processes and can be recovered. The model includes continuous heat sources (data centers, food production, etc.) and intermittent heat sources (underground car parks, sewage).

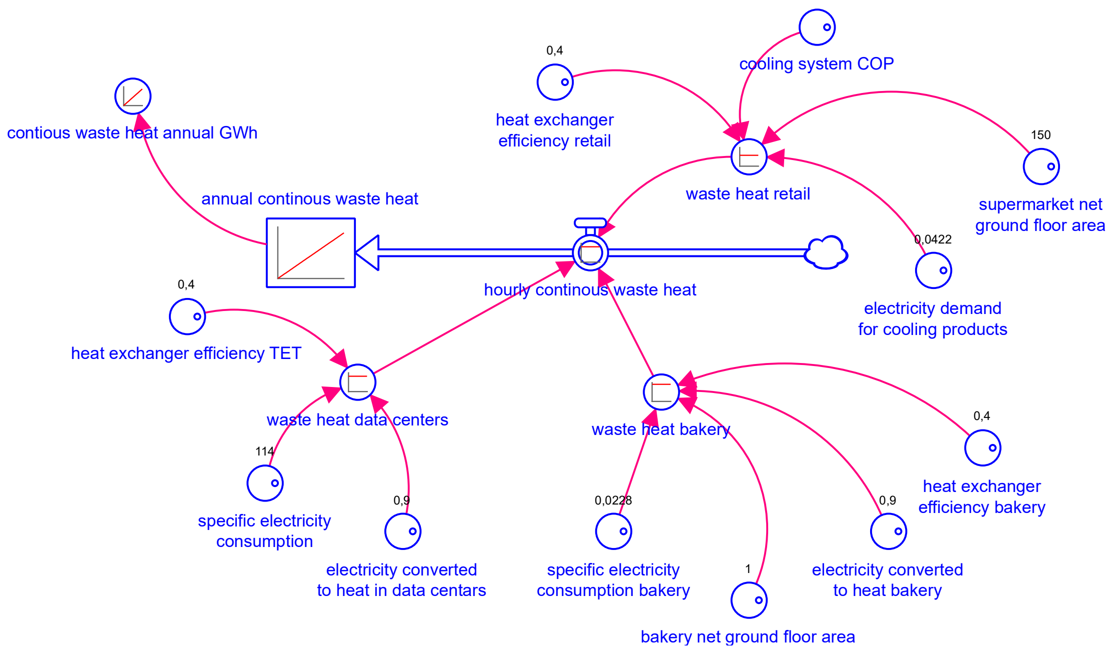


Figure 2.12. Waste heat recovery module

The structure of the heat energy accumulation module contains the parameters necessary for the performance of heat energy demand-supply simulation. The heat produced by RES is taken from the heat RES module (see Figure 2.10.). Heat supply is divided into three accumulated heat energy temperature levels depending on the heat carrier temperature: below 40 °C, 40 - 70 °C and above 70 °C. At the accumulated temperature level up to 40 °C, heat energy is stored from PVT panels, waste heat from continuous and intermittent sources. This heat energy can be used in the 4th generation heat supply system. Excess energy from the temperature level below 40 °C is directed to the accumulated temperature level of 40 - 70 °C. Additional heat in this storage tank is provided by a heat pump powered by PV panels. Heat energy from this accumulation level is used to provide heating and hot water consumption when the outdoor air temperature is above -10 °C. The excess heat is supplied to the district heating system. If the outdoor air temperature is below -10 °C, the third storage volume is used, in which the heat carrier temperature is above 70 °C. Additional heat energy is provided from district heating networks. The structure of the module is shown in Figure 2.13.

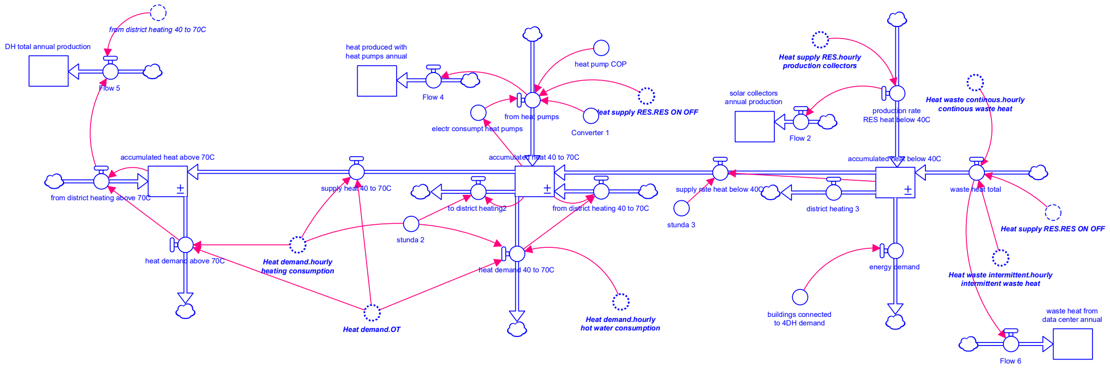


Figure 2.13. Seasonal heat storage module

In the electricity storage module, calculations of the demand - supply from the electricity produced by the RES, the stored electricity and the electricity consumed from the network are performed. The module uses data from electricity supply from RES and electricity demand modules. The structure of the module is presented in Figure 2.14., where the electricity flows are showed.

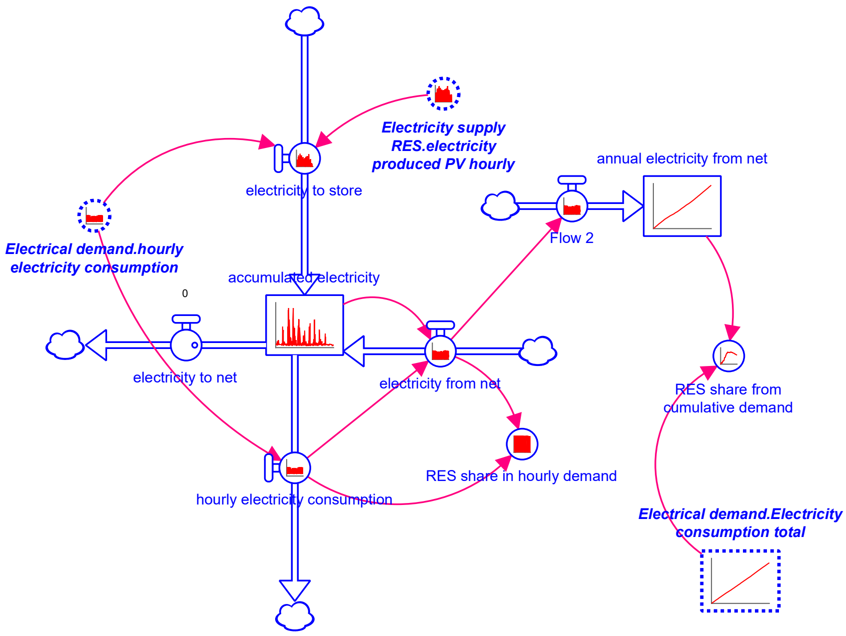


Figure 2.14. Electricity storage module

3.5. Energy Efficiency Obligations Scheme

The model developed within the project integrates the energy efficiency obligation scheme (EEOS) sub-model. The structure of this sub-model is developed in the NRP project Energy efficiency policy assessment and analysis where detailed analysis of the impact of this energy efficiency policy tool is carried out. The EEOS module is integrated into the NECP model within energy efficiency modules (integrated with heat and electricity consumption in different sectors), as in the NECP 2030 expansion of the scope of EEOS is planned. The sub-model includes several sub-modules developed in accordance with the “Energy Efficiency Catalog” established by the Ministry of Economics and the measures provided for therein:

- Energy efficiency technological measures
- One-time publications in mass media
- One-time informative e-mails
- Email campaigns
- Mass media campaigns
- Individual consultations

The EEOS model is an optimization tool. It helps EEOS participants to determine which of activities to carry out. The size of the optimal target audience for various information events is determined. The module uses a logit function, which is used to calculate the share of each measure in the total set of measures based on economic benefits, i. the lowest cost to the largest savings. The target function of optimization is the energy efficiency target set by the legislation for EEOS participants, but the variable parameters are the size of the target audience for different measures.

The structure of the module of energy efficiency technological measures is presented in Figure 2.15. In this example replacement of bulbs, incl. efficiency, planned savings, costs, impact of the measure on the overall savings target, part of the measure from the overall target are included.

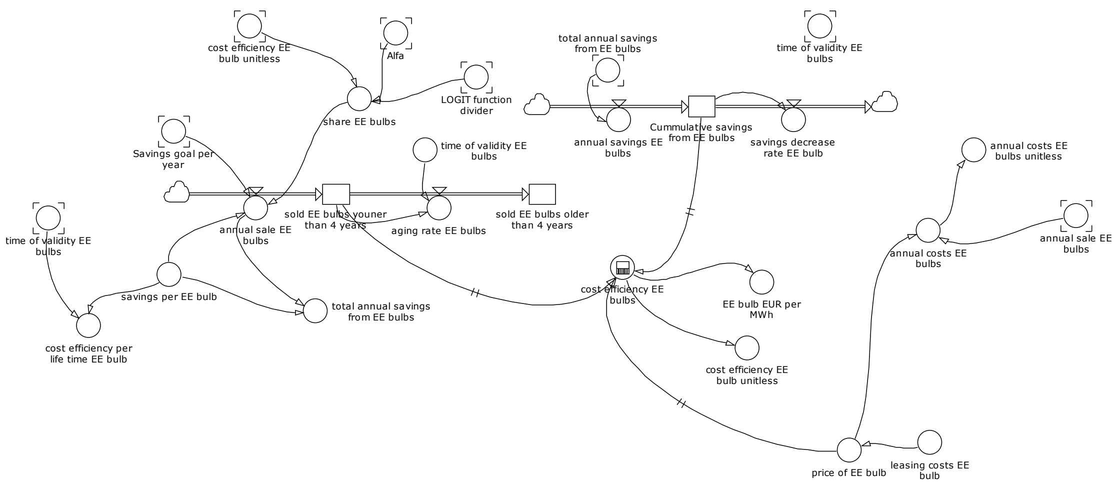


Figure 2.15. Module of energy efficiency technological measures

Figure 2.16. shows the structure of the one-time publication in mass media module. It includes the savings of a single publication, costs, the size of the target audience, its impact on

costs, the impact of the measure on the overall savings target, the share of the measure in the overall target.

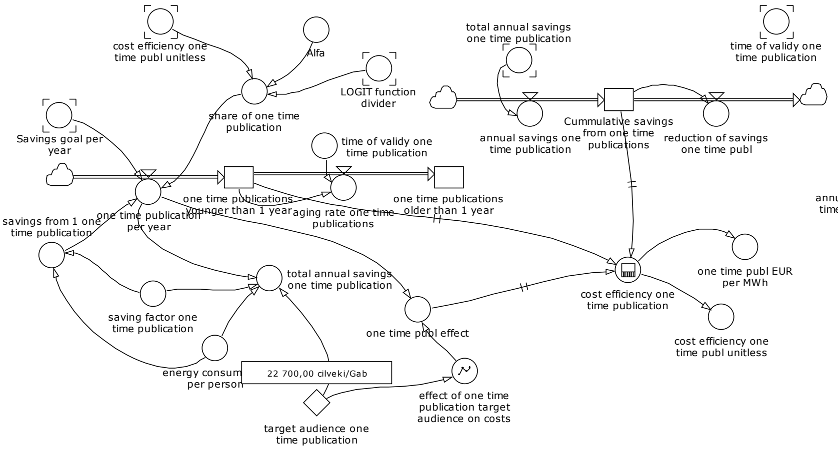


Figure 2.16. One-time publications in mass media module

In Figure 2.17. the structure of the one-time e-mail module is shown. It includes the savings of a one-time e-mail, the cost, the size of the target audience, its impact on costs, the impact of the measure on the overall savings target, the share of the measure in the overall target.

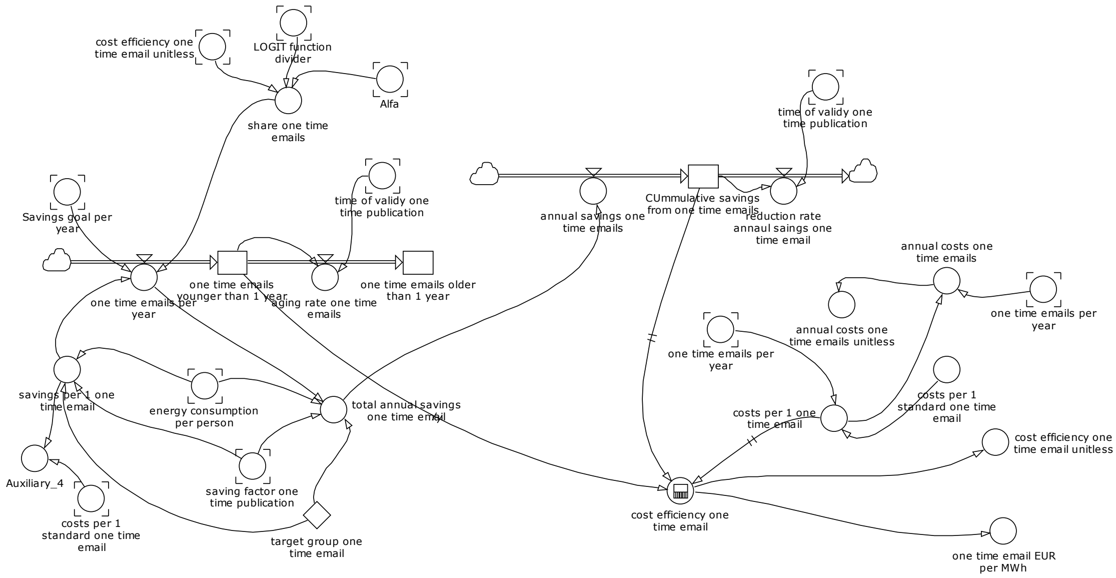


Figure 2.17. One-time e-mail module

Figure 2.18. shows the structure of the individual consultation module. It includes consultancy savings, costs, impact of the measure on the overall savings target, part of the measure from the overall target.

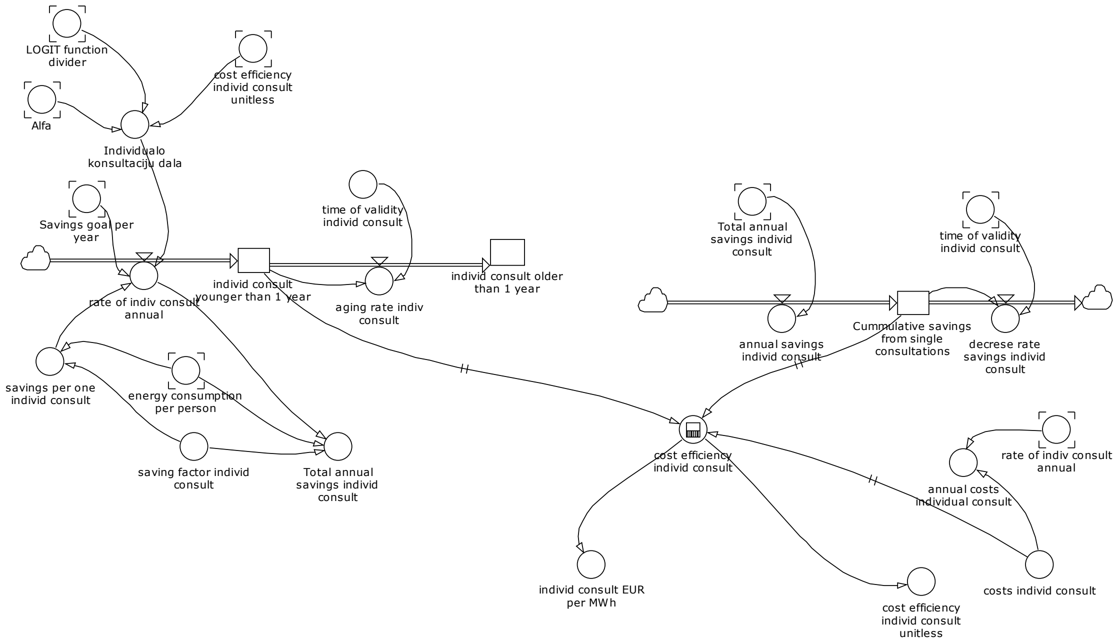


Figure 2.18. Structure of the individual consultation module

Figure 2.19. shows the structure of the media campaign module. It includes campaign savings, costs, audience size, cost impact, impact of the measure on the overall savings target, part of the measure from the overall target.

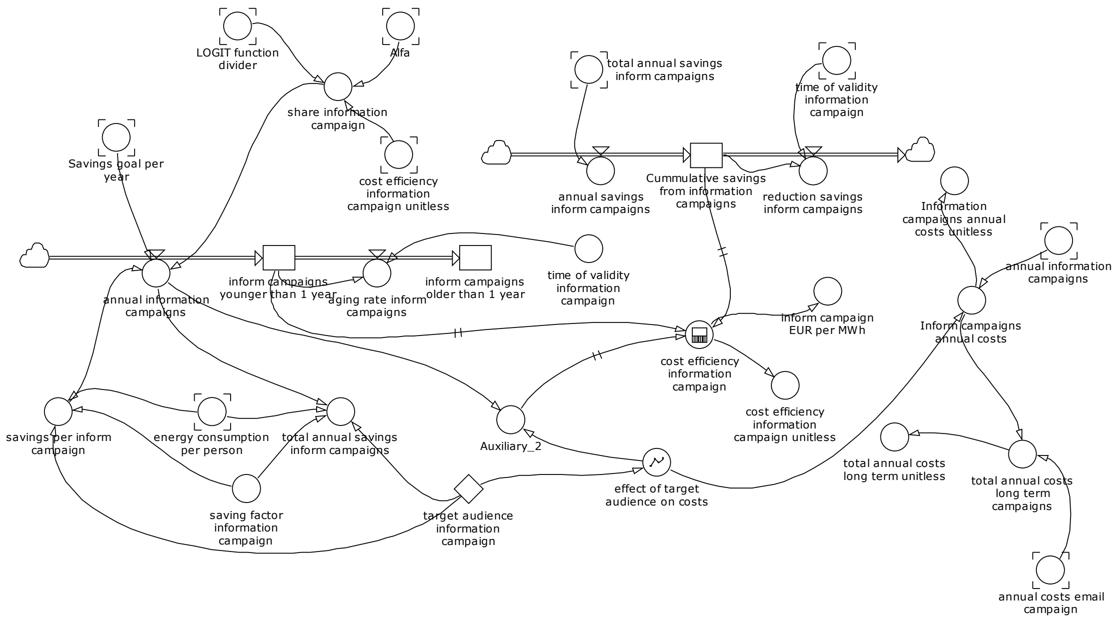


Figure 2.19. Mass media campaigns module

Figure 2.20. shows the structure of the module for the e-mail campaign. It includes campaign savings, costs, audience size, cost impact, impact of the measure on the overall savings target, part of the measure from the overall target.

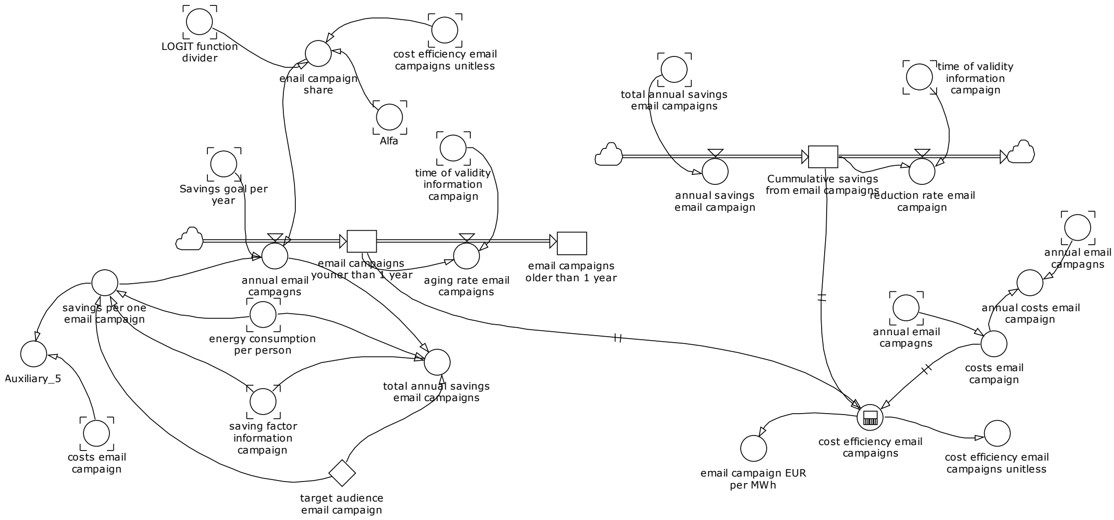


Figure 2.20. Electronic letter campaigns module

Figure 2.21. shows the structure of the savings module, which includes the national target that depends on the amount of energy sold, the cumulative actual target and the difference between these parameters.

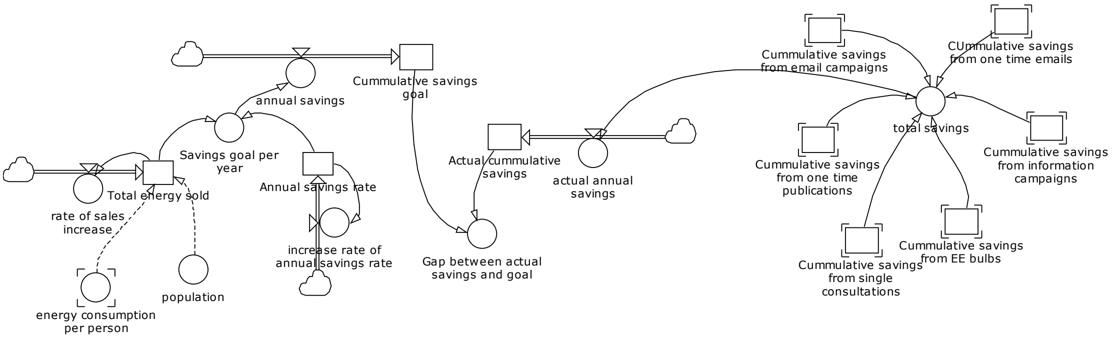


Figure 2.21. EEOS savings module structure

3.6. Use of waste heat in the district heating system

Previously developed NECP system dynamics model has been supplemented with a residual heat utilization module in the district heating system. The structure presented in Figure 2.22. allows simulation of the decision-making process on whether and when to connect to the existing district heating system with waste heat. The model includes the structure of the calculation of the available waste heat, its impact on the capital costs arising from the technical parameters of the connection (diameter, length, temperature), heat loss, available state support and its impact on the heat tariff. An important factor in deciding is the number of insulated buildings that are connected to the district heating system. In the model, centralized supply systems and possibilities to connect to them are modeled separately for Riga, large cities and other systems.

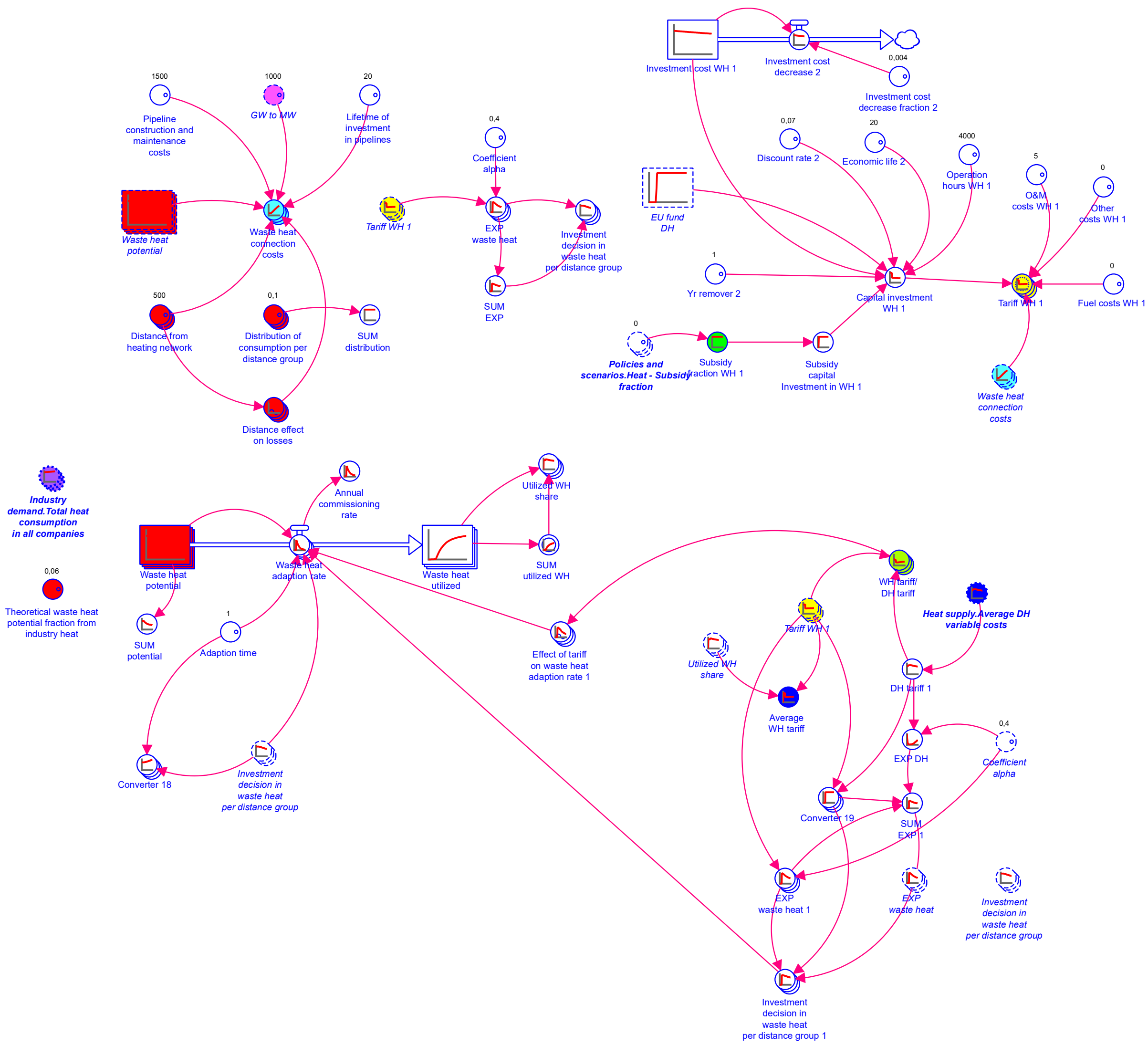


Figure 2.22. Module with waste heat use in district heating system

3.7. Conclusions

The system dynamics model of the Latvian National Energy and Climate Plan (NECP) developed in the first year of the project is successfully:

1) Supplemented with several modules developed in other National Research Programm projects, incl. energy efficiency obligation scheme, use of waste heat in the district heating system, energy community.
2) Performed a manual transition from the modeling tool Powersim to Stella Architect
3) A user-friendly web-based model interface has been developed.

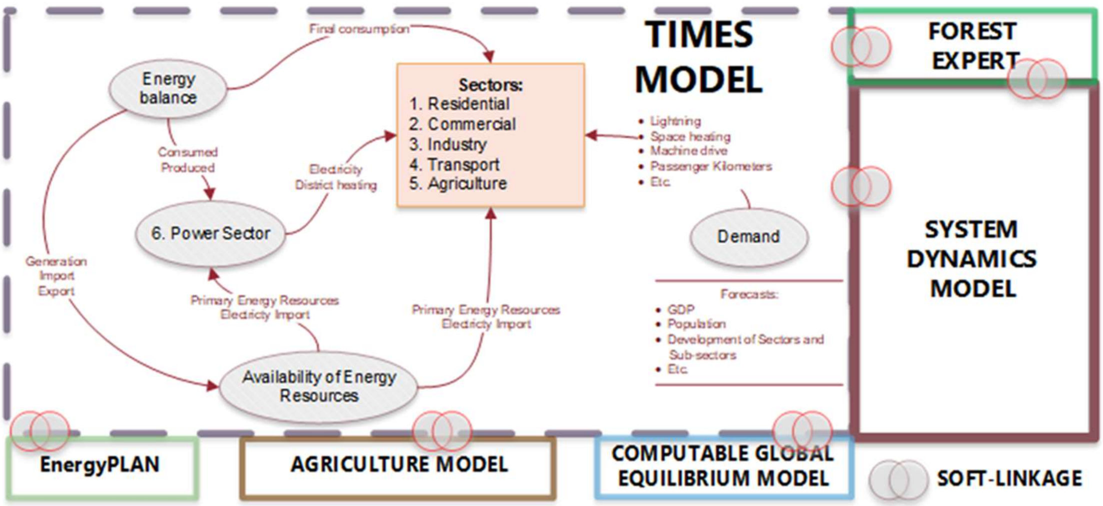
4. IMPLEMENTATION OF MODEL SOFT-LINKAGE

Developed multi model system was improved by soft-linkage between different models and modelling tools to supplement existing models (e.g. TIMES or System Dynamics) and to increase their accuracy and application.

Currently work is underway and the following soft-linkages are made:

- EnergyPLAN and TIMES model;
- System Dynamics and TIMES model
- TIMES model and Computable General Equilibrium calculation method;
- “Forest Expert” model, System Dynamics and TIMES model.

Scheme of Latvian multi modelling system is presented in Figure 3.2.



3.1. Scheme of Latvian multi modelling system

4.1. EnergyPLAN and TIMES

EnergyPLAN is input/output model for analysis of complex energy systems. Model itself is deterministic (particullarly, a given input gives a certain output, in contrast to stochastic models in which probability distributions are obtained). The aim of the model is to determine the optimal operation of the energy system by performing simulation calculations on an hourly basis for one year. Optimization is possible from the technical point of view, finding a solution with minimal primary energy consumption, and from the economic point of view, when finding a solution with minimal costs.

EnergyPLAN allows to analyze very complex energy systems, which include power supply, heat supply (local and district), fuel supply, transport, etc. sectors and corresponding sub-sectors (see. Figure 3.2.).

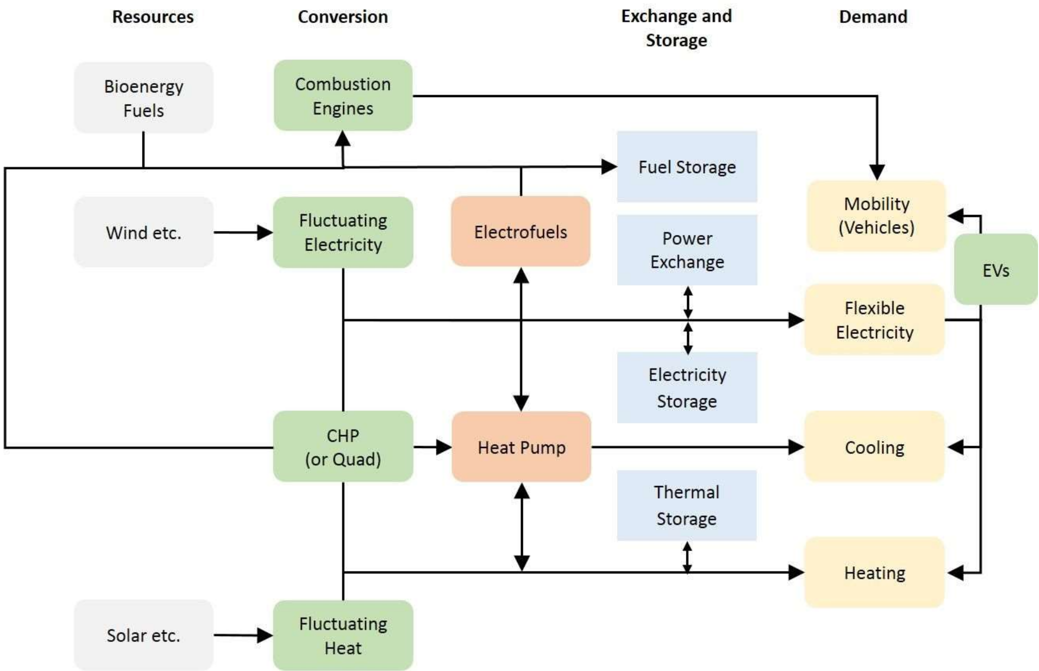


Figure 3.2. Simple scheme of the EnergyPLAN structure (source: www.energyplan.eu)

EnergyPLAN was developed in Aalborg University, Denmark in 1999. It has been continuosly updated and now is available version No. 15.

The advantage of the EnergyPLAN is that it allows to analyze smart energy system, which has a high share of renewable energy technologies, sector coupling and energy storage technologies. In addition, simulation calculations can be performed with up to a hourly based time step. This is an important precondition for modeling power systems with a high proportion of intermittent capacities, such as wind and solar energy. The EnergyPLAN modeling tool has been used in many scientific studies related to the analysis of complex energy systems, and only a few publications can be listed here, which including the results[44]–[49].

EnergyPLAN was used for TIMES model to validate the annual distribution of electricty generation capacities used in TIMES model. This soft-linkage make possible to validate that electriity production is correct not only hole year (yearly distribution of electritity generation), but also for certain periods of time. For example, the annual distribution of hydropower and wind power capacity for 2017 (assumed as a base year) was validated. The figures below show the results obtained with EnergyPLAN, which show the distribution of electricity demand (load), electricity supply (generating capacity) by hours in 2017, if technical optimization is performed (minimized primary energy consumption in the system).

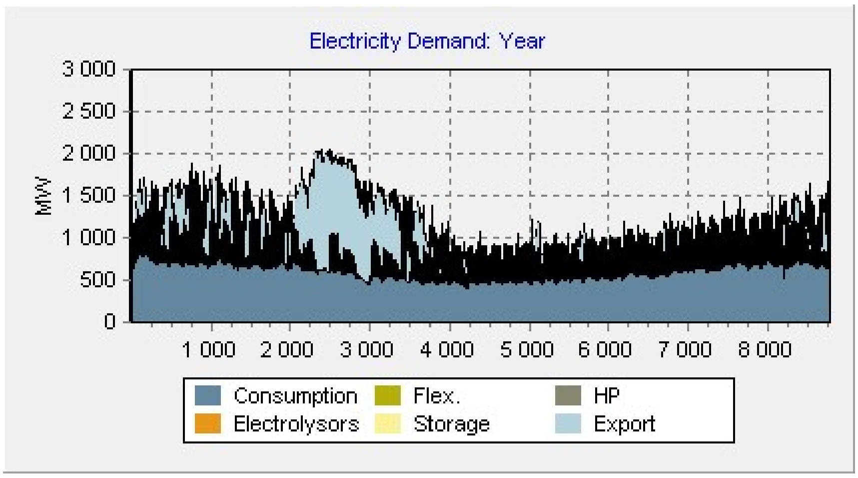


Figure 3.3. Electricity demand (loads) and exports per hour in Latvia in 2017 (EnergyPLAN data)

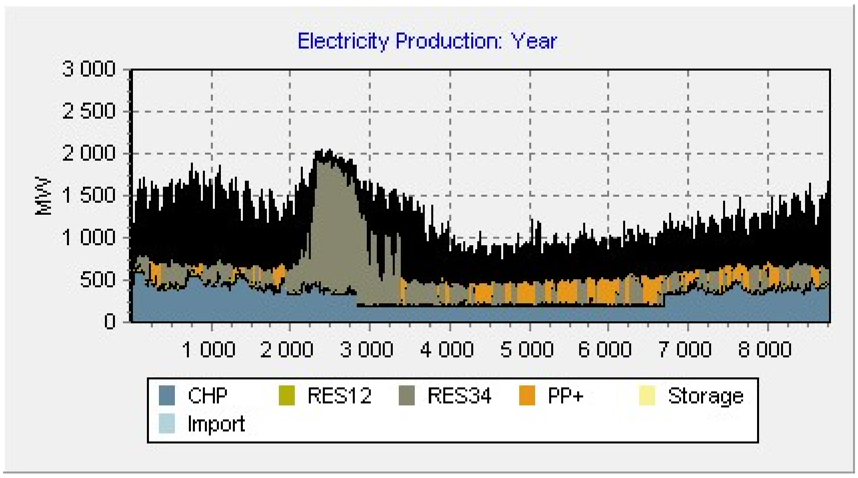


Figure 3.4. Electricity supply (generating capacity) per hour in Latvia in 2017 (EnergyPLAN data); RES34 – HES, VES; CHP – cogeneration plants

4.2. System dynamics model and TIMES model

The output data of the System dynamics model on the renovation rate and costs of residential and public buildings have been used as input data in the TIMES model. In order to make this soft-linkage more stronger, additional sub-processes (the demand for heated area in m^2) in residential and public sectors within TIMES were introduced and elaborated, which are described in more detail in subchapters 1.2. and 1.3.

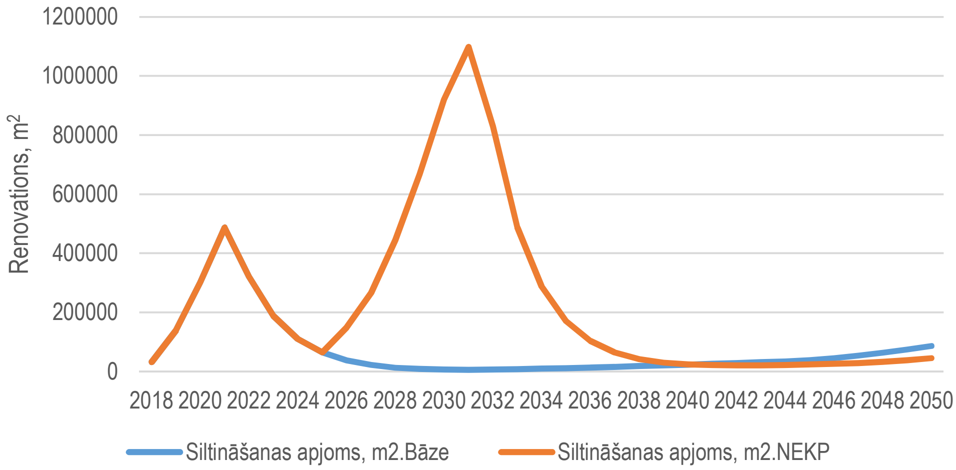


Figure 3.5. Output data for the system dynamic model and TIMES input data on heated m^2 in residential buildings

In Figure 3.5. is presented output of the System dynamics model, that are used for TIMES model as inputs for renovation rate of buildings. There are two scenarious showed – base line scenario where is no new support planned and available and NECP scenario, where support to renovation of residential buildings is planned. In the same way, the soft-linkage is incorporated for public buildings.

4.3. TIMES model and Comupatable General Equilibrium calculation model

The division into sectors or the level of detail of the model is determined by the requirement to link two different types of models - the general equilibrium model and the partial equilibrium model TIMES. The initially chosen division into 35 sectors was not successful due to problems with matching models with different structures, even in "soft-linking". As a result, it has been chosen to split the economy into 20 sectors.

There were already few adaptations of the ORANI type model in Latvia, but this time the challenge is not only the development of the general equilibrium model, but also its connection with the TIMES model, ensuring the achievement of the overall research goals. Considering this condition, Latvia's computable general equilibrium model is not designed in great detail, neither in terms of sectors, types of household, export recipient countries or labor force qualifications.

Summarizing the best experience, we conclude that the most successful results, suitable for political decisions, are not based on the implementation of only one - CGE or TIMES model. However, establishing and maintaining such a link is a huge challenge for researchers.

One of the key questions is - how to identify the points of contact between the two models? A link is formed when an endogenous variable from one model is inserted into the other model as exogenous (fixed). In the CGE model, it is possible to change the status of one variable from endogenous to exogenous and vice versa, as long as the identification conditions are maintained (sufficient number of equations to estimate the unknowns). On the other hand, CGE is a top-down model and its possibilities for adapting to another model are not infinite. According to the experience of Sweden or Portugal, we calculated that it will be necessary to convert the obtained information into a format necessary for the other model when working in Excel. The following is a brief description of the current version of the link, as well as the problems identified that still need to be addressed.

A correlation matrix A is created between Times-end-consumption level 3 and Input-Output table industries (NACE Rev. 2) by product use (CPA * 64) in 2 categories - 'Coke and refined petroleum products' (V19) and 'Electricity, gas, water, steam and air conditioning '(VD).

The matching matrix (A) is supplemented by the variable ‘Industry group’, according to the assumptions of the CGE model.

Further calculations are made at the ‘Industry Group’ level.

Step 1:

Based on the Times-end-consumption data, the average annual growth rates of the 'Industry Group' energy demand scenario are calculated.

$$dTCn = (TC2050/TCto)^{(2050-to)} - 1$$

where

to - base year

dTCn - average annual growth of energy demand in a given period

TC2050 - energy demand forecast in 2050

TCto - energy demand in the base year

The average annual increase in energy demand is assumed to be an energy demand shock to be added to the CGE model according to the TIMES scenarios.

Step 2:

Input-output tables for 2016 are used to calculate output-input ratios by industry.

The output side of the output / input ratio does not include output attributable to Coke and refined petroleum products and Electricity, gas, water, steam and air conditioning supply, in other words energy as a by-product.

The output / input ratio is further divided into 2 components by product of input: the output / input ratio component ‘Coke and refined products and Electricity, gas, water, steam and air conditioning’, and the output / input ratio component ‘Other products’.

Output-input ratio = (Output at basic prices - R19 - RD) / Total input

Where

R19 - Coke and refined petroleum products

RD - Electricity, gas, water, steam and air conditioning supply

Output-input ratio = (Output-input ratio EN -1) + (Output-input ratio OTH -1) +1

where

EN - refers to the contribution of energy products to the output-input ratio

OTH - refers to the contribution of non-energy products to the output-input ratio

The energy demand shock is realized through the first component Output-input ratio EN, assuming that in the short term the non-energy component, (Output-input ratio OTH, is fixed.

Step 3

To transform an energy demand shock into an comprehensible CGE, it needs to be transformed into a change in the GDP of the 'Industry Group'. This is obtained by calculating the relative increase in the output-input ratio: if the energy demand shock versus the shock-free ratio is applied.

Industry group output (GDP) growth =

((Output-input ratio EN -1) * (1+ dTCn) + (Output-input ratio OTH -1) +1) / ((Output-input ratio EN -1) + (Output-input ratio OTH -1) +1) -1

or

Industry group output (GDP) growth =

Output-input factor EN * dTCn / Output-input ratio

These assumptions ensure that the relationship between sectoral output growth shocks and the output-use ratio is inversely proportional, but variations at close output-input ratios depend on the sector's energy dependence. This transition is shown more clearly in Figure 3.56.

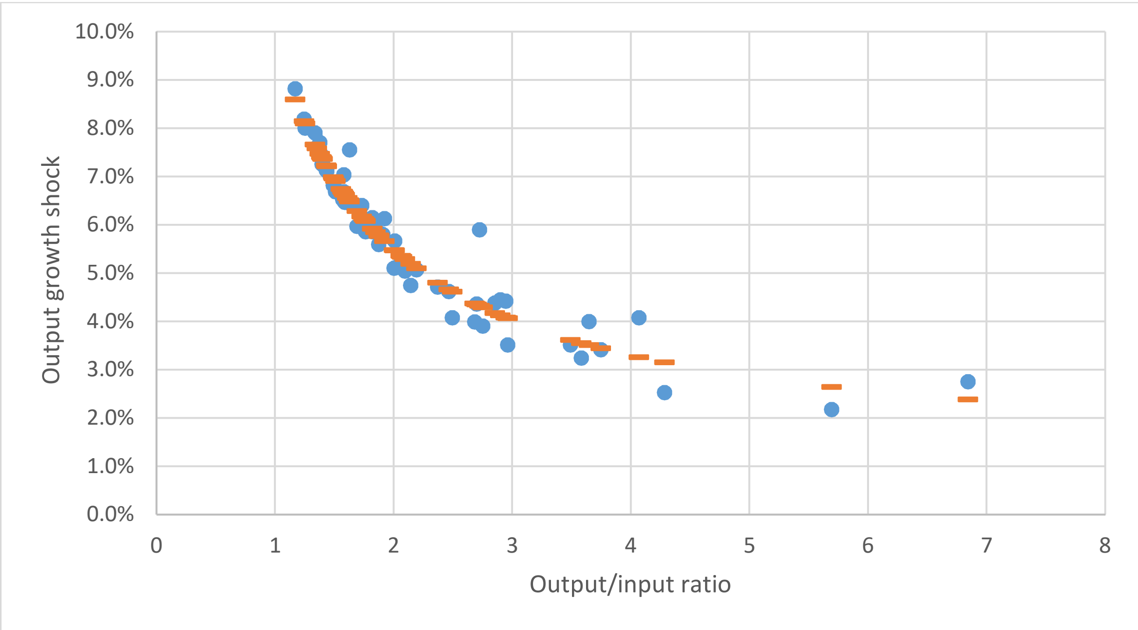


Figure 3.6. Output growth shocks in economic sectors with equal changes in energy demand (10%)

As can be seen, the output growth shock of the Industry Group (GDP) depends directly on the share of energy input in the sector, and it is just logical that the effect of the energy demand shock is greater in sectors with higher energy consumption. (see Figure 3.5. for a diagram.).

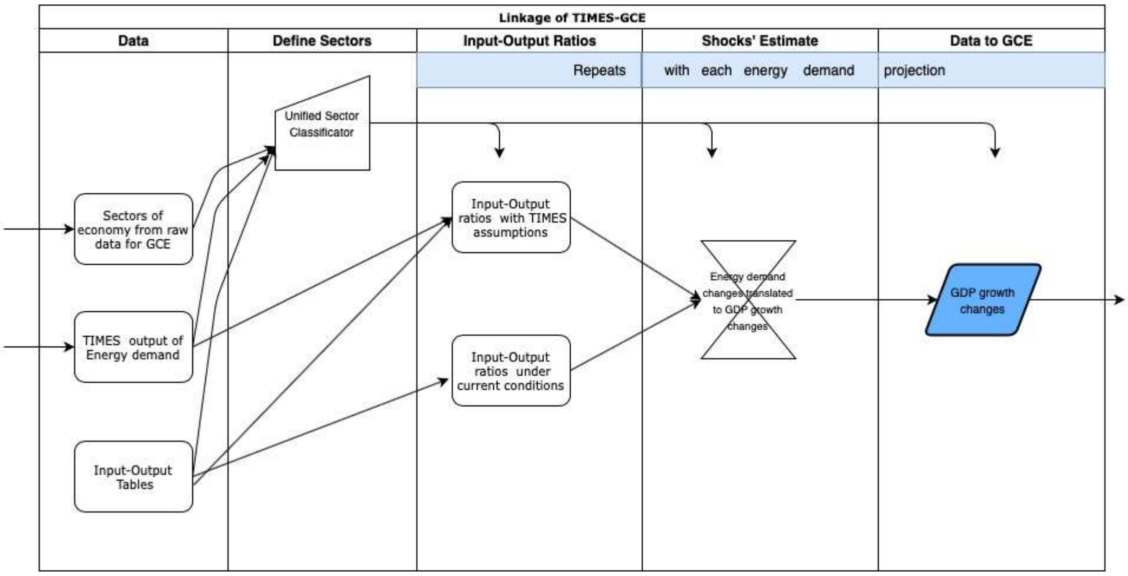


Figure 3.7. Soft binding scheme for CGE and TIMES models

Figure 3.57 shows one stage of one iteration of the connection of both models. When a soft- link between CGE and TIMES models are set up, all necessary calculations are performed in an Excel file (see appendix)

In practice, this means the need to develop criteria that would allow modeling experts to decide that the iteration process is complete.

For the full content of the report, see the progress report developed by University of Latvia, Faculty of Business, management and economics.

4.4. Forest expert, System dynamics model and TIMES model

The modeling shall produce the following performance indicators for forest management modelling scenarios:

- **Capital value.** Describes the value, profit, production income and costs of biological assets
- **Predicted wood co-storage dynamics.** Describes the total stock of growing trees, total felling volumes and area
- **Projected felling volumes by species**. Describes the stock of growing trees, felling volumes and area
- **Forecasts for the outcome of felling volumes** of round timber. Describe the dimensions, size, value and potential market availability of timber.
- **Biomass**. Describes total biomass and the availability of biomass in energy.
- **CO_2 capture.** Describe the total emissions collection and emissions.
- **Employment**. Describes employment (full-time equivalent) in different jobs, pay, tax
- **Protected areas.** Structure of protected areas, limits on economic activity, area, stock

- **Landscape article.** Describes the species and age structure of forest landscape trees
- **Composition of tree species (number of species)** Describes the structure of the groves and the structure of biodiversity

The results are to be used in the future system dynamics modelling process. In order to improve the reliability of the results and to respect the capacity of the developed mathematical models to replicate the processes as accurately as possible, it is recommended that the current system dynamics model for modeling wood forest resources be reviewed.

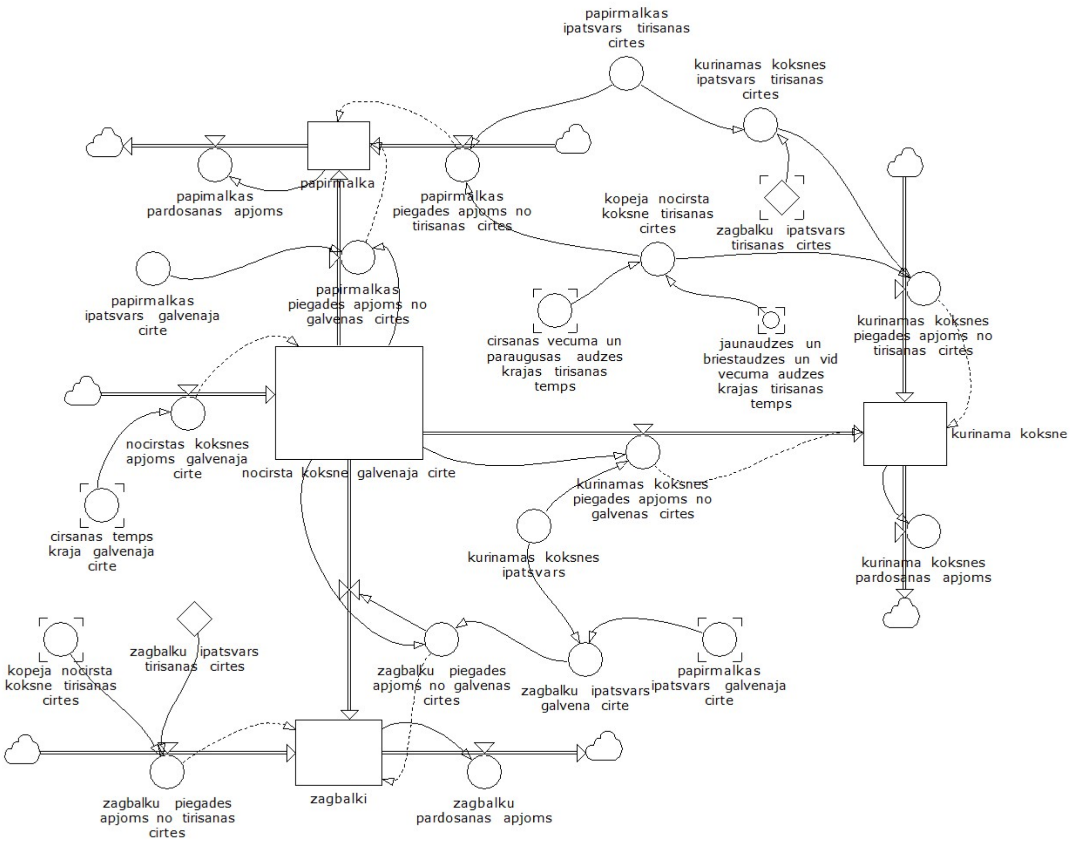


Figure 3.7. System dynamics model for modelling wood forest resources

In the existing system dynamic model (3.7. attēls), the integrated forest resource equations are proposed to be replaced by more accurate calculation results obtained by the forest expert data processing programme, enabling the results to be used in future systemdynamic models solutions. Higher precision will be provided by this computer program, mainly by means of the fact that, unlike the existing system-dynamic forest resource model:

- Analysis of real available forest resources in full detail from the VMD database
- Tree growth rate models are used
- Compliance with BOM standards for predicting timber outcomes
- Tree trunks and assortment forecasting algorithms are used
- It is possible to model forest management objectives, change conditions and compare results.

The forest management class model of the data processing programme “Forest expert” is shown in Figure 3.8.

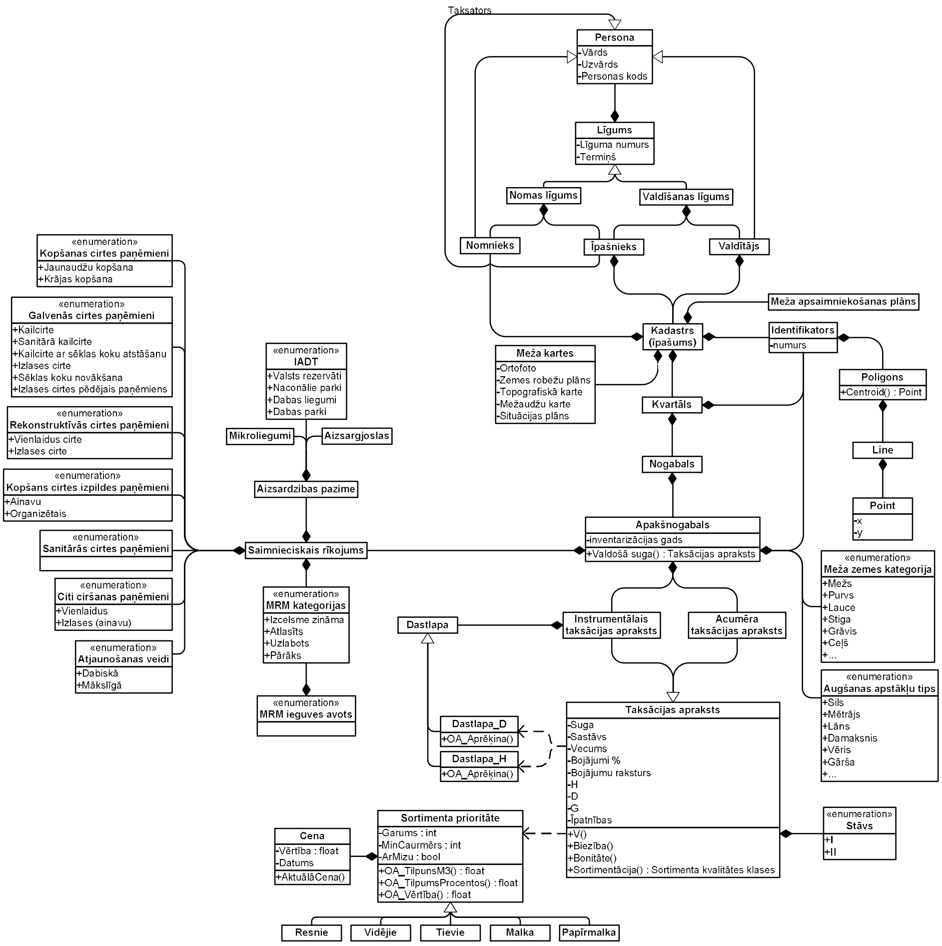


Figure 3.8. Forest management class model

When analyzing system dynamics and Forest expert solutions for the most convenient data exchange format, a Microsoft Excel data format was selected. In this file, a single working sheet will be provided for each scenario calculated by the Forest expert. From this worksheet, the system dynamics model will take the necessary data fields.

For this purpose, the results of the Forest expert calculations will be summarised in the table data structures, Table 3.1. for the system dynamics model and Table 3.2. for the Times model. Wood and paper wood may be assessed as energy wood according to the tasks of future calculations.

Table 3.1.

Description of the data structure of the system dynamic model

Data field name	Data type	Unit of measurement
Year	Integer	-
Species	Text	-
Fat logs	Integer	m^3
Average logs	Integer	m^3
Thin logs	Integer	m^3

Data field name	Data type	Unit of measurement
Firewood	Integer	m^3
Pulpwood	Integer	m^3
Felling residues	Integer	m^3
Biomass from dry branches	Integer	m^3
Biomass from green branches	Integer	m^3
Biomass from needles	Integer	m^3

Table 3.2.

Description of the TIMES model data exchange framework

Data field name	Data type	Unit of measurement
Year	Integer	-
Firewood	Integer	m^3
Pulpwood	Integer	m^3
Felling residues	Integer	m^3
Biomass from dry branches	Integer	m^3
Biomass from green branches	Integer	m^3

See the full content of the report in the progress report developed by Latvian University of Life Sciences and Technologies, Forest Faculty.

5. AGRICULTURAL SECTOR ENVIRONMENTAL POLLUTION INDICATORS AND OPERATIONAL DATA IN AGRICULTURE

The activity data in agriculture were elaborated by using the Latvian Agricultural Sector Analysis Model (LASAM), which was developed as an econometric, recursive, dynamic, multi-period scenario model. This model can be used to forecast potential changes over time for multiple indicators used in the agricultural sector. The LASAM is periodically updated thus increasing the level of details forecasted. The model provides an opportunity to assess the current situation and potential impacts of changes on the level of individual agricultural sectors.

The model includes forecasts for the following agricultural sectors:

- Livestock including dairy and beef cattle, sheep, goat, horse, pig, poultry and laying hen;
- Agricultural crops including cereals (wheat, rye, barley, oats), oilseeds (rape), pulses, maize, vegetables, fruits/berries;
- Agricultural land use and GHG emissions from agricultural sectors, output, value added, and employment.

In addition, the LASAM model includes forecasts by groups of farms depending on the size for the most important agricultural sectors including dairy cattle (1-2 animals, 3-49 animals, 50-299 animals, 300 and more animals), grains (1-9 ha, 10-299 ha, 300 and more ha) , and pigs (1-9 animals, 10-1999 animals, and 2000 and more animals). Separately from other livestock sectors manure is forecasted only in the case of dairy and beef cattle. The input data for the setup of the model and modeling process have been obtained from separate databases including the Farm Accountancy Data Network (FADN) and the Central Statistical Bureau of Latvia (CSB). In order to model changes of individual indicators projections developed by The Commission's Directorate-General for Agriculture and Rural Development (DG AGRI) were used, these projections are included in the model as exogenous variables. For the baseline scenario agricultural commodity prices are based on the projections prepared by DG AGRI up to 2030.

For the full content see the progress report developed by the Department of Environmental Engineering and Water Management of Latvia University of Life Sciences and Technologies.

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