Development of revised national sustainable energy scenarios for Denmark, Latvia and Lithuania

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Integrating Energy Sufficiency into Modelling of Sustainable Energy Scenarios
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Development of revised national sustainable energy scenarios for Denmark, Latvia and Lithuania

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Project overview:
Integrating energy sufficiency into modelling of sustainable energy scenarios

The project was funded by the Baltic-Nordic Energy Research Program and took place 2020-2022. The project partners were Green Liberty (Latvia), INFORSE Europe (Denmark), Lithuanian Energy Institute (Lithuania) and Aalborg University (Denmark). The project was coordinated by Aalborg University. The project had an observer group with members from AirClim (Sweden), Finnish Nature Conservation Society (Finland), Naturvernforbundet (Norway), Association négawatt (France), and Stockholm Environmental Institute (Tallinn Office, Estonia).

The project objectives were:

1. Integrate sufficiency aspects into energy modelling tools applied for development of sustainable energy scenarios
2. Develop modified Danish, Latvian and Lithuanian national sustainable energy scenarios, which build upon the combination of sufficiency, efficiency and renewable energy
3. Create national policy dialogues among public and private actors in the Nordic and Baltic countries about energy scenarios that include energy demand changes from a sufficiency perspective and discuss the feasibility of these scenarios and the possibilities and limitations for socio-economic and regulatory changes enabling transition towards these scenarios
4. Disseminate the methodology for integration of sufficiency into energy modelling tools and development of scenarios, and disseminate the experiences with developing and applying these tools and scenarios to Nordic and Baltic stakeholders and to scientific journals

The following reports are available from the project:

Systematisation of experiences with energy sufficiency initiatives (Work package 2):
The report presents the applied understanding of energy sufficiency in the project and gives a literature-based overview of energy sufficiency actions within energy consumption in households and within mobility respectively. Furthermore, the report presents data, which enables integration of sufficiency actions into energy modelling.

Integration of sufficiency into energy modelling tools (Work package 3):
The report describes how sufficiency-based changes in energy demand within energy consumption in households and within mobility can be quantified at national level and can be included through exogenous and endogenous modelling approaches in EnergyPlan and MESSAGE modelling tools.

Development of adjusted national sustainable energy scenarios (Work package 4):
The report analyses how much energy sufficiency measures can contribute to the reduction of national greenhouse gas emissions. The report presents revised national sustainable energy scenarios for Denmark, Latvia and Lithuania based on the EnergyPlan and MESSAGE modelling tools with the integration of energy sufficiency.

National policy dialogues (Work package 5):
The report presents the developed concepts for national policy workshops aiming at exploring how policy measures can influence preferences for sufficiency-based reductions of energy consumption. Furthermore, the report presents the experiences from the national policy dialogues organised in Denmark, Latvia and Lithuania.

Dissemination to other Nordic and Baltic countries (Work package 6):
The report presents the experiences from a two-day workshop with dissemination of perspectives on and methods within energy sufficiency to Baltic and Nordic countries that were developed in the project. Furthermore, the report presents the joint cross-national discussions and experience sharing among the participants at the workshop. Finally, the report presents ideas for further research and knowledge development within energy sufficiency.

The reports can be requested by sending an email to the project coordinator Michael Søgaard Jørgensen, Department of Planning, Aalborg University, Denmark at msjo@plan.aau.dk

Table of Content

1. Introduction

The report has been written as part of the project “Integrating energy sufficiency into modelling of sustainable energy scenarios”, which is funded by The Baltic Nordic Energy Research Programme. The project is coordinated by Aalborg University and conducted in collaboration between Aalborg University, INFORSE-Europe, Lithuanian Energy Institute and Green Liberty Latvia. The aim of the project is to contribute to the development of more advanced strategies for systemic, sustainable transition of energy production and use, based on new social practices that reduce energy consumption. This contribution is met through developing new, improved national 2030 energy and climate scenarios based on the feasibility of reaching a net-zero emission and 100% renewable energy system by 2050. Besides building upon existing national sustainable energy scenarios, the new scenarios developed in the project integrate experiences from recent national sustainable energy practice initiatives within the categories; household energy consumption and mobility.

This report is a deliverable of work package 4 “Development of revised national sustainable energy scenarios for Denmark, Latvia and Lithuania " and analyses how much energy sufficiency measures can contribute to reduction of national greenhouse gas emissions in 2030 and 2050. The report presents revised national sustainable energy scenarios for Denmark, Latvia and Lithuania based on the EnergyPlan and MESSAGE modelling tools with integration of energy sufficiency measures.

In the pursuit of this contribution, modified Danish, Latvian and Lithuanian national sustainable energy scenarios have been developed, building upon the combination of sufficiency, efficiency and renewable energy.

The topic addressed in WP4 is: How much can energy sufficiency with changes in citizen practices contribute to reduction of greenhouse gas emissions in 2030 and 2050? This topic is analysed by using the EnergyPlan and MESSAGE modelling tools for the development of three modified national energy sustainable energy scenarios, which include energy sufficiency aspects.

The report shows how energy sufficiency can be modelled in three different countries. The use of two different modelling tools shows model-related influence on scenarios. The cases analysed in the report are Denmark (chapter 2), Lithuania (chapter 3) and Latvia (chapter 4). The scope of the modelling is limited to direct energy use in households.

2. Danish Energy Scenarios

2.1 Brief description of the model EnergyPlan

EnergyPlan is a complete energy sector model, covering all energy forms and all types of energy consumption. It is an exogenous model regarding energy demands and regarding investment decisions and it only handles a specific year that is defined by the user. It is easy to use, and calculates with an annual break-down of the year; but for multi-annual analysis, it is necessary for each year to generate inputs and run the model.

The demand-side inputs for EnergyPlan are final energy demands (electricity, heat, fuels). Generally, EnergyPlan does not distinguish between end-use efficiency and sufficiency. These are to be combined in the determination of the input parameters of final energy demands. Typically the energy service demand including sufficiency is multiplied with the energy efficiency factor (specific energy demand), but it can be modified with for instance rebound-effects.

So, when modelling energy sufficiency in EnergyPlan the results of the energy sufficiency measures are modelled as reduced energy demand. Details on how to integrate sufficiency measures into the modelling and examples can be found in work package 3 report "Integration of sufficiency into energy modelling tools" chapter 4.

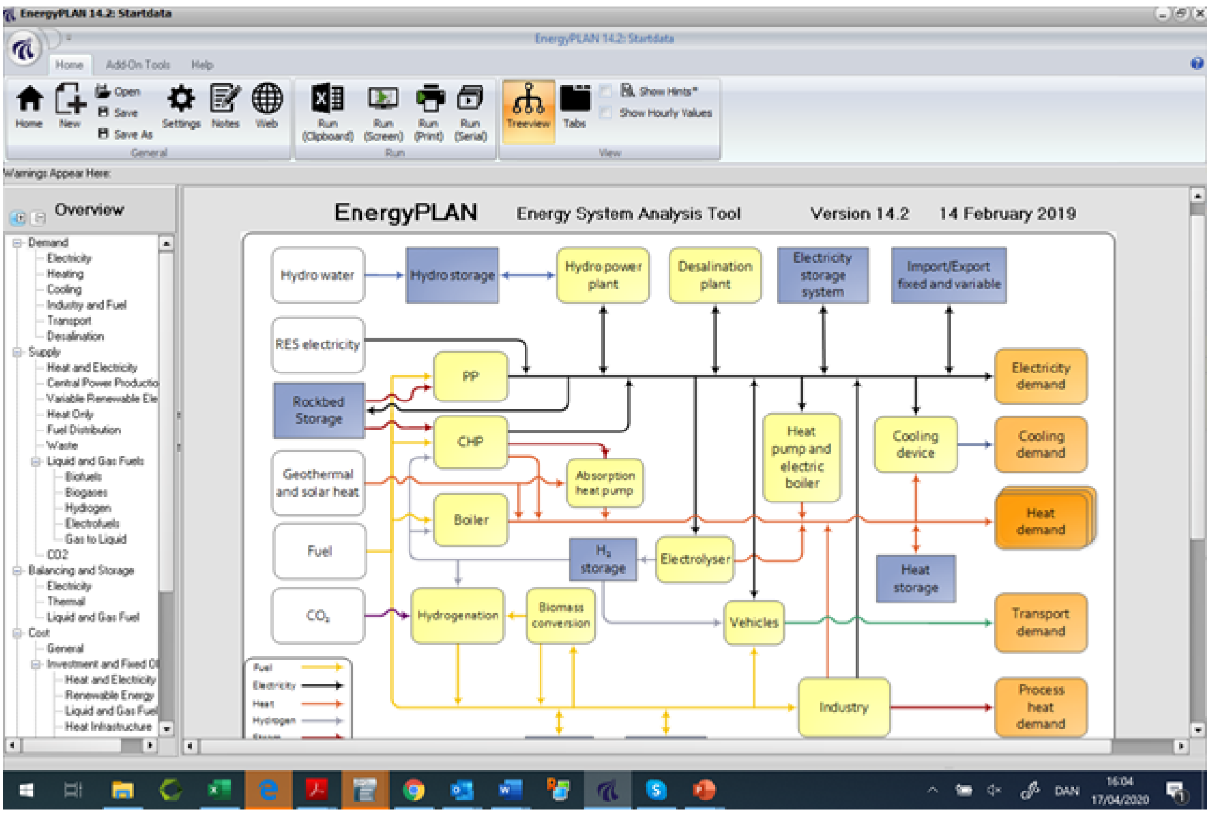

Figure 2.1 The main energy flows in EnergyPlan

Figure 2.1 is an illustration of the Energy Plan energy flows. The flows go to the 5 main types of demand: electricity, space heating, space and district cooling, transport, as well as process heat and fuel demands (covering the productive sectors of manufacturing, agriculture etc.). The four first energy demands are directly influenced by energy sufficiency while the process energy is only indirectly influenced by sufficiency via the purchase and consumption of products. The energy flows for each of the five end uses are divided in a number of different flows, depending on the structure of demand. For electricity, a flexibility of demand that can relocate in time, can also be specified.

2.2 Existing Danish existing energy scenarios

Every year the Danish Energy Agency publishes Denmark’s Climate Status and Outlook which includes a business-as-usual energy scenario until 2030-2035. The results of the latest are presented in section 2.2.1. In 2013 the Danish Energy Agency modelled four different fossil free energy scenarios for 2050; we have not included results or further information from these. They can be found at https://ens.dk/service/fremskrivninger-analyser-modeller/scenarieanalysen (in Danish).

The Danish Society of Engineers (IDA) has developed an ambitious energy scenario in cooperation with Aalborg University. This scenario is presented in section 2.2.2.

2.2.1 Business as usual energy scenario until 2030

The Danish Energy Agency has published Denmark’s Climate Status and Outlook 2021 (CSO21) in April 2021 (revised 29 June 2021).
https://ens.dk/sites/ens.dk/files/Basisfremskrivning/cso21_-_english_transllation_of_kf21_hovedrapport.pdf[1].

CSO21 is a technical assessment of how Danish greenhouse gas emissions, and Danish energy consumption and energy production, is expected to evolve over the period up to 2030 based on a frozen-policy scenario – a scenario including existing and agreed policy measures. Thus, CSO21 examines how far Denmark is in reaching its climate target of 70% reduction in greenhouse gas emissions by 2030 compared to 1990 with current regulation and policies. CSO21 includes measures that have been decided by the Danish Parliament before 1 January 2021. Some of the latest policy measures that have been included in CSO21 are the 2020 climate agreement for energy and industry, etc., the 2020 green road transport agreement, the 2020 green tax reform agreement, and the 2021 Finance Act.

Denmark’s total, territorial greenhouse gas emissions have been cut by 40% in 2019 compared to 1990, excluding emissions from biomass energy. Based on current adopted policies the reduction is expected to be 55% in 2030 compared to 1990. Figure 2.2 shows the emissions and the gap to achieve the Danish target of 70% greenhouse gas emission reduction in 2030 compared to 1990.

[1] The Danish version including background notes and data is published at https://ens.dk/service/fremskrivninger-analyser-modeller/klimastatus-og-fremskrivning-2022

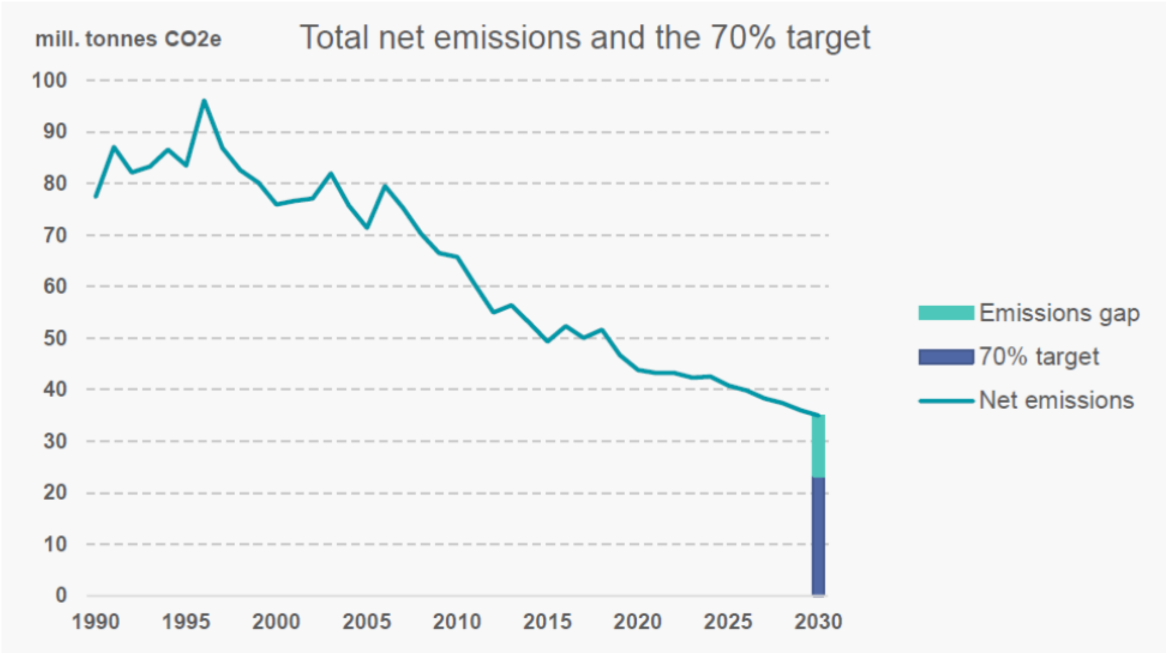

Figure 2.2. Total net emissions and the 70% target. From CSO21 (Figure 2.1).

The emissions are calculated using UN IPCC methodology. The scenario includes greenhouse gas emissions from energy use (households, transport, service sector, industry and construction, fuel production, and electricity and district heating). Emissions for international shipping and air transport as well as emissions from burning biomass are not included. Further CSO21 also includes waste and F gases plus agriculture, forestry and fisheries.

In the household sector (individual heating), the emissions will fall from 2.1 mill CO_2e to 0.5 mill. CO2e in the period 2019 to 2030. The housing area is expected to increase by 2% for individual houses and 10% for multistory buildings. But the buildings will be better insulated; and oil and gas boilers will be phased out and replaced by heat pumps and district heating.

In the transport sector emissions will be reduced from 13.5 mill tonnes CO_2e to 11.5 mill tonnes CO_2e. There will be a growing number of kilometres driven, but the vehicles will be more efficient and there will be a partial shift to biofuels and electric cars.

Emissions from the electricity and district heating sector will be reduced from 4.7 million tonnes CO2e to 0.3 million tonnes in the period 2019 to 2030. The reduction is due to phase-out of coal fired CHPs and reduction of natural gas fired CHPs, more heat pumps in district heating, and more wind of photovoltaics.

Natural gas will be substituted by biogas in the gas mains used by industry and for heating, which will result in 2.3 mill tonnes lower CO_2e and CCS will account for a reduction of 0.9 mill tonnes CO_2e in the period 2019 to 2030.

The total renewables share will be 58% in 2030. The renewables share will be 97% in electricity and 72% in mains gas. In figure 2.3 is shown the development in energy consumption and in figure 2.4 is shown the CO_2e emissions in 2019 and 2030 from energy use.

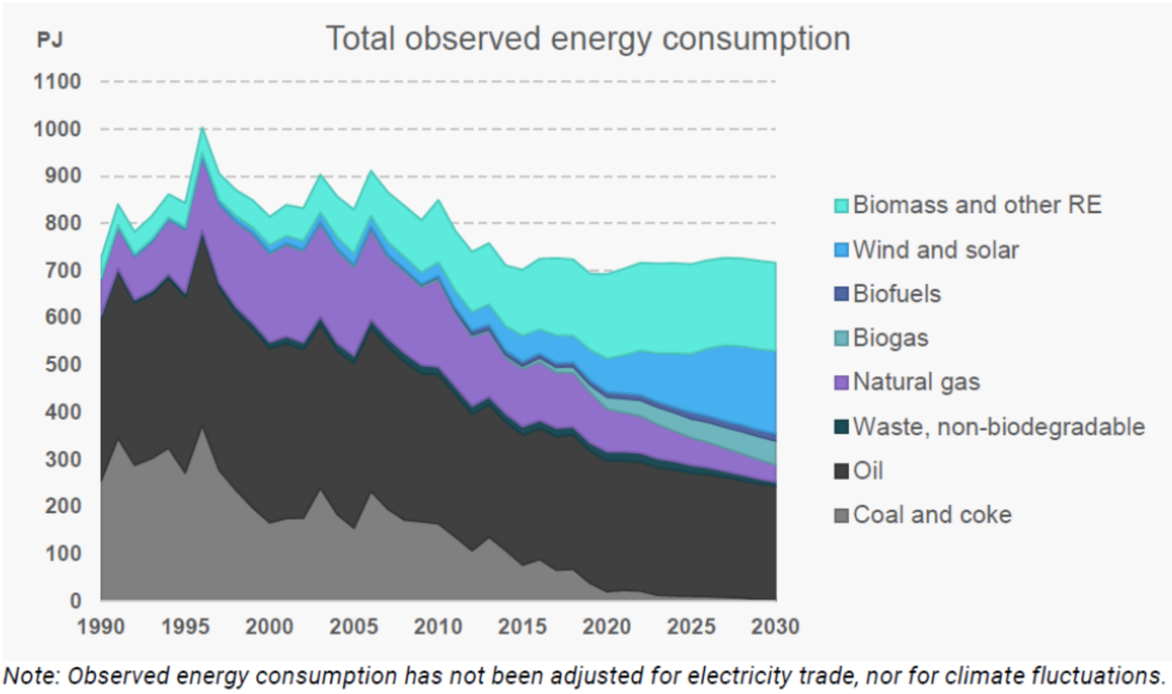

Figure 2.3. Total energy consumption 1990-2030. In 2030 the total energy consumption will be 722 PJ. From CSO21 (Figure 2.6).

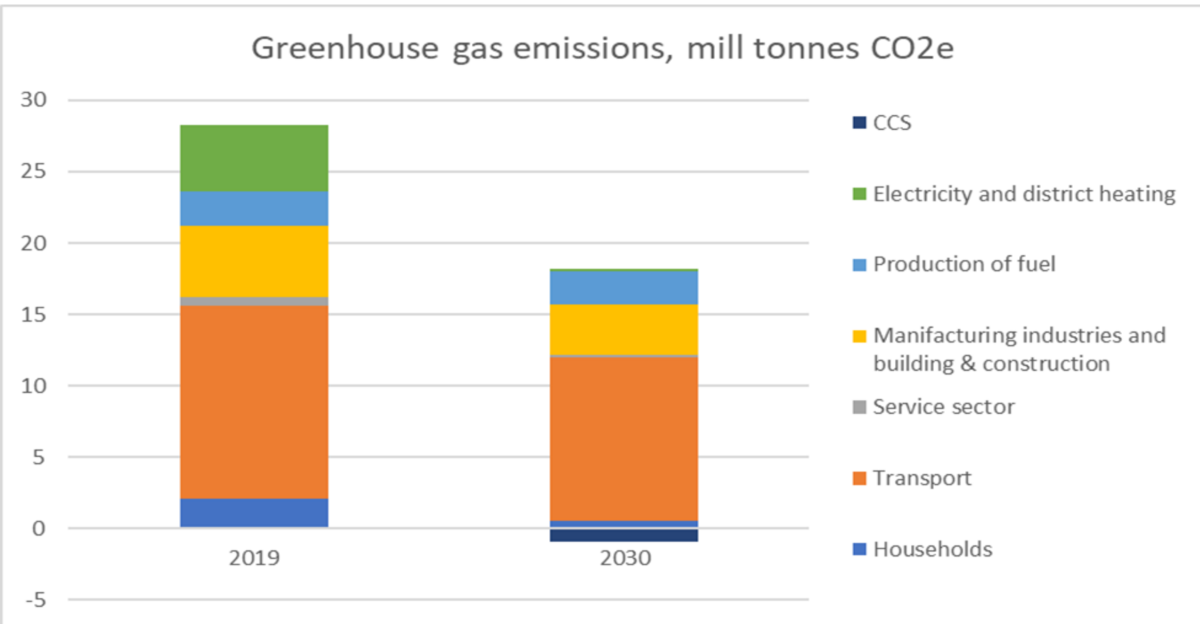

Figure 2.4. Greenhouse gas emissions from the energy sector in 2019 and 2030 for a business as usual scenario. In 2030 the total emission will be 17.3 million tonnes CO_2e. Data is from CSO21 background data[2].

[2] https://ens.dk/service/fremskrivninger-analyser-modeller/klimastatus-og-fremskrivning-2022, data sheet with data behind the scenario results (in Danish).

2.2.2 IDAs Klimasvar 2030 and 2045

IDAs Klimasvar is an ambitious Danish energy scenario developed by Aalborg University[3] for the Danish Association of Engineers published in 2021[4]. IDAs Klimasvar is characterised by a strong reduction of CO_2 emissions, leading to 70% reduction by 2030 of CO_2 emissions from energy use, combined with lower biomass use. It also includes a 100% transition to renewable energy until 2045.

IDAs Klimasvar needs an investment of 5-600 billion DKK from 2020 to 2030. The cost for depreciation and interest of the investment will be covered by savings in fuel costs, making it a no-cost option for Danish society through to 2030. Since the scenario was developed fuel prices have risen considerably, so the economy will be better compared with business as usual with present fossil fuel prices, but it may be a temporary rise.

IDAs Klimasvar includes energy use; other sectors are not included. International air and ship transport is not included. The greenhouse gas emission from energy use was 52 Mt in 1990 and will be reduced by 70% to 11 Mt in 2030. In 2020 the emission was 30 Mt so a reduction of 19 Mt is needed from 2020 to 2030 to reach the 70% goal.

IDAs Klimasvar is developed using the EnergyPlan tool. The consumption in 2020 is based on the base scenario 2018 from the Danish Energy Agency.

Below is a short description of the actions in the four sectors: heat, electricity, transport and industry.

Heat

Heat savings of 12% until 2030 by renovation of existing buildings, including correct use of technologies, e.g. ventilation systems. Change to 4th generation district heating with lower temperature and thus lower heat loss, 50% of the network is changed by 2030. Oil and gas boilers are substituted by heat pumps and district heating; more houses are supplied with district heating; more use of excess heat from industry and data centres; continued use of wood, waste and biogas in CHP, and use of wood chips and straw in district heating plants. 1300-1400 MW wind for heat pumps, solar heating for individual houses and district heating, geothermal for district heating. For buildings outside the district heating network, phase out of oil and gas for heating, rapid expansion of heat pumps and less use of biomass for heating.

Electricity

Electricity is mainly "classical electricity consumption", i.e. electricity for lighting and apparatus. 10% electricity savings until 2030 by using efficient equipment and using it correctly. More biogas, wood chips and straw in electricity production. Expansion of other renewables in electricity production: 130 MW wave power, 5000 MW (+4000 MW)

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[3] Developed by the following researchers from Institute of Planning, Aalborg University: Henrik Lund, Brian Vad Mathiesen, Jakob Zinck Thellufsen, Peter Sorknæs, Miguel Chang, Mikkel Strunge Kany og Iva Ridjan Skov

[4] https://ida.dk/om-ida/ida-mener/klima-energi-og-cirkulaer-oekonomi/klimasvar

photovoltaics by 2030, minimum 4800 MW (+600 MW) onshore wind and 6630 MW (+4630 MW) offshore wind by 2030.

Transport

Transport includes personal and goods transport. Annual growth in km driven is reduced from 2% per year (base scenario) to 1.6% per year by introducing road pricing and traffic zones. Change of 2% of car transport and 10% of domestic air transport to train and collective transport until 2030; change of 2% of car transport to bicycles until 2030. Change to electric vehicles (1.3 million electric cars in 2030). Electro fuels from hydrogen from electrolysis combined with carbon from various sources.

Industry

Service and heavy industry. Energy savings of 12% by 2030, efficiency in electricity, cooling, district heating and heat pumps. Fossil fuel is substituted by electricity and biomass; change to district heating. At oil rigs, wind substitutes natural gas.

Primary energy use in 2030

The primary energy use in 2030 will be 144,5 TWh or 520 PJ. Of these 173 PJ comes from fossil fuels. In figure 2.5 is shown the primary energy use for the different sources.

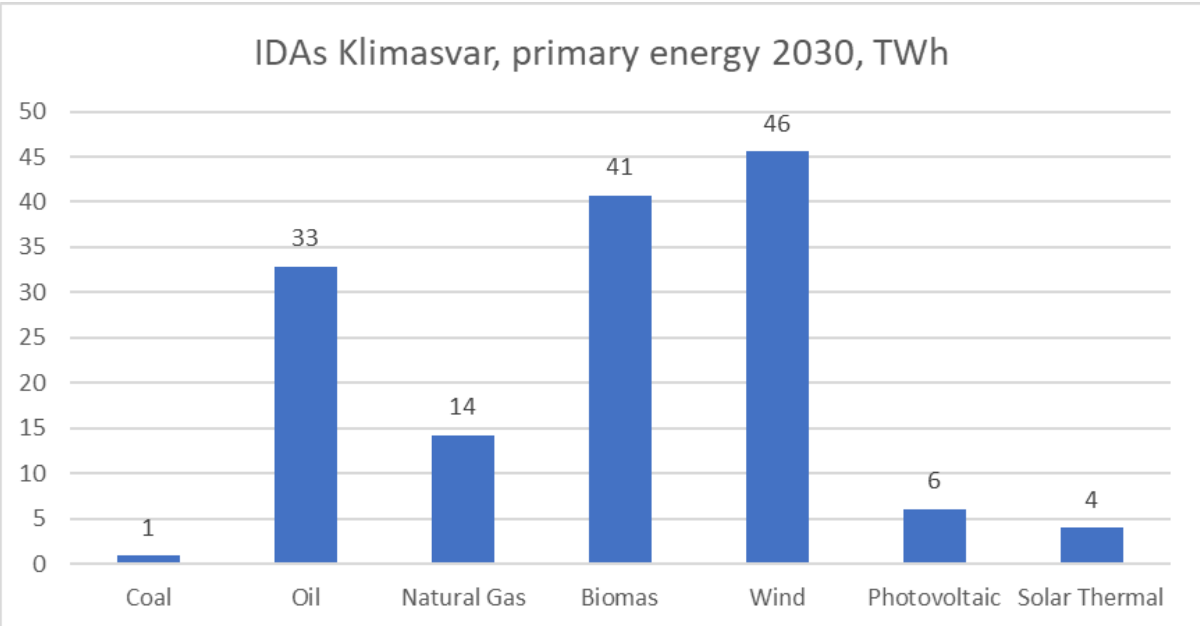

Figure 2.5. Primary energy use in 2030 for the IDAs Klimasvar energy scenario.

2.3 Energy sufficiency measures to implement in energy scenarios

We have analysed potential energy sufficiency measures for the household sector. A detailed description of the measures and empirical background can be found in work package 2 report “Systematisation of experiences with energy sufficiency initiatives” chapter

5 and 6. This includes sufficiency measures for "classical electricity consumption" (lighting and apparatus), heating (room heating and hot water), and personal car transport.

2.3.1 Electricity

It is possible to live a modern life with much less electricity use than the average Danish family. We have included sufficiency measures that give moderate changes in lifestyle – such as using fewer appliances or using them in a shorter time. In table 2.1 is a list of sufficiency actions and the reductions in electricity consumption for eac action. A more detailed description of the measures can be found in work package 3 report "Integration of sufficiency into energy modelling tools" section 3.1.1 and 3.1.7.

Household electricity demand	Consump-tion 2019	Action	Saving	Consump-tion with sufficiency
Per HH 2019, kWh/year	3234		20%	2590
Cooking	278	Optimise	20%	222
Fridge, combined fridge/freezer	281	Half HH with two fridges	16%	236
Washing machine	176	Wash less	37%	111
Dryer	228	Dry outside every second time, dry less	68%	73
Lighting	260	Turn off when not in use	30%	182
TV, DVD a.o.	442	Turn off when not in use, see more TV together	20%	354
Stereos, game consoles	105	Turn off when not in use	30%	74
PC, printer, a.o.	269	Turn off when not in use	20%	215
Network (router, modem, TV boxes)	105	Turn off at night and during work hours	35%	68

Standby - TV, PC, Stereo, Washing m, Dishwasher, Dryer	70	Turn totally off when not in use	50%	35
Other – including all uses with no proposed action	1020	No action	0%	1020

Table 2.1 Electricity consumption in Danish households excl. Heating (2019), electricity savings from various sufficiency measures and electricity consumption in 2030 after sufficiency measures.

The sufficiency measures reduce the electricity demand for households by 20%, which is 1,85 TWh (9,7 PJ) in 2030 compared to IDAs Klimasvar.

2.3.2 Heating

The sufficiency measures to reduce heating include a reduction in living space for households that face changes like retirement or children moving out. They can either move to a new place, rent out a room, or the house can be divided in two units. This will slow down the growth of living space per capita. Another sufficiency measure is reduction of indoor temperature by, on average 1/3 ºC. Sufficiency measures to reduce hot water consumption includes change to efficient shower heads and taps; and taking fewer and/or shorter baths. The measures are described in work package 3 report “Integration of sufficiency into energy modelling tools” section 3.1.2-3.1.6.

The heat sufficiency measures result in a total reduction of heat demand for households of 7.8% equal to 10.1 PJ (2.81 TWh) out of 130 PJ in 2030 compared to IDAs Klimasvar.

	Reduction in heat demand		
	%	PJ	TWh
Reduction in living space	0.8	2.2	0.61
Reduction in indoor temperature	1.7	1.0	0.28
Reduction in hot water demand	5.3	6.9	1.92
Total reduction in heat demand	**7.8**	**10.1**	**2.81**

Table 2.2. Reduction in household heat demand with sufficiency measures in 2030 compared to IDAs Klimasvar

2.3.3 Transport

For personal transport, we include as a sufficiency measure a partial transition from personal cars to bi-cycles and public transport. There are many policies that can support such a change and there is a large potential to move away from personal cars. We use a combination of policies from a plan for transition to sustainable mobility in Denmark that was developed in 2020 by three societies within the Danish Society of Engineers, IDA (IDA Rail, IDA Green Technology, IDA Transport and Urban Planning)[5]. A description of the policies can be found in work package 2 report “Systematisation of experiences with energy sufficiency initiatives” section 6.1 and 6.2. Some of these measures are also included in IDAs Klimasvar.

The combined effects of the proposals in the plan for transition to sustainable mobility have been calculated for the different travel distances for the target year 2030 with the largest reductions in car transport for the shortest travelling distances. The main finding is that the measures can reduce car travel by 43% in 2030 compared with a business-as-usual development with continued growth in car transport of 2% per year 2020 – 2030. In addition, the plan includes a change of 50% of personal cars to electric cars, giving a total emissions reduction of 70% in domestic transport.

In addition to the measures proposed in the plan for transition to sustainable mobility, we propose to include urban zones, where car driving is limited to electric cars only. We estimate that this measure in itself will reduce car use by 0.5%. The result of combining these urban zones with the plan for transition to sustainable mobility will then be a 43.5% reduction of car use.

As some of the sufficiency measures already are included in IDAs Klimasvar, we calculate the energy demand for personal cars in IDAs Klimasvar excluding the efficiency measures in this plan, and we subtract the reductions resulting from the sufficiency measures from this demand. IDAs Klimasvar includes a change of 39% of personal cars to electric cars, therefore we develop two scenarios one with 39% electric cars and one with 50% electric cars, as used in the plan for transition to sustainable mobility. The demands and reductions are shown in table 2.3.

Sector/scenario	Demand in IDAs Klimasvar	Reductions with energy sufficiency	Demand with energy sufficiency
Personal car fuel, 39% electric cars	62 PJ	43,5% equal to 25 PJ	37 PJ
Transport electricity, 39% electric cars	10 PJ	4 PJ	6 PJ
Personal car fuel, 50% electric cars	n.a.	32 PJ from IDAs Klimasvar	30 PJ
Transport electricity, 50% electric cars	n.a.	3 PJ from IDAs Klimasvar	7 PJ

Table 3.3 Reduction in energy demand for personal cars from sufficiency measures in the transport sector compared to IDAs Klimasvar. Two scenarios for the share of electric cars are included.

[5] Omstilling til Bæredygtig Mobilitet (Transition to Sustainable Mobility) by Hartmann, Jørgensen and Wellendorf (2021). https://detfaellesbedste.dk/wp-content/uploads/2021/11/IDA_anbefal_til_baeredygtig_mobilitet_210106_opdat_210418.pdf

2.4 Modified IDAs Klimasvar with integration of energy sufficiency

The main results from the two sufficiency scenarios modelled in EnergyPlan with technical optimisation are shown in table 2.4. Figure 2.6 shows the primary energy use for different sources.

	IDAs Klimasvar 2030	IDAs Klimasvar 2030 + sufficiency	IDAs Klimasvar 2030 + sufficiency + 50% electric cars
Primary energy use (PJ/TWh)	520 / 145	477 / 132	473 / 131
Fossil fuel use (PJ)	173	138	133
Biomass fuel use (PJ)	147	138	139
CO_2 emissions (million tonnes)	12,0	9,6	9,2
Costs of fuel + energy system (million Euro)	21 963	21 229	21 134

Table 2.4. Scenario results for 2030: IDAs Klimasvar and IDAs Klimasvar plus additional sufficiency measures in household heating, household electricity, and personal transport.

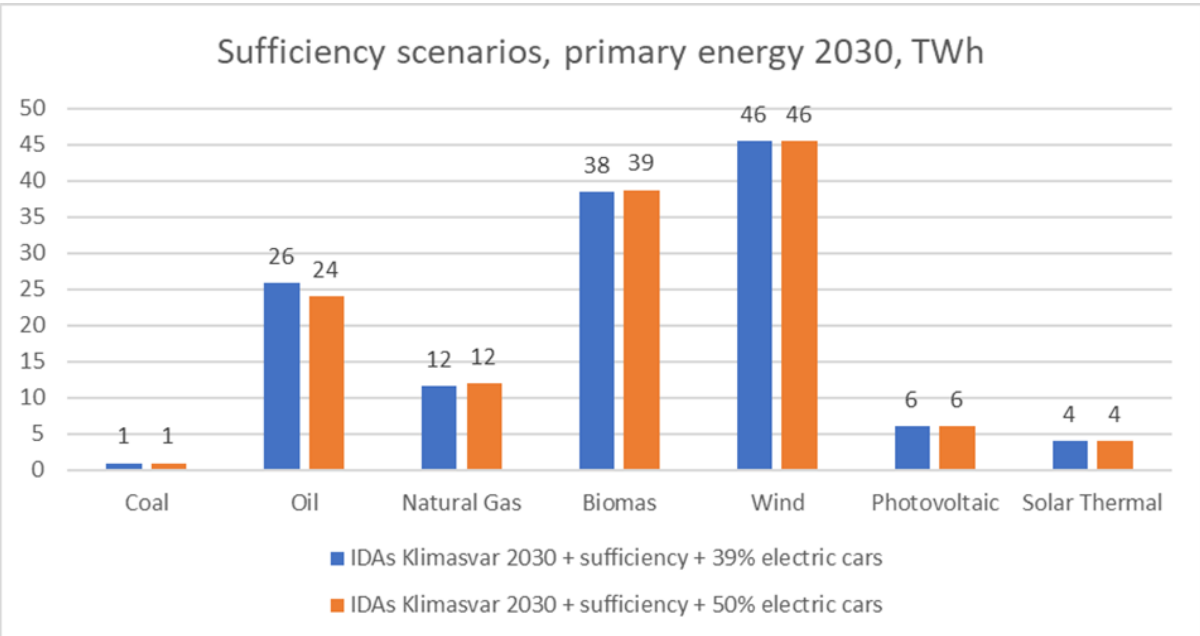

Figure 2.6 Primary energy use for IDAs Klimasvar plus additional sufficiency measures.

The scenario results show that with the proposed additional sufficiency measures, Danish primary energy demand will be reduced by 8%. This is in particular reductions in fossil fuel that will be reduced by 20% while biomass will only be reduced by 6%. The higher reduction of fossil fuels and lower reduction of biomass is because biomass is a major source of power production and is not contributing to transport fuels in IDAs Klimasvar.

With the large reduction of fossil fuel, CO_2 emissions are reduced by 20%. CO_2 emissions from biomass combustion are not included.

The reduction in costs is because of reduced fuel demand. The costs of sufficiency measures are not included.

For the scenario with sufficiency + 50% electric cars, the reductions are slightly higher: 9% in primary energy, 23% in fossil fuels and 23% in CO_2 emissions. For biomass, the reduction is a little bit lower with 50% electric cars, namely 5%, which is due to the higher electricity demand for transport.

2.5 Comparing IDAs Klimasvar with/without energy sufficiency and the official scenario

In the following sections we compare energy demand in households, primary energy demand, and greenhouse gas emissions for the official Danish Scenario - the Danish Energy Agency baseline (SCO21) with IDAs Klimasvar 2030 and IDAs Klimasvar 2030 with additional sufficiency.

2.5.1 Energy demand in households

The energy demand in households for electricity, heating and personal car transport is shown in figure 2.7.

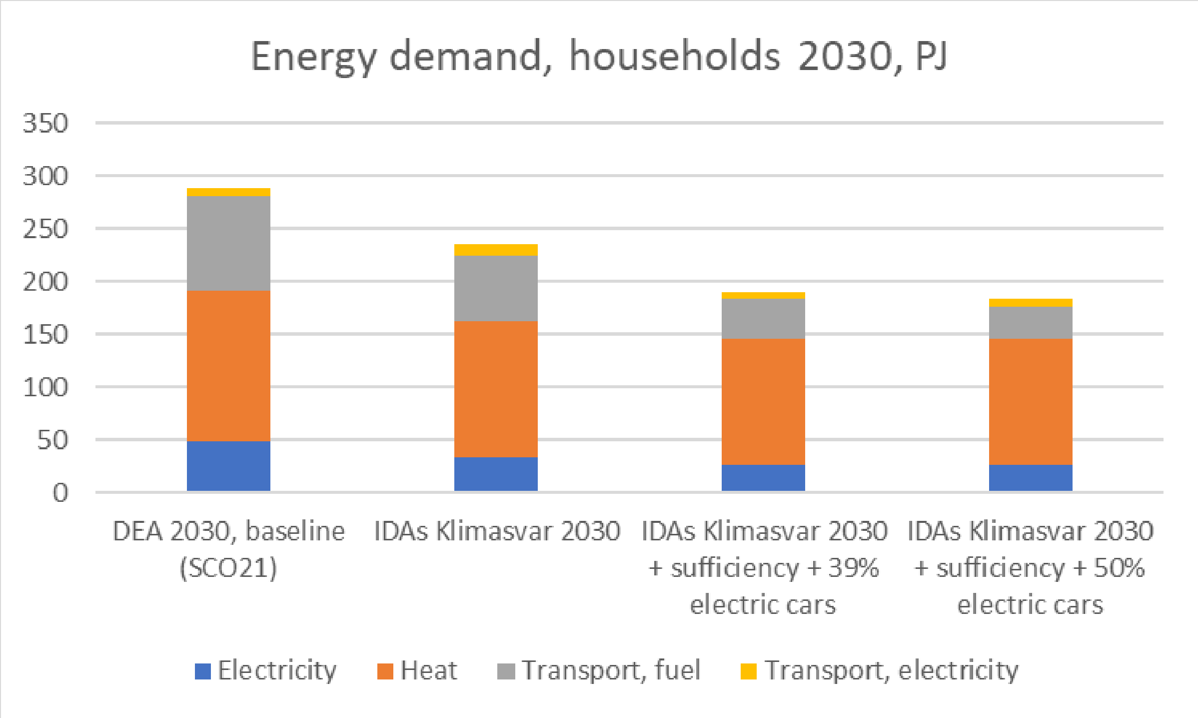

Figure 2.7 Energy demand in households including personal transport.

The energy demand in households is 19% lower for IDAs Klimasvar compared to SCO21; for IDAs Klimasvar with additional sufficiency. it is 35% lower and with 50% electric cars 37% lower. The demand is lower for classical electricity use, heat and transport fuel. The electricity demand for transport is higher.

The energy demand in households is only part of the total energy demand, as there is also an energy demand from the service and production sector.

2.5.2 Primary energy consumption

The primary energy consumption for different sources are shown in figure 2.8.

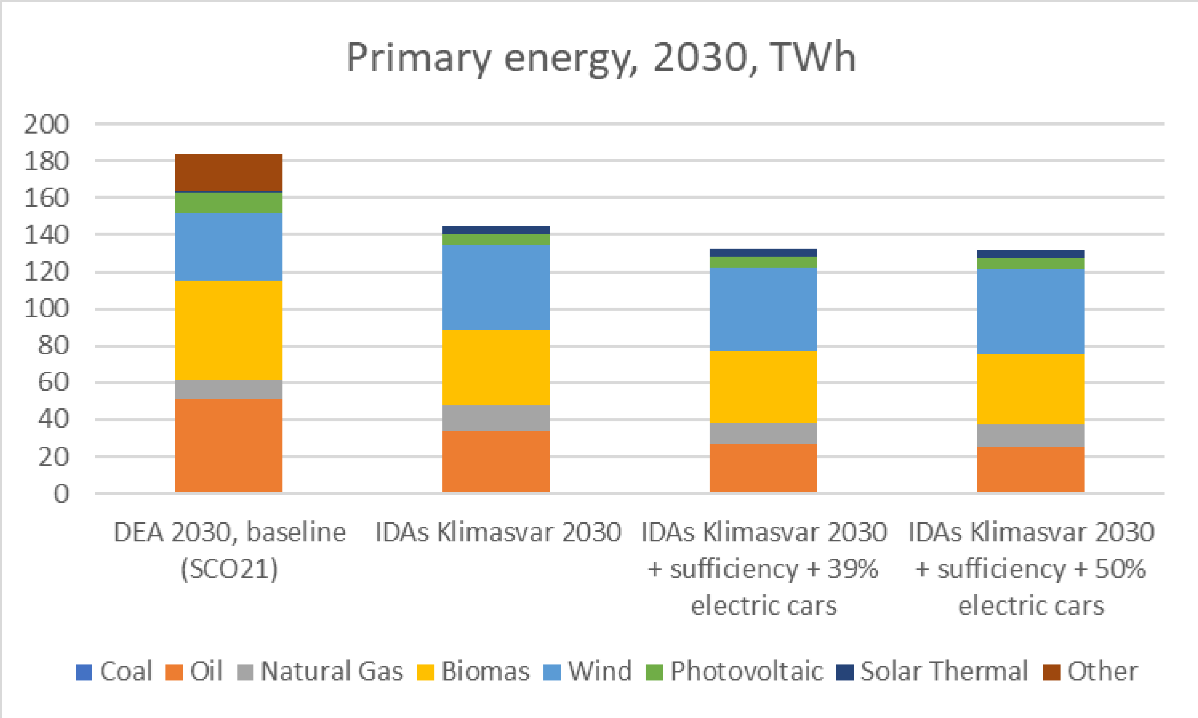

Figure 2.8 Primary energy use for the different scenarios.

The primary energy use is 21% lower for IDAs Klimasvar compared to SCO21; for IDAs Klimasvar with additional sufficiency it is 28% lower and with 50% electric cars 29% lower. Especially, the use of oil and biomass is lower. The use of wind power is higher for IDAs Klimasvar and IDAs Klimasvar with additional sufficiency compared to SCO21.

The primary energy use is 8% lower with additional sufficiency compared to IDAs Klimasvar. With 50% electric cars it is 9% lower.

2.5.3 Greenhouse gas emissions

The greenhouse gas emissions are shown in figure 2.9.

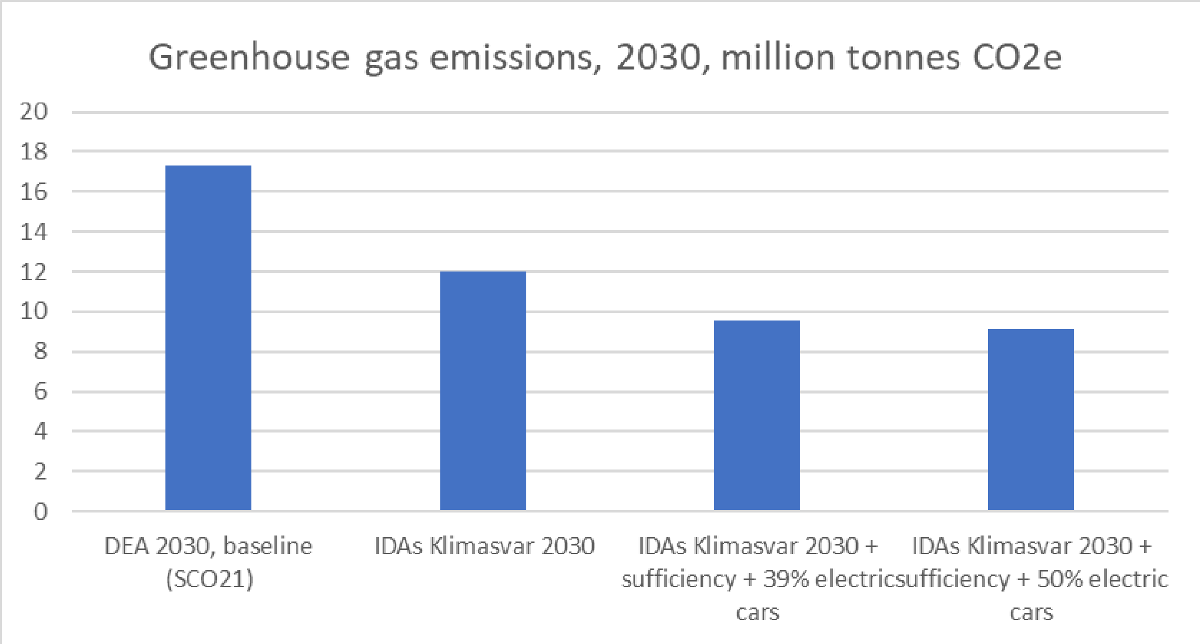

Figure 2.9 Greenhouse gas emissions for the different scenarios.

The greenhouse gas emissions are 31% lower for IDAs Klimasvar compared to SCO21; for IDAs Klimasvar with additional sufficiency it is 45% lower and with 50% electric cars 47% lower.

Though the primary energy use is only 8% lower with additional sufficiency compared to IDAs Klimasvar the greenhouse gas emissions are 20% lower with additional efficiency compared to IDAs Klimasvar. This is because the renewable energy production is the same and a great part of the reduction in primary energy use is reduction of fossil fuels.

A small reduction in energy demand will give a comparatively large reduction in greenhouse gas emissions with the same amount of renewable energy in the energy system. Focus on energy sufficiency in households and campaigns for energy sufficiency can be combined with campaigns for the correct use of energy efficient buildings, which is necessary to achieve the energy efficiency reductions included in IDAs Klimasvar.

3. Lithuanian Energy Scenarios

The MESSAGE modelling framework was used to create illustrative energy development scenarios for Lithuania. The modelling of sufficiency scenarios is based on an exogenous approach, representing sufficiency measures by exogenously assumed final energy demand reductions. Therefore, the modelling focuses on the energy system consequences and an indicative assessment of the possible impact scale of demand reductions caused by the introduction of energy sufficiency.

3.1 Brief description of the model

The mathematical model represents the Lithuanian energy system and covers the period up to 2080. Linear programming is used to find the least discounted cost solution on the development and operation of the energy system over the entire period considered. However, the analysis is focused on the period up to 2050 as the most policy-relevant time frame.

The principal structure of the model used in the analysis is depicted in Figure 3.1.

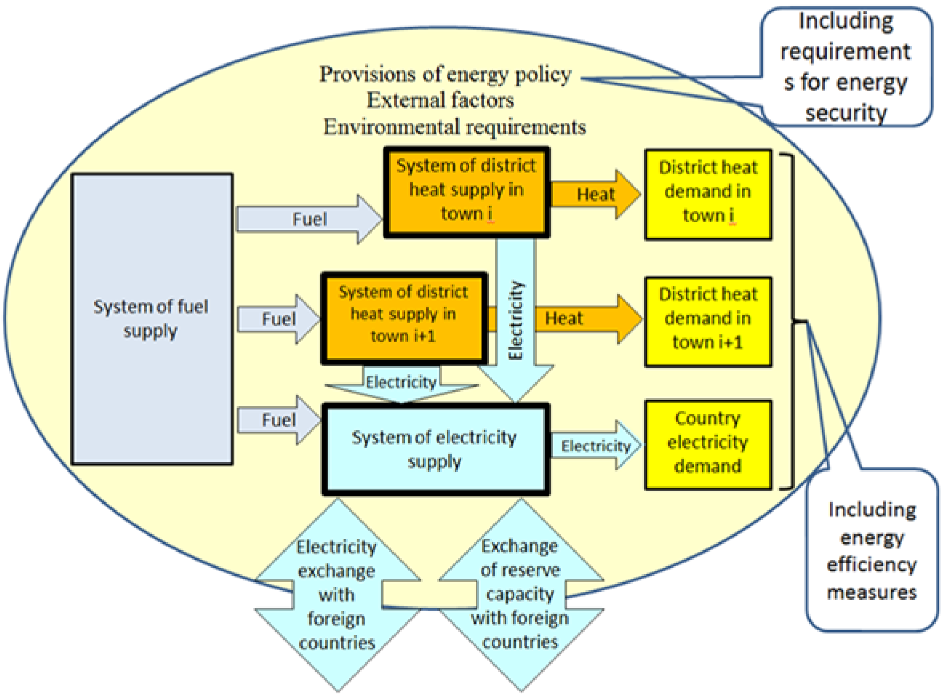

Fig. 3.1. The structure of the model used

The single-country model used in the analysis represents the fuel supply system that includes all the main fuels in Lithuania explicitly describes the largest district heating systems (district heating in the largest cities and towns is modelled separately) and electricity generators. The district heat demands are also separated by the geographical locations, while other energy demands are provided on a country-wide basis.

As mentioned, the model highlights the energy system impacts of demand reductions caused by various sufficiency measures but does not include explicit modelling of energy sufficiency measures themselves. The analysis of particular measures can only be feasible using an endogenous approach or performing pre-calculations for each sufficiency measure. In principle, such pre-calculations are of endogenous nature as they determine the amount of sufficiency introduced. Also, the costs related to the implementation of sufficiency measures are neglected in the model, i.e., the modelling result is not determined by the cost of possible sufficiency measures.

3.2 Description of base case and sufficiency scenarios

The calculations are based on the example of a scenario used to prepare Lithuania's current National energy strategy [https://enmin.lrv.lt/uploads/enmin/documents/files/Nacionaline%20energetines%20nepriklausomybes%20strategija_2018_EN.pdf]. This scenario is considered as a baseline scenario in this analysis. It assumes final demand growth for most kinds of energy, except district heat and final consumption of fossil fuels. Such national policy targets as the aim to increase local electricity production are introduced to the scenario. In the baseline, the CO2 price is assumed to grow from 52 Eur/t in 2020 until 104 Eur/t in 2030 and stay constant afterwards. No other bounds on CO2 emissions are applied to explore the impact of sufficiency.

The electricity production structure in the baseline is shown in Figure 3.2.

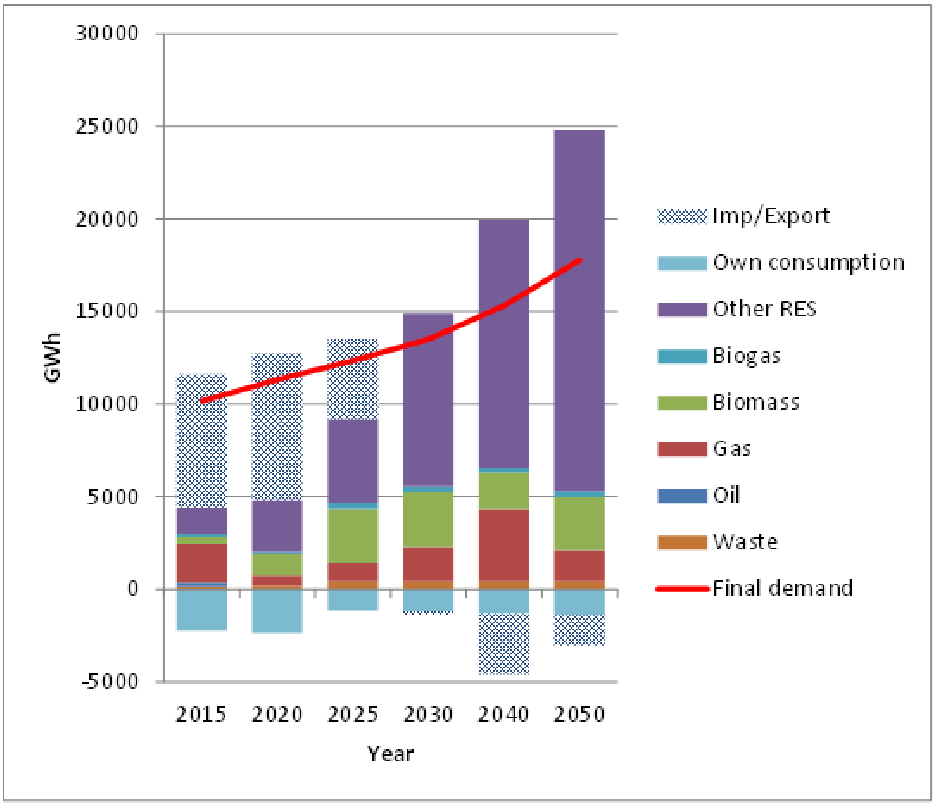

Fig. 3.2. Electricity production structure by primary energy source under the Base scenario

The most noticeable trend is the shift from importing the major part of electricity to local production following national energy policy goals. As can be seen in Figure 3.2, in the baseline Lithuania will become a net electricity exporter in 2030. This is achieved mainly by increasing local electricity generation using renewable energy sources. The electricity production from renewable energy sources increases more than five times, mainly due to the increasing electricity production by wind and solar power plants. The role of biomass powerplants also increases following the introduction of major CHP projects. Increasing electricity production from natural gas somehow contradicts overall decarbonisation trends, but the model uses natural gas power plants to enable increasing electricity generation from renewable energy sources.

The situation in the district heating does not demonstrate such drastic changes as with electricity. The production structure is shown in Figure 3.3.

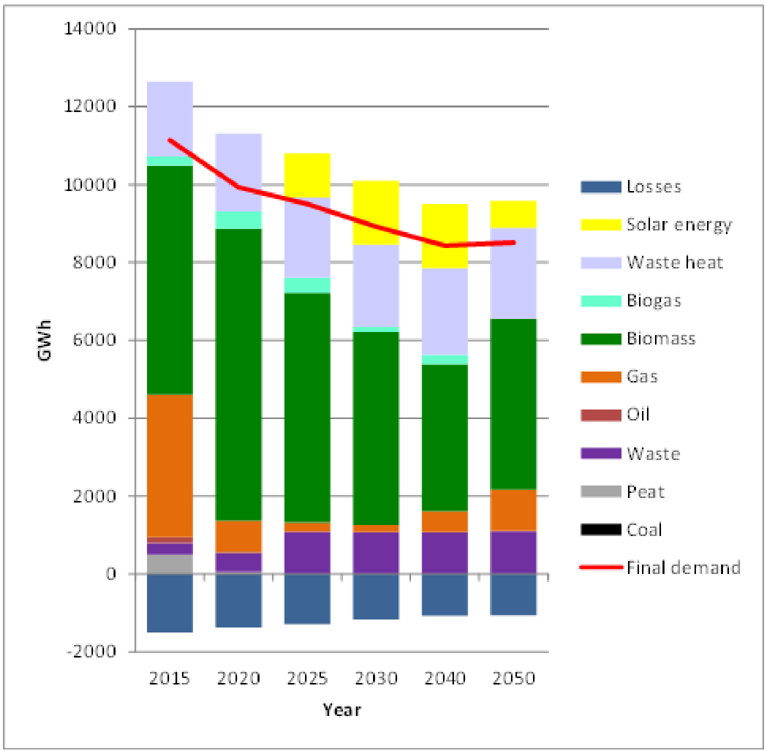

Fig. 3.3. District heat production structure by primary energy source under the Base scenario

The Lithuanian district heating sector has already undergone a major transformation from fossil fuels to carbon-neutral biomass. Decreasing energy demand is foreseen mainly due to increasing energy efficiency caused by the modernisation of building stock. The District heating sector follows this without significant changes in the production structure.

The overall trends of primary energy consumption for energy uses are shown in Figure 3.4.

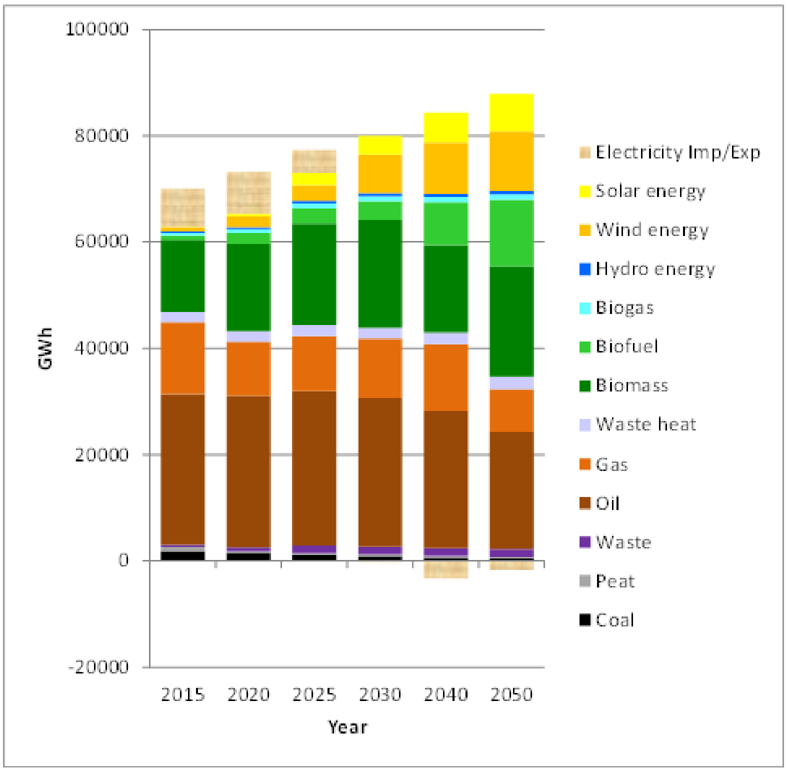

Fig. 3.4. Primary energy requirement under the Base scenario

The figure complements previous observation on the increasing RES share in the fuel and energy balance achieved by solar, wind, and bioenergy consumption growth. Fossil fuel use in the Base scenario is decreasing but not enough to reach deep decarbonisation. This is illustrated by Figure 3.5, which shows the main sources of carbon emissions from fuel combustion.

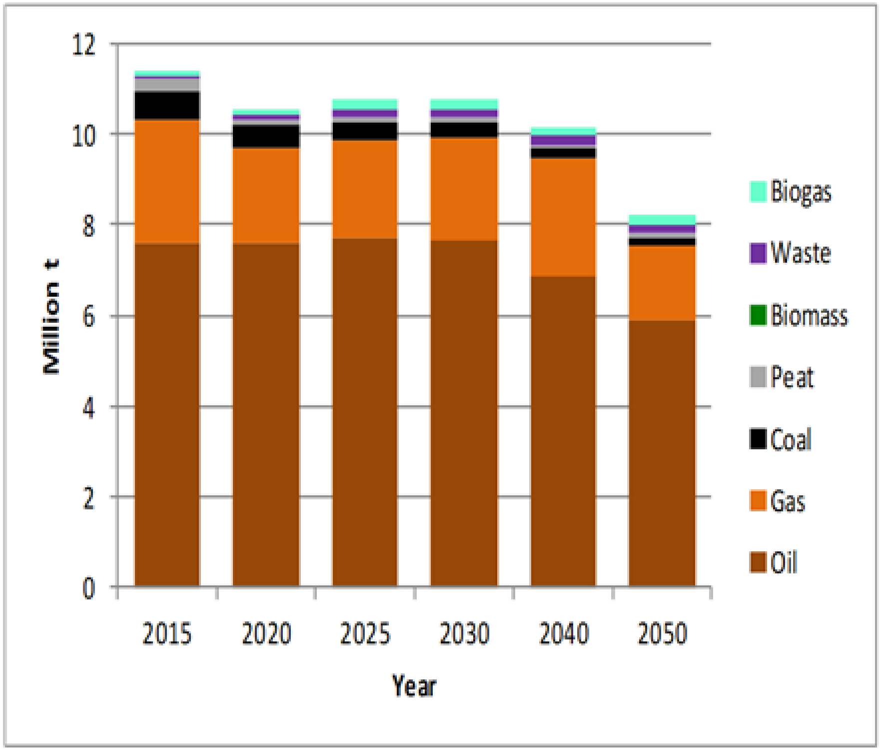

Fig. 3.5. CO_2 emissions from fuel combustion

Oil products used in the transport are foreseen to be the main carbon emission source in the rather conservative Baseline. Also, significant emissions are determined by natural gas burning for various purposes. As a result, only a modest CO_2 emission decrease is achieved in the Base scenario.

The scenarios with sufficiency-caused energy demand reductions follow all the conditions set for the baseline, except reduced demands. As the development of the energy system is not affected by carbon constraints, the differences in calculated emissions represent the impact of the scale of sufficiency assumed in each scenario.

The complete list of scenarios considered is provided in Table 3.1 below.

Table 3.1. Scenarios analysed

Group of scenarios	Scenario	Description
Base	Base	Basic scenario
Bottom-up	Households	Sufficiency causes energy demand reduction in households only
	Transport	Sufficiency causes energy demand reduction in transport only
	HousTransp	Sufficiency causes energy demand reduction in households AND transport

Survey	Suff-voluntary	Demand reductions are based on self-reported energy consumption reduction potential without additional incentives. The reduction potential of 2.5 % is gradually reached by 2030; afterwards, the energy demand trends from the basic scenario are followed.
	Suff-paid	Demand reductions are based on self-reported energy consumption reduction potential in case support to households is provided. The reduction potential of 3.5 % is gradually reached by 2030; afterwards, the energy demand trends from the basic scenario are followed.
	Suff-median	All households follow the median consumption level. The reduction potential of 20.4 % is gradually reached by 2040; afterwards, the energy demand trends from the basic scenario are followed.
	Suff-medianless	Consumption reductions are assumed only for households whose consumption is above the median (energy poverty issues are not tackled). The reduction potential of 30.5 % is gradually reached by 2040; afterwards, the energy demand trends from the basic scenario are followed.

In addition to the baseline, there are two other groups of scenarios. Bottom-up scenarios are created based on sufficiency assumptions developed in the CACTUS project [https://cactus-energy-sufficiency.eu/]. This project analysed different factors affecting energy consumption, and assumptions for sufficiency scenarios were made [https://youtu.be/YSUfhwIVycY?t=5951], [https://cactus-energy-sufficiency.eu/wp-content/uploads/2022/03/CACTUS_II.3_SufficiencyIndicators_Assumptions_2050targets_FOR-PUBLICATION.xlsx]. These assumptions were used to create three energy demand scenarios to be analysed using the energy system model. Compared to the Base scenario, the bottom-up scenarios assume energy demand reductions in households, transport, or both.

The survey group of scenarios uses a representative survey of Lithuanian households to make assumptions about the possible demand reductions caused by energy sufficiency. The survey was conducted in November-December 2020 and covered 1008 households in 35 urban and 41 rural settlements. This survey was a part of on-demand research project "Households in the context of energy transition", carried out by Lithuanian Energy Insitute in cooperation with the Ministry of Energy and funded by Lithuanian Research Council. The fieldwork was performed by UAB "Vilmorus".

All scenarios in this group use energy demand dynamics from the Base scenario, but introduce some demand reductions calculated from the survey data.The Suff-voluntary and Suff-paid scenarios introduce energy demand reduction potential obtained from households' answers about their willingness to reduce energy consumption to minimise climate impacts without and with additional support from the state. As the reduction is based on voluntary actions, it was assumed that it may be reached relatively quickly until 2030.

The Suff-median and Suff-medianless scenarios use median energy consumption per adult equivalent in Lithuanian households to benchmark energy consumption level that is generally acceptable in society. Obviously, energy consumption in a home depends not only on behavioural reasons but also on a variety of other factors, including energy efficiency level and housing type. However, the national median provides a solid ground to argue that a similar energy consumption level is achievable by the majority of households and thus can be effectively used as a sufficiency benchmark. As this approach provides more extreme energy demand reductions than voluntary sufficiency, the scenarios assume they could be reached by 2040. The Suff-median scenario assumes that all households reach the national median energy consumption per adult equivalent. This means that increased energy consumption is assumed in households that currently use less energy than the national median and reduced in households that consume more than the median. In contrast, Suff-medianless assumes only demand reductions in households that currently consume more than the median. Thus, it might be argued that Suff-median, to some extent, takes into account energy poverty alleviation due to the assumption of increased energy consumption in households whose energy consumption is below the national median.

The energy demand differences among the scenarios are shown in Figure 3.6.

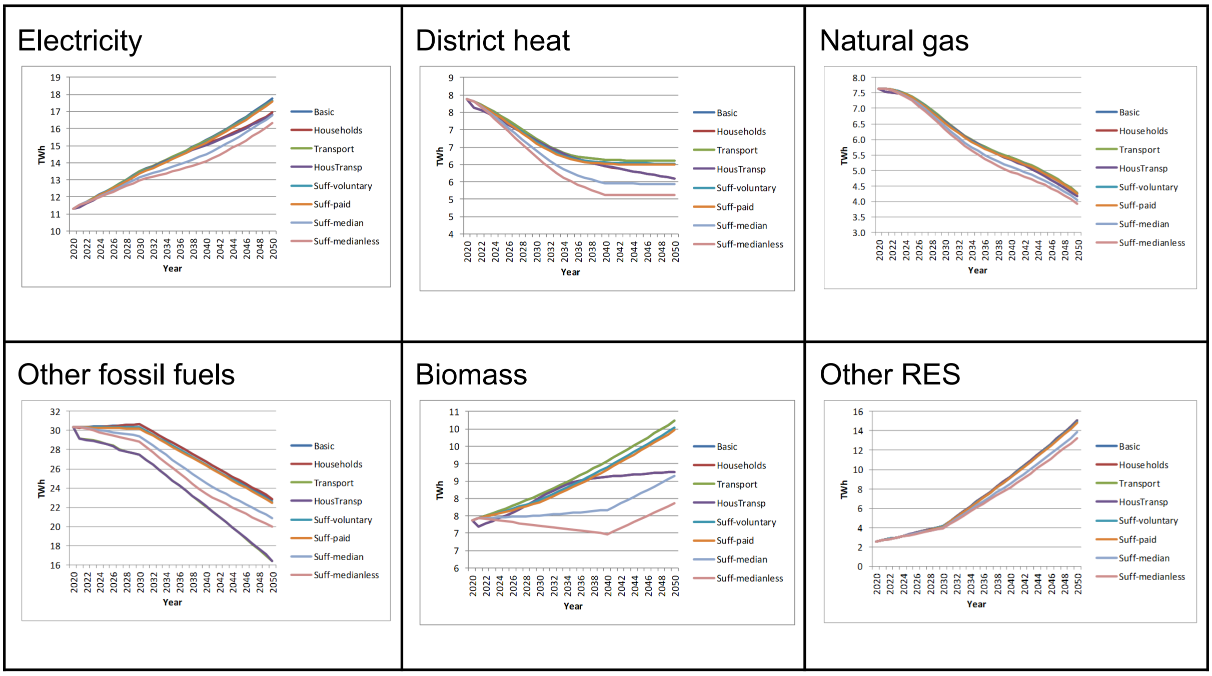

Fig. 3.6. Final demands under different scenarios with sufficiency

The Suff-medianless scenario provides the most significant demand reductions of all energies, except other fossil fuels that cover transport fuels as well. For other fossil fuels, the most considerable demand reduction is observed in the Transport scenario.

3.3 The impacts of sufficiency on the energy sector and GHG emissions

The implementation of energy sufficiency actions results in energy demand reductions and, consequently, impacts the development and operation of the energy sector. Such impacts can be illustrated by the case of the electricity sector (see Fig. 3.7). Both the scale and direction of impact differs depending on the scenario considered. In 2050, more electricity is produced in the transport scenario than in the Base scenario, while other sufficiency scenarios considered result in decreased local electricity generation and reduced imports from abroad. However, the most affected fuel in electricity production is biomass which is considered carbon neutral. Although reduced electricity production from biomass fails to directly contribute to carbon emission reductions, saved biomass resources may contribute to the decarbonisation in other sectors. The scale of electricity production and import reductions is, to some extent, related to the assumed final demand reductions.

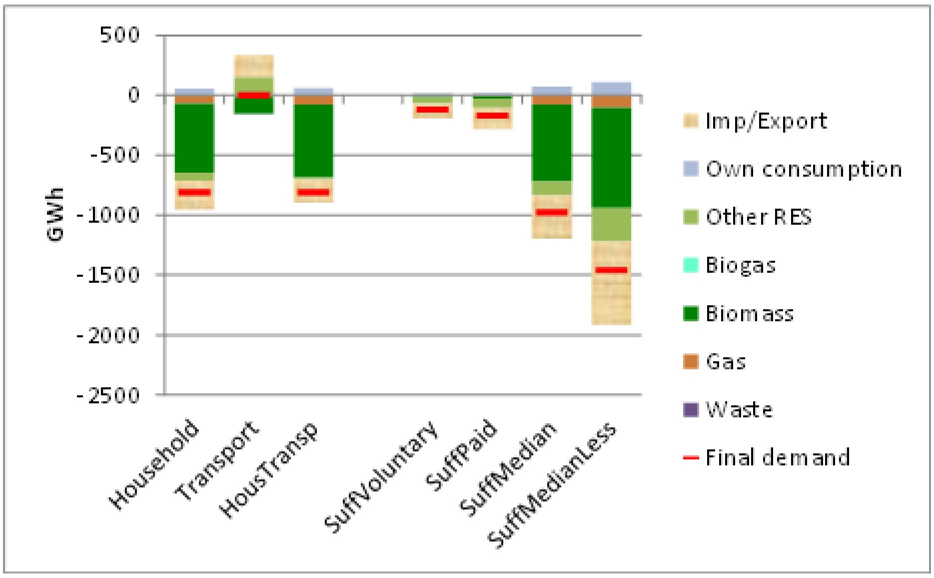

Fig. 3.7. Changes in electricity production in 2050 by primary energy (compared to the Base scenario)

Very similar trends are observed in the power generation capacity structure. Figure 3.8 shows observed changes in the installed capacity of power plants.

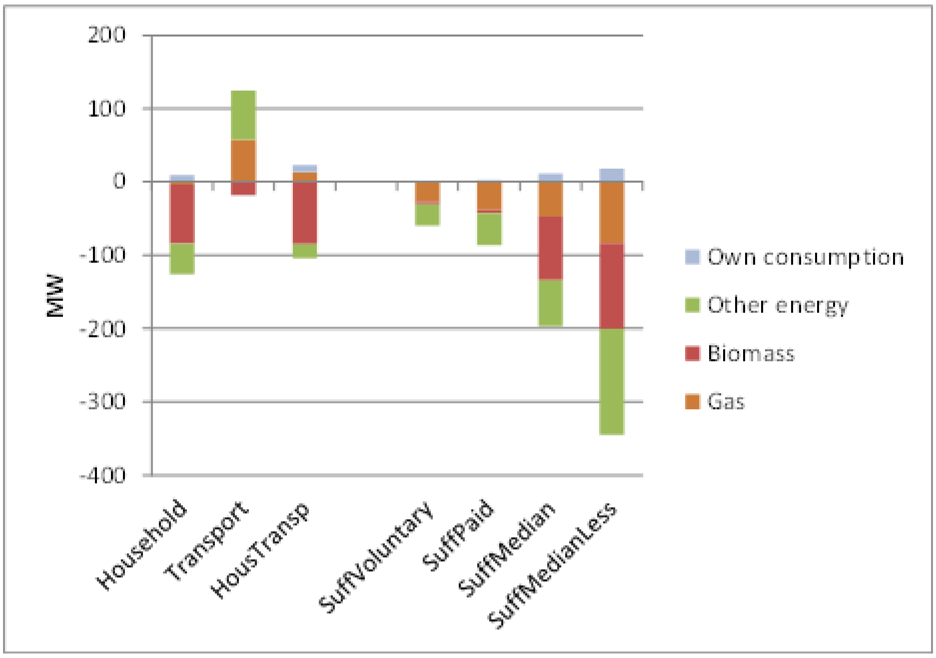

Fig. 3.8. Changes in the installed capacity of power plants in 2050 (compared to the Base scenario)

Implementation of sufficiency measures may lead to approximately 100 MW changes in overall installed capacity at power plants in Lithuania. In extreme cases, this may reach 200 – 300 MW.

In the district heating sector, heat production in biomass CHP decreases, but also less heat is produced by large-scale solar plants in most sufficiency scenarios.

Such changes in power and heat generation reduce primary energy consumption in the country, as shown in Figure 3.9.

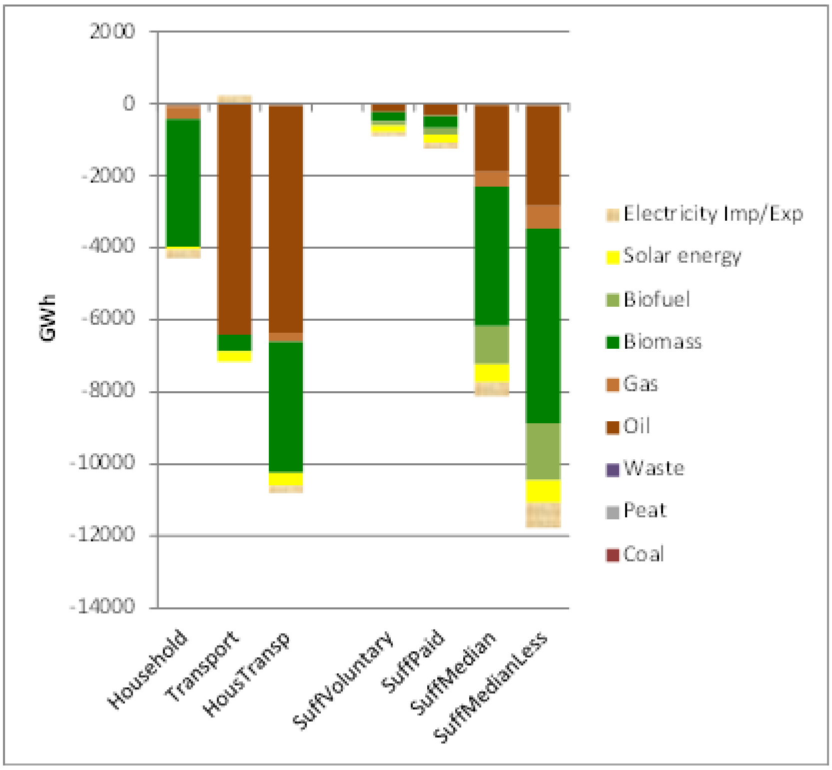

Fig. 3.9. Changes in the primary energy consumption in 2050 (compared to the Base scenario)

The most significant reduction of primary energy requirement in Lithuania is expected to come from oil (primarily when sufficiency measures are targeted to the transport sector) and biomass. As with electricity production, the reduction of primary energy consumption is associated with the scale of assumed demand reductions.

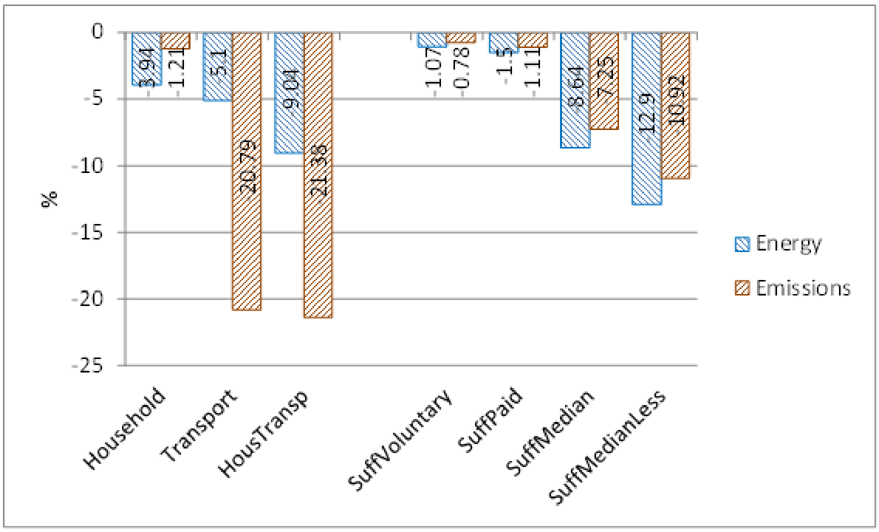

Fig. 3.10. Percentage changes in the primary energy consumption and CO_2 emissions in 2050 (compared to the Base scenario)

However, there is no strong correlation between final energy consumption and emission reductions. As shown in Figure 3.10, CO_2 emission reductions in Lithuania tend to be lower than total final energy demand reductions in the scenarios where sufficiency measures are more concentrated on energy consumption at home (for heating, appliances, etc.). This can be explained by the fact that in the base scenario, a large share of energies related to energy consumption at home is produced using emission-free renewable energy sources. When sufficiency measures target transport, overall emission savings may exceed the overall reduction of final demand. This provides clear evidence that if carbon emission reductions are considered the primary policy goal, energy sufficiency actions and policies should be focused on most polluting sectors and fuels.

On the other hand, carbon emission reduction is just one of the benefits of a more sufficient lifestyle. Many co-benefits of sufficiency are also indirectly related to decarbonisation. For example, reduced demand for critical materials or biomass may enable decarbonisation in other areas.

4. Latvian Sufficiency Energy Scenarios

To create energy sufficiency scenarios for Latvia the same MESSAGE model was used as described in the chapter 3 regarding Lithuanian scenarios. For the methodology used, please refer to chapter 3.1.

4.1 Description of base case and sufficiency scenarios

Business as usual scenario assumes final demand growth for most kinds of energy, except district heat and final consumption of fossil fuels. Such national policy targets as the aim to increase local electricity production are introduced to the scenario. In the baseline, the CO_2 price is assumed to grow from 52 Eur/t in 2020 until 104 Eur/t in 2030 and stay constant afterwards. No other bounds on CO_2 emissions are applied to explore the impact of sufficiency.

The most noticeable trend is the shift from importing the major part of electricity to local production following national energy policy goals. As can be seen in Figure 4.1, in the baseline scenario Latvia will reach electric energy self-sufficiency by 2050. This is achieved mainly by increasing local electricity generation using renewable energy sources. The electricity production from renewable energy sources increases from 48% of the total electricity demand in 2020 to 85% in 2050, mainly due to the increasing electricity production by wind and biomass. Continuing electricity production from natural gas somehow contradicts overall decarbonization trends, but the model uses natural gas power plants to enable increasing electricity generation from renewable energy sources.

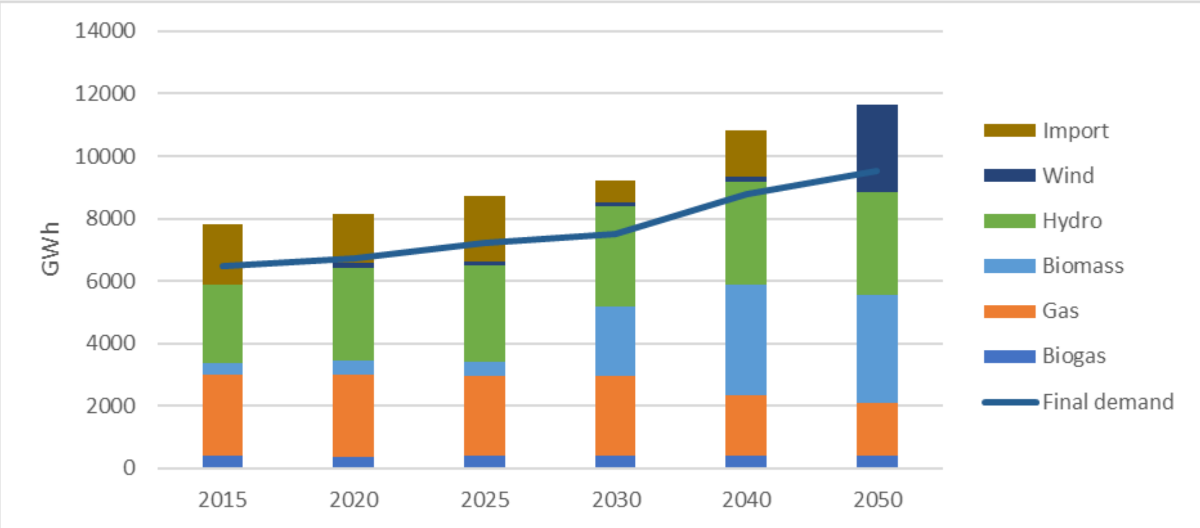

Figure 4.1. Electricity production structure by primary energy source under the Baseline scenario, GWh

The situation in the district heating does not demonstrate such drastic changes as with electricity. The production structure is shown in Figure 4.2. The Latvian district heating sector has already partly undergone a major transformation from fossil fuels to carbon-neutral biomass. It is foreseen that increasing the energy efficiency of buildings will be driving the decrease in energy demand while increasing heating floor space and people switching to district heating will lead to the increasing demand for district heating energy.

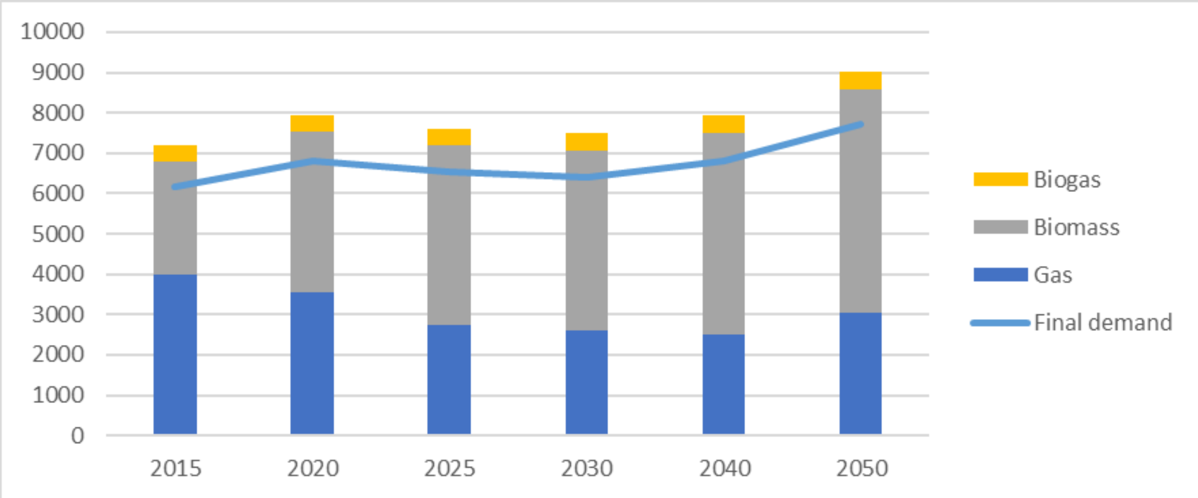

Fig. 4.2. District heat production structure by primary energy source under the Baseline scenario

An increasing share of renewable energy sources (RES) in the fuel and energy balance is achieved mainly by growth in wind and bioenergy consumption. Fossil fuel use in the Baseline scenario is decreasing but not enough to reach deep decarbonization. This is illustrated by Figure 4.3, which shows the main sources of carbon emissions from fuel combustion for the heat and power sector of Latvia. Also, significant emissions are determined by natural gas burning for various purposes. As a result, only a modest (24%) CO_2 emission decrease is achieved in the Baseline scenario.

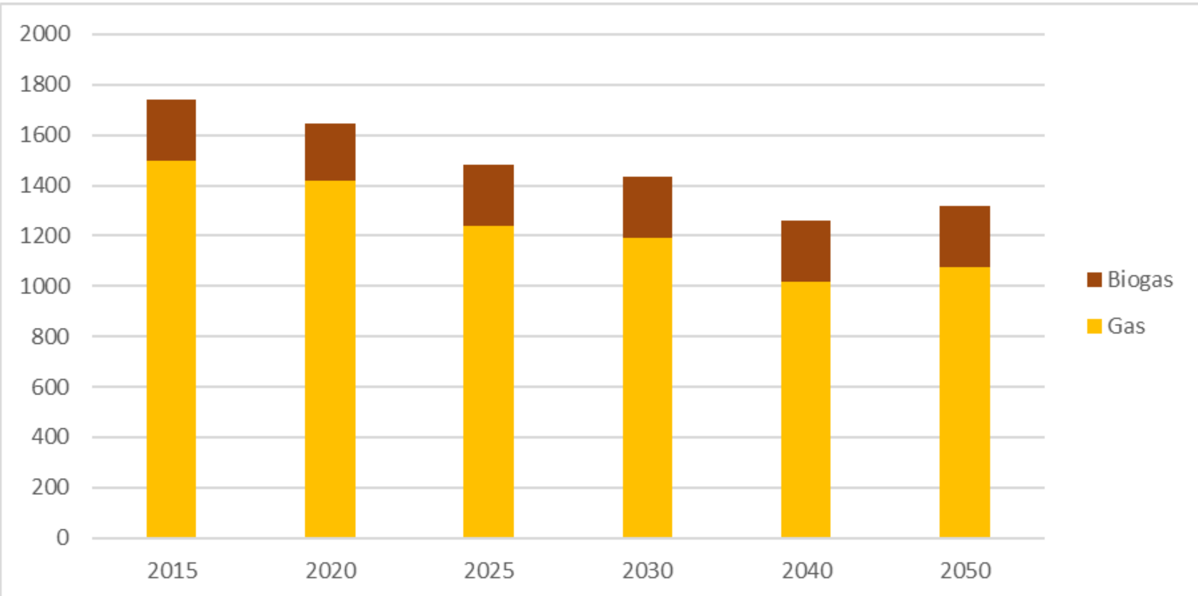

Fig. 4.3. CO_2 emissions from fuel combustion

4.2 Sufficiency scenarios

The scenarios with sufficiency-caused energy demand reductions follow all the conditions set for the baseline, except reduced demands. As the development of the energy system is not affected by carbon constraints, the differences in calculated emissions represent the impact of the scale of sufficiency assumed in each scenario. The complete list of scenarios considered is provided in Table 4.1 below.

Table 4.1. Scenarios analyzed

Group of scenarios	Scenario	Description
Base	Base	Baseline scenario
Bottom-up	Households	Sufficiency causes energy demand reduction in households only
	HousTransp	Sufficiency causes energy demand reduction in households AND transport
Survey	Suff-voluntary	Demand reductions are based on self-reported energy consumption reduction potential without additional incentives. The reduction potential of 2.5% is gradually reached by 2030; afterwards, the energy demand trends from the basic scenario are followed.
	Suff-paid	Demand reductions are based on self-reported energy consumption reduction potential in case support to households is provided. The reduction potential of 3.5% is gradually reached by 2030; afterwards, the energy demand trends from the basic scenario are followed.
	Suff-median	All households follow the median consumption level. The reduction potential of 20.4% is gradually reached by 2040; afterwards, the energy demand trends from the basic scenario are followed.

	Suff-medianless	Consumption reductions are assumed only for households whose consumption is above the median (energy poverty issues are not tackled). The reduction potential of 30.5% is gradually reached by 2040; afterwards, the energy demand trends from the basic scenario are followed.

In addition to the baseline, there are two other groups of scenarios. Bottom-up scenarios are created based on sufficiency assumptions developed in the CACTUS project. This project analyzed different factors affecting energy consumption, and assumptions for sufficiency scenarios were made . These assumptions were used to create three energy demand scenarios to be analyzed using the energy system model. Compared to the Baseline scenario, the bottom-up scenarios assume energy demand reductions in households.

The survey group of scenarios uses households survey data to make assumptions about the possible demand reductions caused by energy sufficiency. All scenarios in this group use energy demand dynamics from the Baseline scenario but introduce some demand reductions calculated from the survey data. The Suff-voluntary and Suff-paid scenarios introduce energy demand reduction potential obtained from households' answers about their willingness to reduce energy consumption to minimize climate impacts without and with additional support from the state. As the reduction is based on voluntary actions, it was assumed that it may be reached relatively quickly until 2030. The Suff-median and Suff-medianless scenarios use median energy consumption per adult equivalent to benchmark energy consumption level that is generally acceptable in society.

Energy consumption in a home depends not only on behavioral reasons but also on a variety of other factors, including energy efficiency level and housing type. However, the national median provides a solid ground to argue that a similar energy consumption level is achievable by the majority of households and thus can be effectively used as a sufficiency benchmark. As this approach provides more extreme energy demand reductions than voluntary sufficiency, the scenarios assume they could be reached by 2040. The Suff-median scenario assumes that all households reach the national median energy consumption per adult equivalent. This means that increased energy consumption is assumed in households that currently use less energy than the national median and reduced in households that consume more than the median. In contrast, Suff-medianless assumes only demand reductions in households that currently consume more than the median. Thus, it might be argued that Suff-median, to some extent, takes into account energy poverty alleviation due to the assumption of increased energy consumption in households whose energy consumption is below the national median.

The energy demand differences among the scenarios are shown in Figure 4.5. The Suff-medianless scenario provides the most significant demand reductions of all energies.

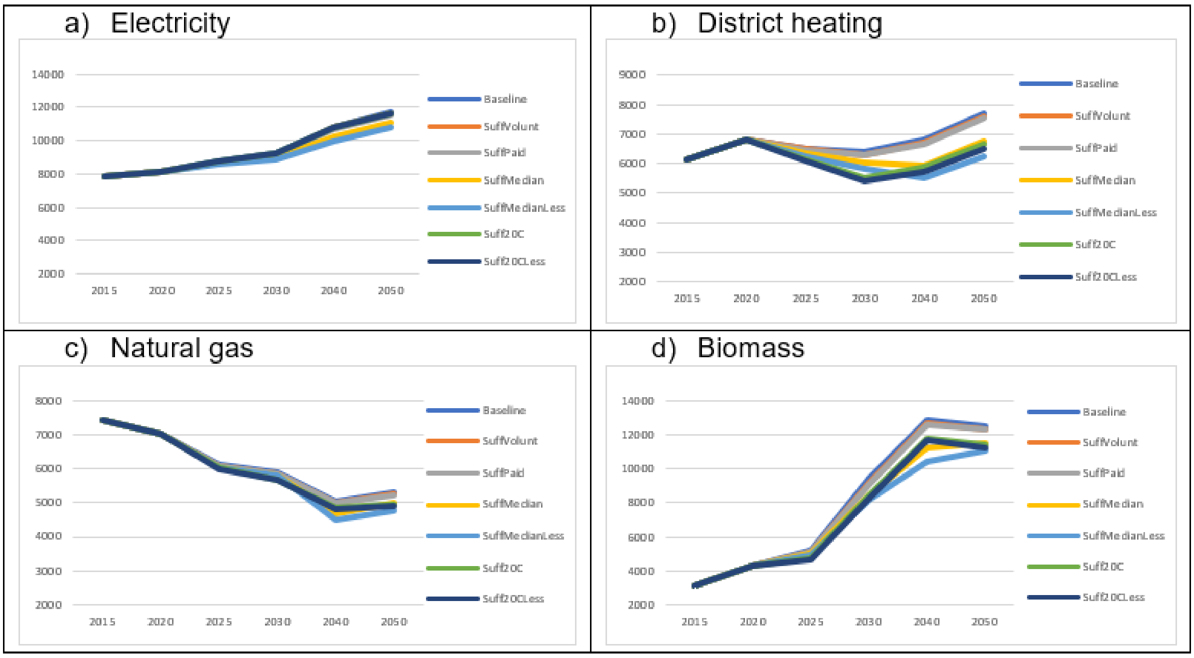

Fig. 4.5. Final demands under different scenarios with sufficiency, GWh

4.3 The impacts of sufficiency on the energy sector and GHG emissions

The implementation of energy sufficiency actions results in energy demand reductions and, consequently, impacts the development and operation of the energy sector. Such impacts can be illustrated by the case of the electricity sector (see Fig. 4.5). Both the scale and direction of impact differ depending on the scenario considered. In 2050, more electricity when compared to the Baseline scenario is produced only in the energy poverty reduction scenarios (Suff-median and Suff-medianless), while other sufficiency scenarios resulted in decreased power demand. However, the most affected fuels in electricity production are wind and biomass both being considered carbon neutral. Although reduced electricity production from biomass fails to directly contribute to carbon emission reductions, saved biomass resources may contribute to the decarbonization in other sectors. The scale of electricity production and import reductions is, to some extent, related to the assumed final demand reductions.

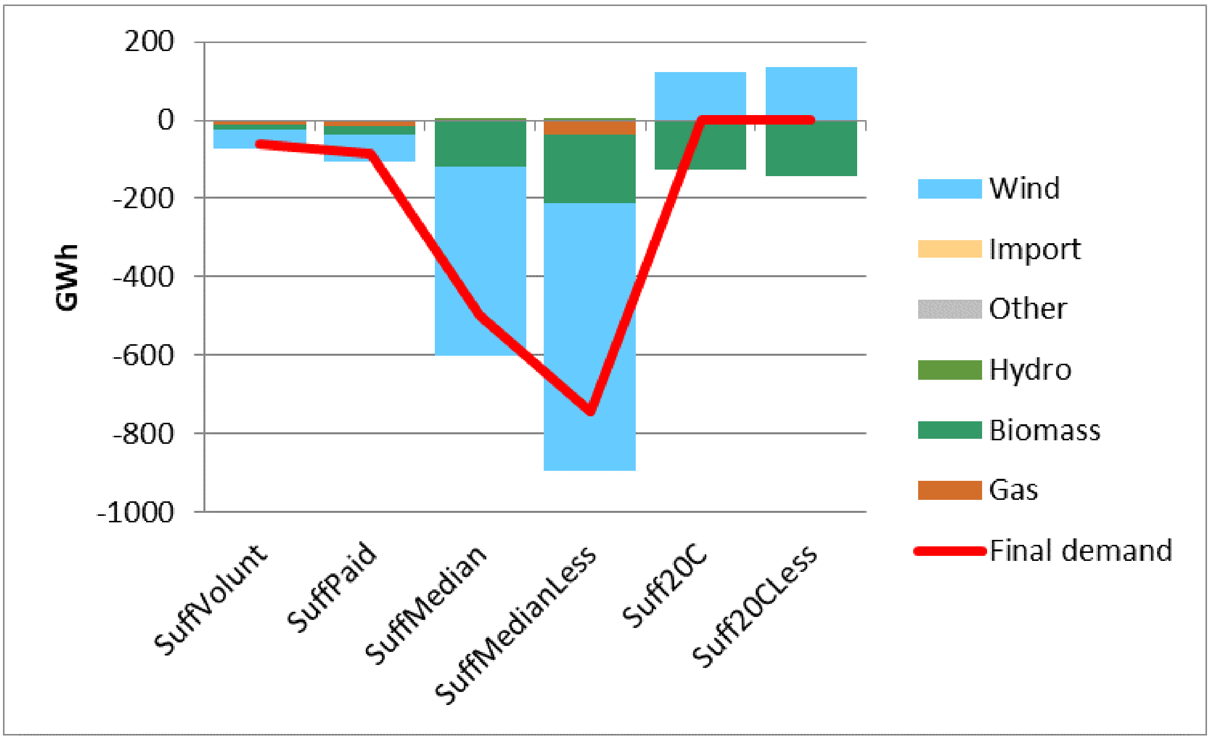

Fig. 4.5. Changes in electricity production in 2050 by primary energy (compared to the Baseline scenario)

Very similar trends are observed in the power generation capacity structure. Figure 4.6 shows observed changes in the installed capacity of power plants Implementation of sufficiency measures may lead to an approximately significant reduction in overall installed capacity at power plants in Latvia with the biggest potential reductions in the wind sector. In the extreme case, a possible capacity reduction can be more than 300 MW.

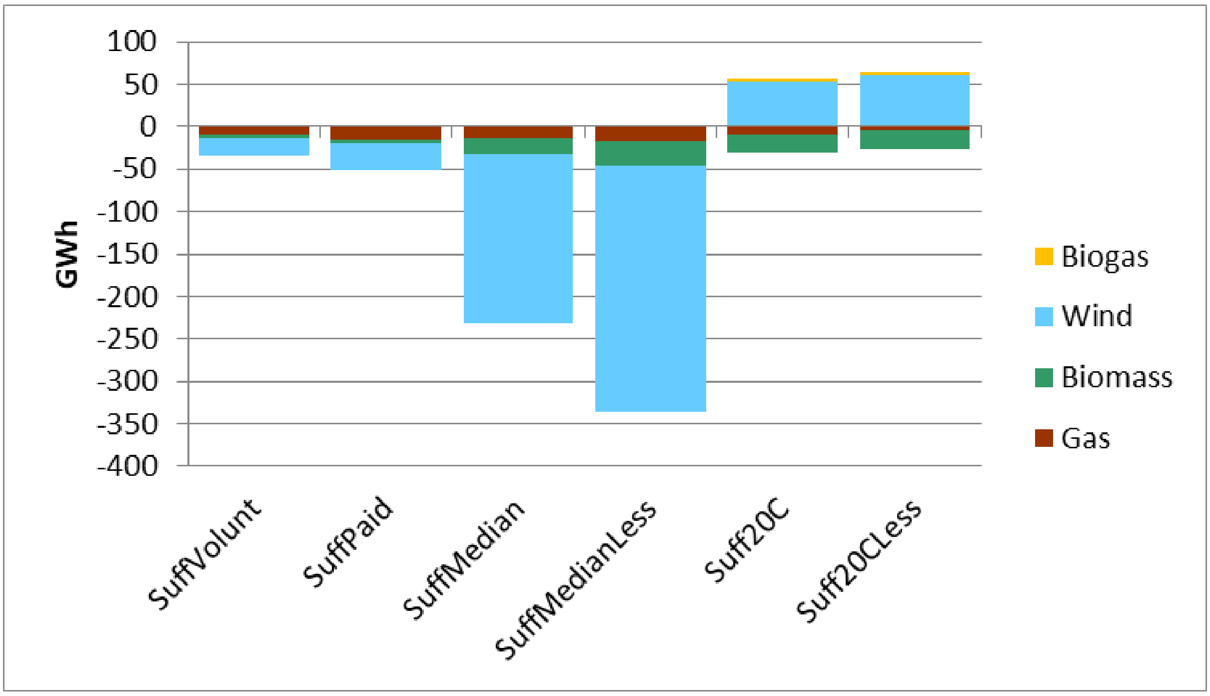

Fig. 4.6. Changes in the installed capacity of power plants in 2050 (compared to the Baseline scenario)

In the district heating sector, heat production in biomass and natural gas CHP decreases. Such changes in power and heat generation reduce primary energy consumption in the country by a maximum of 2000 GWh, as shown in Figure 4.7.

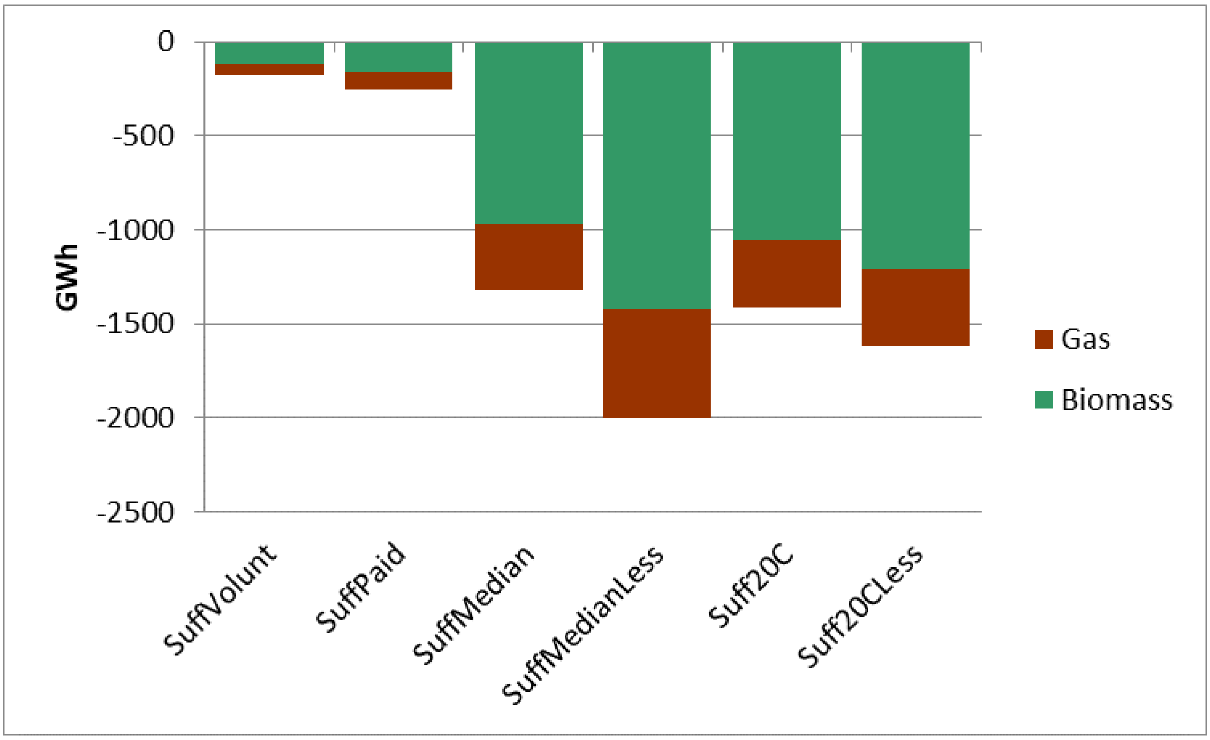

Fig. 4.7. Changes in the primary energy consumption in 2050 (compared to the Baseline scenario)

The most significant reduction of primary energy requirement in Latvia is expected to come from biomass. As with electricity production, the reduction of primary energy consumption is associated with the scale of assumed demand reductions. There is a rather strong correlation between final energy consumption and emission reductions. As shown in Figure 4.8, CO_2 emission reductions in Latvia tend to be lower than total final energy demand reductions in almost all the scenarios. This can be explained by the fact that in the baseline scenario, a large share of energies related to energy consumption is produced using RES. This provides clear evidence that if carbon emission reductions are considered the primary policy goal, energy sufficiency actions and policies should be focused on most polluting sectors and fuels.

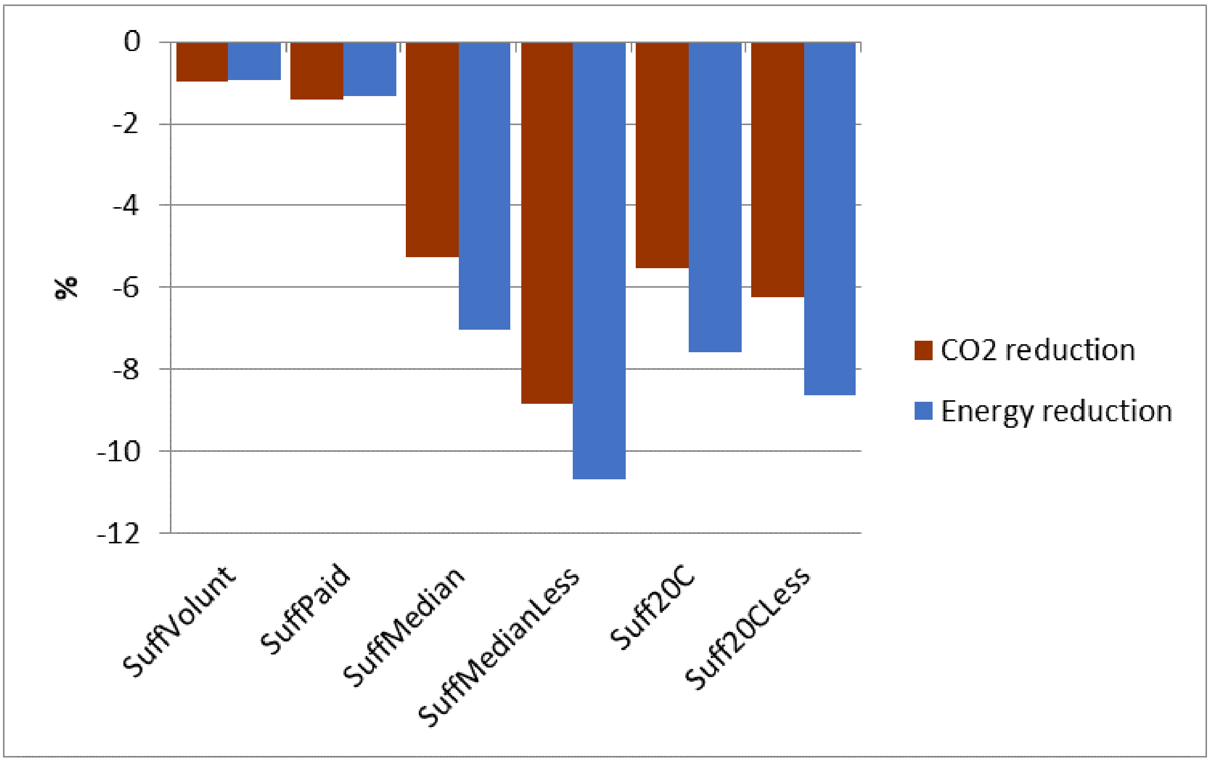

Fig. 4.8. Percentage changes in the primary energy consumption and CO_2 emissions in 2050 (compared to the Base scenario)

On the other hand, carbon emission reduction is just one of the benefits of a more sufficient lifestyle. Many co-benefits of sufficiency are also indirectly related to decarbonization, e.g. reduced demand for critical materials or biomass may enable decarbonization in other areas.