COMPREHENSIVE ASSESSMENT OF HIGH-EFFICIENCY COGENERATION AND EFFICIENT DISTRICT HEATING CAPACITIES IN THE REPUBLIC OF LITHUANIA

Source: Study "Prospective development analysis of Lithuania's energy sector in the light of EU strategic energy initiatives. Feasibility study of high-efficiency cogeneration development and district heating" conducted by the Lithuanian Energy Institute in 2014

I. GENERAL PROVISIONS

1. In Lithuania the district heating system is an integral part of the single energy sector, technically and energy flow-wise closely connected to the power grid, fuel supply (in particular, gas) and other systems. Cogeneration plants generating both heat and electricity are the strongest link between district heating and power grids. Cogeneration plants of various types meeting the same heating needs can also essentially cater for various electricity needs. The capacity of the district heating system must be rationally used with a view to achieving national energy policy objectives in the areas of energy security and energy efficiency.

Generating a large share of district heating energy in water boilers substantially reduces or eliminates the possibility of setting up and cost-effectively using cogeneration plants. In such a case the remaining option for generating electricity is less economical condensing power plants that waste a large share of primary energy through cooling installations. Diverse types of cogeneration plants also results in the district heating system directly affecting the security or reliability of electricity supply to national consumers often referred to as energy independence in respect of electrical energy. What matters here is that the ratio of electricity and heat generated by different types of cogeneration plants (running on different primary energy resources) widely varies. For example, cogeneration plants running on biofuel can generate about 0.3 units (0.3 MWh) of electricity per one unit (1 MWh) of heat. The ratio of electricity to heat generation in this case is ~0.3. The ratio of electricity and heat generated by modern gas-operated cogeneration plants can be up to one approximately. Thus, various cogeneration plants which meet the same thermal needs can generate substantially different volumes of electricity. This leads to the conclusion that lines of evolution of the district heating system are also inextricably linked to the national energy security policy.

2. The functioning of district heating systems is inseparable from fuel supply systems while fluctuating thermal needs require storing fuel. Thermal needs change substantially throughout the year. During the winter season the need is the highest while in summer it drops to the minimum. The coldest season is characterised by significant temperature fluctuations throughout the day leading to fluctuations in consumers' thermal needs. The latter are inevitably passed on to primary energy resources (fuel supply) links and at the same time affect the supply of these resources to other consumers. Some primary energy resources such as oil products, coal and to a certain extent biofuel are easy and inexpensive to store, which helps to compensate for fluctuations in demand. Natural gas storage however requires investment-intensive gas storage facilities. Where these are not available, gas supply contracts should provide for significant gas supply fluctuations causing the purchasing price of gas and the cost of heat and electricity generated to increase for final consumers, or else heat and electricity generation technology should run on another fuel making it possible to level out uneven consumption of natural gas.

3. In some cases natural gas and electricity may compete with district heating. District heating consumers may choose to disconnect

from the district heating system and install individual heat generation sources running on natural gas or electricity as a primary energy source.

4. The district heating system has connections even to the forestry and farming sectors, domestic and municipal waste management and other sectors, given that primary energy sources in the district heating system may be products or waste of those other sectors (such as wood and wood waste, energy plants, straw and other agricultural waste, domestic and municipal waste). Apart from direct and obvious technical and energy connections, connections between the district heating system and other energy sector systems or national industries are expressed indirectly, through the country's financial capacity to expand, modernise and operate current and cutting-edge technologies and infrastructures, through foreign trade balance, nature protection, etc. For instance, a country choosing to allocate greater financial resources to the development of one or other industry or energy system inevitably cuts the available funding that could be allocated to other industries or energy systems. Greater consumption of local and renewable primary energy resources improves the national foreign trade balance as it reduces the need to import fossil fuels but at the same time creates some negative consequences as more is spent on imported equipment that is not manufactured at the national level. Changes in the primary energy balance within the district heating system inevitably affect the environmental situation and, given the general international commitments of the country in the area of environment protection, inevitably alter patterns in other energy systems or industries.

5. The district heating system's connections with the final consumers of its product, i.e. households, the service industry and the manufacturing industry, are of great importance. Energy efficiency measures installed at the level of the final consumer not only reduce the load on the district heating system but also make it possible to reorganise the supply infrastructure (e.g. by restoring the capacity at the end of the life cycle) and to reduce the need for investment and heat transmission losses.

6. The above considerations show that the prospective evolution and functioning of the district heating system must be analysed in close connection with the evolution and functioning matters of other energy systems, environmental aspects, national energy policy provisions, etc. Such an analysis should also cover all links including the extraction, treatment and supply of primary energy resources as well as heat (and electricity) generation, supply and consumption. Given the conditions in Lithuania, great renovation needs of residential buildings and works ongoing in this area, the consumption link is of particular importance.

7. Programmes for the development and functioning of the national energy sector or individual systems therein are to be drafted in accordance with and on the basis of the common provisions of the European Union energy policy. The main provisions of the European Union energy policy rather closely linked with the district heating system are as follows:

a) Much attention is paid to the development of renewable energy resources for generating electricity and/or heat. The objective is to ensure that in 2050 a major proportion of energy generated comes from renewable energy resources.

b) Focus on consumption efficiency.

c) Priority is given to decentralised and small-scale production. It should be noted that the emphasis is put on the development of micro generation and/or accumulation by consumers.

d) Ensuring competition and development.

8. The assessment of the evolution and functioning of the district heating system is drawn up in accordance with the aforesaid provisions, a comprehensive analysis of the evolution and functioning of electricity and district heating and fuel supply systems carried out on the basis of modern mathematical models and taking into account behavioural patterns of final consumers in the area of energy efficiency improvement, requirements and national commitments in the field of environment protection and energy security aspects.

II. ANALYSIS OF THE CURRENT SITUATION AND DEVELOPMENT POTENTIAL. CONCLUSIONS AND RECOMMENDATIONS

II-1. Strengths, weaknesses, opportunities and threats

9. Strengths of district heating systems:

9.1. District heating accounts for an important part of the heat supply balance in Lithuania. Large areas in all cities in the country are covered by well-developed district heating (DH) systems.

9.2. The heat supply market is relatively stable and consistent while individual urban districts are characterised by highly concentrated heat consumption.

9.3. All heat supply links employ very experienced professionals ensuring safe operation of the systems and capable of implementing large-scale investment projects. Within the last three years the DH sector has managed to balance financial flows, generate profit and increase investments, which creates more possibilities for attracting financial resources for future investments.

9.4. The country enjoys a well-developed road infrastructure, which bodes well for the aspirations to increase the share of local and renewable resources in heat generation.

9.5. The biggest production sources are often in convenient locations next to main roads and streets, to the right side of dominating winds and with powerful inlets of natural gas, water and electricity.

9.6. DH systems often have sufficient standby capacities, communications connections and sufficient areas suitable for building new capacities running on biofuel.

9.7. Universities and colleges in the country train energy professionals, there are specialised research institutes and quite a few consultancy companies active in this area.

9.8. The country also enjoys a highly socially-oriented programme with appropriations to support the upgrading of multi-apartment buildings: JESSICA.

10. Weaknesses of district heating systems:

10.1. More than 80% of multi-apartment buildings which are the main customers of the DH system consume thermal energy highly inefficiently. There is an urgent need for large-scale capital makeovers of multi-apartment and public buildings and for the installation of energy-saving measures (upgrade and ensure heat insulation).

10.2. So far the majority of consumers do not have the technical possibilities for regulating their heat consumption on an individual basis.

10.3. More than half of multi-apartment buildings still do not have condominium management associations, which means that co-owners of multi-apartment buildings cannot make their own decisions on the rational management and upgrading of their joint properties.

10.4. Some residents of multi-apartment buildings are disadvantaged persons, which means that it is difficult for them to embark on an upgrade project and to contribute to co-financing efforts of the other owners.

10.5. The current social welfare system does not encourage disadvantaged persons to be involved in decision-making processes on the modernisation of multi-apartment buildings.

10.6. Municipalities are not ready to provide professional counselling to co-owners of multi-apartment buildings on matters of founding condominium management associations and upgrading buildings and to coordinate the renovation process of multi-apartment buildings block by block.

10.7. Consumer debts for heat supply are high and are not decreasing. Urban municipalities are often among debtors (mainly for heat supplied to schools and pre-school establishments). A municipality is also the majority shareholder of a heat supply undertaking, which is why any conflict that may arise is not always resolved in best interests of heat consumers.

10.8. Urban DH networks are being renovated too slowly and have capacity excess, especially in industrial parts of cities where the potential is underused, which implies additional heat transmission losses. New consumers (shopping centres, sports arenas, etc.) emerge in new locations and need new pipelines.

10.9. As little as up to 2% of pipelines are renovated annually, event with the help of EU structural assistance while the minimal required technical recovery level is at least 3.5%.

10.10. The prevailing fuel within the fuel structure is still natural gas.

10.11. Urban DH systems have great excessive generation capacities whose maintenance leads to higher heat prices for final consumers.

10.12. In accordance with the current heat pricing methodology applicable in Lithuania, heat supply undertakings are not too interested in investing in necessary upgrades of urban DH systems.

10.13. The position of some municipalities in respect of the disconnection of individual apartments from the common heating system of the building and of individual buildings from urban DH systems by replacing district heating with the polluting option of ensuring heating with individual boilers is ambiguous and inconsistent.

11. Opportunities of district heating systems:

11.1. As Lithuanian cities have DH systems spread over large areas, they enjoy great opportunities for making good use of:

- local and renewable energy resources,
- technological benefits of cogeneration plants,
- heat excess from industries,
- more polluting but cheaper fuels (sorted municipal waste, peat, fuel oil, woodchips, etc.),
- the efficiently managed combustion process and smoke treatment, thus causing less environmental pollution,
- the credibility of the large system where several producers work in parallel and can ensure standby capacities in the case of accidents or repairs,
- the added value created by top-class professionals (as compared with individual fuel stocking, equipment maintenance, ash removal, etc.).

11.2. By modernising its district heating systems Lithuania can substantially improve the implementation of its international commitments with a view to achieving the objective of generating 23% of the total final energy consumption from renewable resources by 2020 at the same time improving energy efficiency.

11.3. Large cities in Lithuania making use of their DH systems can generate energy using sorted municipal waste and at the same time tackle environmental problems.

11.4. Broader use of resources for generating thermal power might reduce heat production costs, which means a respective possible drop in heat prices for final consumers.

11.5. The block-by-block modernisation of multi-apartment buildings may not only reduce final heat costs but also essentially improve the living conditions for many urban dwellers.

11.6. A consistent and well-planned upgrade of DH pipelines block by block is carried out in parallel with the modernisation of multi-apartment buildings, which allows redesigning the mains in those blocks, thus reducing energy losses in DH pipelines even more, diminishing pollution and saving funds for investments and maintenance.

11.7. Growing fossil energy prices on global markets result in the rapid development of new technologies mainly running on renewable energy resources. Revamping urban heat supply systems creates real opportunities for implementing new efficient technologies.

11.8. With EU structural assistance used efficiently, it is possible to upgrade urban heat supply infrastructures faster.

12. Threats for district heating systems:

12.1. More than 80% of buildings in cities are energy-inefficient while the average age of multi-apartment buildings has gone over the threshold of 40 years, which is why they are in need of urgent modernisation. If the modernisation process does not reach adequate levels, buildings will become critically depreciated rendering their renovation technically and economically no longer feasible. This would prevent any improvement in heat efficiency.

12.2. Given low energy efficiency in buildings, energy bills are high creating social tension, adversely affecting the national and municipal budgets because of growing payments for imported fuel and expenditure on social welfare for eligible persons. If heat costs in buildings are not substantially reduced, it will be impossible to cut energy bills, which will lead to growing consumer dissatisfaction and debt, increasing costs of compensations to disadvantaged persons and worsening trade balance.

12.3. If multi-apartment buildings are renovated with inadequate speed, the attractiveness of multi-apartment districts as residential locations will drop, which will lead to smaller numbers of young families earning sufficient income and capable of investing in residential improvements in such blocks. This may result in deeper social exclusion and greater social tension throughout entire districts in cities.

12.4. No systematic block-by-block modernisation of multi-apartment buildings will translate into zero possibility of rationally redesigning and renovating DH networks block by block. This results in great losses in heat transmission pipelines and higher heat prices for final consumers.

12.5. A part of building modernisation is the modernisation of heating systems in those buildings enabling each consumer to adjust their heat consumption individually. Without a comprehensive upgrade of buildings, redesigning heating systems is expensive and inefficient. No possibility to adjust individual heat consumption results in growing consumer dissatisfaction and prompts extreme actions harmful to buildings and municipal heat supply systems where heating systems of individual apartments or the entire buildings are to be disconnected from district heating and individual heating systems inefficient in terms of heat supply on an urban scale are to be installed. This compromises engineering systems of buildings and cities without alleviating and even worsening the situation of all heat consumers and increasing overall heat supply costs in the city and environmental pollution.

12.6. The interest and possibilities of city municipalities to invest in municipal heat supply systems or their individual sections are scarce. With decreasing EU assistance, the already inadequate investments in the renovation of heat supply systems may be depleted even more.

12.7. Given higher energy demand on global markets, fossil fuel prices remain high and stable. As the fuel component accounts for about two thirds of the current heat price, changes in fuel prices translate into changes in heat prices for final consumers.

12.8. The current procedure for encouraging the development of cogeneration plants does not make investment in the development of cogeneration plants more attractive, which is why development plans for the DH sector are based on the development of small boiler facilities and technological benefits of cogeneration plants may be left unused.

II-2. State of play

<u>Generation link</u>

13. The state-of-play description of heating facilities is based on the information supplied by Statistics Lithuania in official annual fuel and energy balance sheets published and regularly updated in the database of Statistics Lithuania as well as on data of the database of the Lithuanian District Heating Association and a survey of heat supply undertakings and data of other publications. District heating facilities are one of the crucial components of the country's energy sector in providing final consumers with heat for heating their residences, getting hot water and catering for technical needs of undertakings. In accordance with the data of the general population and housing census of 2011 published by Statistics Lithuania, 52.6% of all conventional dwellings (in one- or two-apartment houses and apartments in multi-apartment buildings) and 75.6% of dwellings in urban areas are heated by district heating systems. In 2012, final consumers received 8556 GWh of heat including 5670 GWh (66.3%) supplied to residents, 2321 GWh (27.1%) consumed by commercial and service industries and 565 GWh (6.6%) consumed by manufacturing, construction and agriculture sectors.

14. District heating is offered by 32 heat supply undertakings efficiently coordinated by the Lithuanian District Heating Association contributing to the planning of strategic initiatives for the development of heating facilities, the renovation of undertakings and heat supply networks, broader use of renewable energy resources for generating electricity and heat, the improvement of legislation and other initiatives. In 2012 the undertakings belonging to the Association supplied 7522 GWh of heat to final consumers including heat generated by own sources and purchased from independent producers, and their share in the total balance of heat supplied by district heating networks accounts for 87.9%. The market is dominated by the largest companies supplying heat to the cities in Lithuania: in 2012 UAB Vilniaus energija supplied about 28.2% of total heat supplied to final consumers throughout the country, AB Kauno energija – 14.6%, AB Klaipėdos energija – 9.7%, a regional company AB Panevėžio energija – 7.7%, and AB Šiaulių energija – 4.7%. An important role is played by UAB Litesko whose branches in 2012 generated and supplied to final consumers 683 GWh, or 8.0% of heat consumed by industries on the national level.

15. In smaller towns of the country an important role in providing final consumers with heat is played by power plants and boiler facilities of industrial enterprises and other heat producers for whom heat generation is not the main activity. In 2012, 12.1% of heat was supplied to final consumers from those sources. Those sources include power plants and boiler facilities of industrial enterprises which generated 560 GWh of electricity and 396 GWh of heat. The fuel balance of those enterprises consists of 53.2% of natural gas, 31.2% of renewable energy resources and 15.6% of oil products.

16. In accordance with the data of Statistics Lithuania, heat generation sources are power plants, boiler facilities, installations producing heat from chemical process energy and geothermal installations. Changes in the role of these sources are shown in Fig. 1. For instance, in 2012, all sources of energy production generated 12904.2 GWh of heat including 5433.5 GWh (42.1%) produced by power plants, 4633.1 GWh (35.9%) by boiler facilities, 93.9 GWh (0.7%) by UAB Geoterma and 2743.7 GWh (21.3%) from chemical process energy in fertiliser production. However a lion's share of heat generated by chemical processes (in 2012 – 71%) is consumed directly for technological needs of enterprises while 25 to 30% is used to generate electricity. The development of district heating is directly affected only by as much as 100 GWh, or 3 to 4% of that residual heat supplied to consumers in Kėdainiai Town. A similar role is attributable to UAB Geoterma which supplies all energy produced to the heating networks of Klaipėda City. In 2012, the total amount of heat from all sources was 10141 GWh including 8556 GWh supplied to final consumers.

Fig. 1 clearly shows a trend towards declining transmission losses in heating networks. The modernisation of heating networks and the renovation of pipelines carried out by heat supply undertakings have made it possible to reduce heat transmission losses from 2813 GWh in 2000 to 1585 GWh in 2012, or from 25.1% to 15.6% of all heat supplied to the network.

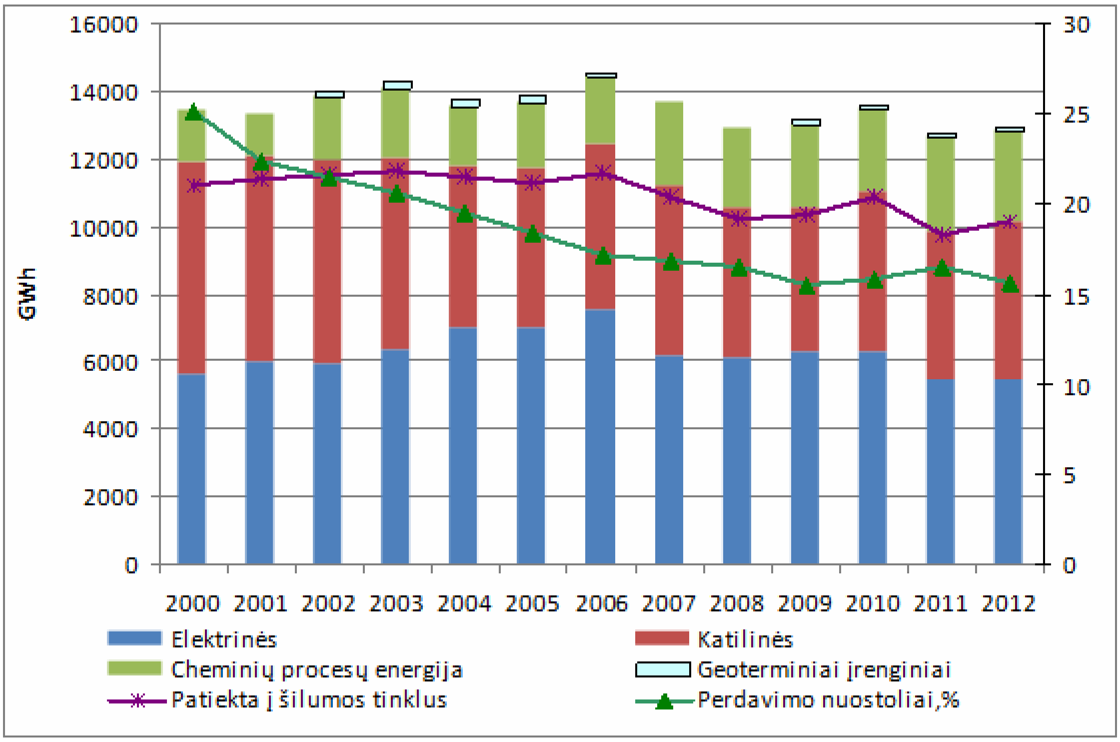


Fig. 1. Heat generation and supply to networks in 2012

Elektrinės	Power plants
Cheminių procesų energija	Energy of chemical processes
Patiekta į šilumos tinklus	Supplied to heating networks
Katilinės	Boiler facilities
Geoterminiai įrenginiai	Geothermal installations

Perdavimo nuostoliai, %	Transmission losses, %

17. An important aspect of the modernisation of district heating sources is – changes in the balance of fuel used for generating heat with gradual increases of the volume of wood fuel and waste used for generating electricity and heat. In 2012, power plants and boiler facilities generated 2807 GWh of heat from renewable energy resources and the share of these resources in the fuel balance was 29.5%. The method of combustion of fossil fuel produced 2.6 times more heat, i.e. 7260 GWh. To generate heat, power plants and boiler facilities used 617 000 toe of natural gas, and its share in the fuel balance accounted for 61.3%. The share of oil products used for generating heat more than halved during the last decade. In 2012, the quantity used was 86 000 toe while the fuel balance share dropped to 8.6%. The role of coal and peat is very humble, with consumption being just about 5 500 toe. Any future changes in fuel used for generating heat will be dependent on how fast natural gas is replaced by biofuel and on volumes in district heating systems in Vilnius and Kaunas.

18. Analysis of the state of play in selected cities. An overview of the state of play in the heating sector and development trends between 2011 and 2013 in the largest Lithuanian cities (Vilnius, Kaunas, Klaipėda, Šiauliai, Panevėžys, Alytus, Marijampolė, Kėdainiai, Mažeikiai, Utena and Elektrėnai) is based on information on heating sector indicators gathered with the help of specially designed tables and through a survey of heat supply undertakings supplying heat to district heating systems of these cities. Below is information only about indicators of the main district heating networks of the aforementioned cities, i.e. it does not include networks and sources owned by the same enterprise but located in other towns or districts and regional networks within the same city that are not connected with the main integrated district heating network in the said cities. The installed capacity of heat sources in these cities is about 68% of the total installed capacity of all heating installations in Lithuania, which means that it offers a good illustration of actual developments and trends in the Lithuanian heating sector [1, 2].

19. An analysis of some developments in the installed capacity of heat production installations (boilers and cogeneration units) in Lithuania since 2011 shows a clear trend for the expansion of heat production capacity using local biofuel and phasing out imported gas. Moreover, new cogeneration plants running on biofuel are being installed and electricity production from this fuel is being developed. In 2012, the cities in question were equipped with new biofuel-operated heat production facilities of the capacity of 94 MW including boilers of 44MW and cogeneration plants of 49.8 MW (Table 1). Biofuel-operated cogeneration plants worth mentioning have been installed in Šiauliai (27 MW), Alytus (13.7 MW) and Utena (8.7 MW) as well as some biofuel-operated boilers in Kaunas (20 MW), Panevėžys (16 MW) and Utena (8 MW). New economisers of the capacity of 32 MW were also installed in new and existing boiler facilities and power plants. Within 9 months of 2013 another 68 MW of new capacity was installed in the form of biofuel-operated heat production facilities and 24 MW of economisers. 50 MW included in that figure account for the heating capacity of the cogeneration plant built in 2013 by Fortum Klaipėda and the 13.6 MW capacity of its economiser. The main fuel for that plant is municipal waste but biofuel can also be incinerated. Kaunas biofuel boiler facilities were also expanded in 2013 (18 MW). According to contracts, the plan was by the end of 2013 to install gas-operated boilers of 18 MW and 15 MW in Pergalės and Šilko boiler facilities in Kaunas but there were some issues with coordinating their commissioning and it was delayed until early 2014. Between 2011 and 2013 no more new fossil-based combustion plants were installed in other cities listed.

20. An analysis of plans of heat supply undertakings for the near future shows that the trend for developing biofuel-operated installations will certainly remain (Table 1). If plans of enterprises are implemented, 2014

m. should bring at least 106 MW more, and 2015 – 70 MW as the capacity of biofuel-operated installations, with new economisers of the respective capacities of 35 and 22 MW. It is worth mentioning new biofuel boiler facilities planned in Vilnius (20 MW), Kaunas (48 MW), Šiauliai (20 MW), Klaipėda (16 MW) and other cities [3]. There is also a 40 MW biofuel-based boiler facility in Elektrėnai that will cater for the heating needs of the city, UAB
Kietaviškių gausa and the plant Lietuvos elektrinė ensuring standby capacities.

Table 1. Data of installed and planned capacities between 2011 and 2015

City/municipality DH	*Existing/new installed capacity*	*Installed capacities of heating installations, MW*			*Additional capacity planned and supported, MW*	
		2011	*2012*	*2013*	*2014*	*2015*
11 selected cities	**Installed capacity, total:**	**5955**	**6085**	**6167**	**216.9**	**174.4**
	including new biofuel-based installations	0	94	162	123.5	144
	including new economisers	0	32	57	12.7	30.4
	Maximum/minimum load in 2011	2153/201				
Vilnius	**Installed capacity, total:**	**2170**	**2170**	**2170**	**31.2**	**0.0**
	including new biofuel-based installations				28.0	
	including new economisers				3.2	
	Maximum/minimum load in 2011	857/70				
Kaunas	**Installed capacity, total:**	**1411**	**1443**	**1461**	**0.0**	**83.2**
	including new biofuel-based installations		20	38		66.0
	including new economisers		8	8		17.2
	Maximum/minimum load in 2011	396/48				
Klaipėda	**Installed capacity, total:**	**776**	**776**	**841**	**17.5**	**31.8**
	including new biofuel-based installations			50	17.5	28
	including new economisers			14.6		3.8
	Maximum/minimum load in 2011	277/26				
Šiauliai	**Installed capacity, total:**	**220**	**257**	**257**	**0.0**	**25.0**
	including new biofuel-based installations		27.4	27.4		20.0
	including new economisers		10.2	20.0		5.0
	Maximum/minimum load in 2011	137/14				
Panevėžys	**Installed capacity, total:**	**287**	**307**	**307**	**0.0**	**12.0**
	including new biofuel-based installations		16	16		12.0
	including new economisers		4	4		
	Maximum/minimum load in 2011	136/7				
Alytus	**Installed capacity, total:**	**235**	**254**	**254**	**38.0**	**0.0**
	including new biofuel-based installations		13.7	13.7	38	
	including new economisers		4.9	4.9		
	Maximum/minimum load in 2011	82/8				
Marijampolė	**Installed capacity, total:**	**151**	**151**	**151**	**31.5**	**12.4**
	including new biofuel-based installations					10.0
	including new economisers				1.5	2.4
	Maximum/minimum load in 2011	67/11*				
Kėdainiai	**Installed capacity, total:**	**68**	**68**	**68**	**0.0**	**0.0**
	including new biofuel-based installations					
	including new economisers					
	Maximum/minimum load in 2011	31/2.4				
Mažeikiai	**Installed capacity, total:**	**82**	**82**	**82**	**0.0**	**0.0**
	including new biofuel-based installations					
	including new economisers					
	Maximum/minimum load in 2011	45/4				
Utena	**Installed capacity, total:**	**95**	**116**	**116**	**0.0**	**10.0**
	including new biofuel-based installations		16.7	16.7		8.0
	including new economisers		5.1	5.1		2.0
	Maximum/minimum load in 2011	46/5				
	Installed capacity, total:	**460**	**460**	**460**	**98.7**	**0.0**

Elektrėnai	including new biofuel-based installations				40.0	
	including new economisers				8.0	
	Maximum/minimum load in 2011		79/6			

*With the load of a sugar factory. ***Sources:*** Survey data, LDHA reports [1, 2] and EU support website [3].

Table 2 contains data on changes in fuel consumption for producing energy between 2011 and 2013 in heating sources connected to the main district heating networks of the 11 cities in question. The available data does not allow accurately separating fuel consumption by cogeneration plants for producing electricity and heat, which is why the data given in the table also cover fuel consumption for generating electricity at cogeneration plants supplying heat to district heating networks. The data for 2013 cover fuel consumption up to October.

Table 2. Data on changes in fuel consumption for producing energy between 2011 and 2013

City	***Fuel***	***Fuel consumption, thousand toe***			***Fuel consumption, %***		
		2011	***2012***	***2013 09***	***2011***	***2012***	***2013 09***
11 selected cities	**Fuel consumption, total:**	**769**	**745**	**526**	**100**	**100**	**100**
	including natural gas	669	604	383	86.9	81.0	72.8
	including biofuel	86	122	99	11.2	16.3	18.8
Vilnius	**Fuel consumption, total:**	**327**	**321**	**217**	**100**	**100**	**100**
	including natural gas	261	254	168	79.9	78.9	77.3
	including biofuel	43.6	44.3	35.3	13.3	13.8	16.3
Kaunas	**Fuel consumption, total:**	**190**	**180**	**115**	**100**	**100**	**100**
	including natural gas	190	177	101	100.0	97.9	87.8
	including biofuel	0.0	2.9	14.0	0.0	1.6	12.2
Klaipėda	**Fuel consumption, total:**	**68.9**	**70.7**	**72.2**	**100**	**100**	**100**
	including natural gas	60.8	61.2	44.0	88.2	86.5	60.9
	including biofuel	6.6	7.5	14.9	9.6	10.6	20.7
Šiauliai	**Fuel consumption, total:**	**39.1**	**37.5**	**28.7**	**100**	**100**	**100**
	including natural gas	39.1	27.9	11.5	100.0	74.6	40.0
	including biofuel	9.3	16.1	0.0	23.7	43.0	0.0
Panevėžys	**Fuel consumption, total:**	**63.3**	**52.9**	**47.7**	**100**	**100**	**100**
	including natural gas	63.3	42.0	36.2	99.9	79.4	75.8
	including biofuel	0.0	10.7	11.6	0.1	20.2	24.2
Alytus	**Fuel consumption, total:**	**26.3**	**26.2**	**17.7**	**100**	**100**	**100**
	including natural gas	26.3	17.2	8.0	100.0	65.7	45.0
	including biofuel	0.0	8.9	9.7	0.0	34.1	55.0
Marijampolė	**Fuel consumption, total:**	**25.6**	**25.9**	**17.8**	**100**	**100**	**100**
	including natural gas	17.1	17.2	11.9	66.7	66.3	66.7
	including biofuel	8.5	8.7	5.9	33.3	33.7	33.3
Kėdainiai	**Fuel consumption, total:**	**1.62**	**1.83**	**0.95**	**100**	**100**	**100**
	including natural gas	1.62	1.83	0.95	100.0	100.0	100.0
	including biofuel	0.00	0.00	0.00	0.0	0.0	0.0
Mažeikiai	**Fuel consumption, total:**	**14.27**	**14.52**	**9.18**	**100**	**100**	**100**
	including natural gas	2.49	2.417	1.883	17.5	16.6	20.5
	including biofuel	11.4	12.1	7.3	79.9	83.4	79.5
Utena	**Fuel consumption, total:**	**13.43**	**14.08**		**100**	**100**	
	including natural gas	6.78	3.75		50.5	26.7	
	including biofuel	6.64	10.24		49.4	72.7	
Elektrėnai	**Fuel consumption, total:**						
	including natural gas						
	including biofuel						

Sources: Survey data, LDHA reports [1, 2].

21. As is apparent from the data provided, natural gas consumption is decreasing every year but it still remains the main fuel for generating energy in the cities in question. In 2011, heat and energy were generated with 669 000 toe while in 2012 – 604 000 toe, with their respective

shares accounting for 86.9% and 81% of total fuel consumption. Another obvious trend is that biofuel consumption is growing, i.e. in 2011 biofuel consumption was 86 000 toe, and in 2012 it was 122 000 toe. In 2011 biofuel accounted for 11.2% of fuel consumed for generating heat and electricity. In 2012 its share increased to 16.3% while during the first three quarters of 2013 it went up to 18.8% of total fuel consumption. In the future biofuel consumption will possibly grow as well when the biofuel-based heat production units are used to the full and given that the capacity of biofuel boiler facilities and cogeneration plants is to grow in the near future too.

2 Table 3 presents data on changes in heat production between 2011 and 2013 at heating sources connected to the main district heating networks in the eleven cities in question. Data for 2013 also cover heat production up to October. The data presented show that in 2011 and 2012 the volume of heat generation in the cities in question remained almost unchanged and amounted to 6855 to 6874 GWh. About half of heat (46 to 52%) was generated by cogeneration units of power plants while the rest was produced by boiler facilities and electric water heating boilers. The state of play with heat production in different cities certainly is very different depending on the available infrastructure. The available data only show approximately how much heat is produced using biofuel because there are no data on heat production volumes separated by boiler facilities or power plant units. According to experts, in 2011 the amount of heat energy produced from biofuel was 670 GWh, in 2012 – 990 GWh, and within the nine months of 2013 – 1000 GWh. Based on those data, the preliminary estimate is that the volume of heat generated from biofuel increased by about 10% in 2011 and about 23% in 2013.

Table 3. Data on changes in heat generation between 2011 and 2013

City	*Generati on*	*Heat generation, GWh*			*Heat generation, %*		
		2011	*2012*	*2013 09*	*2011*	*2012*	*2013 09*
11 selected cities	**Heat generation, total:**	**6855**	**6874**	**4388**	**100**	**100**	**100**
	including by power plants	3562	3170	2105	52.0	46.1	48.0
	including by boiler facilities	3293	3704	2283	48.0	53.9	52.0
	including with biofuel	671	988	1003	9.8	14.4	22.9
Vilnius	**Heat generation, total:**	**2712**	**2789**	**1852**	**100**	**100**	**100**
	including by power plants	1824	1621	1094	67.3	58.1	59.0
	including by boiler facilities	887.4	1168.1	758.6	32.7	41.9	41.0
	including with biofuel	354.9	363.2	278.9	13.1	13.0	15.1
Kaunas	**Heat generation, total:**	**1420**	**1355**	**895**	**100**	**100**	**100**
	including by power plants	940	775	386	66.2	57.2	43.2
	including by boiler facilities	479.2	579.8	508.8	33.8	42.8	56.8
	including with biofuel		14.4	128.0	0.0	1.1	14.3
Klaipėda	**Heat generation, total:**	**910.1**	**914.1**	**481.7**	**100**	**100**	**100**
	including by power plants	95.1	96.8	50.2	10.4	10.6	10.4
	including by boiler facilities	815.0	817.2	431.5	89.6	89.4	89.6
	including with biofuel	30.0	28.8	128.5	3.3	3.1	26.7
Šiauliai	**Heat generation, total:**	**429.0**	**394.4**	**245.6**	**100**	**100**	**100**
	including by power plants	0.0	63.9	105.5	0.0	16.2	42.9
	including by boiler facilities	429.0	330.5	140.2	100.0	83.8	57.1
	including with biofuel		63.2	104.8	0.0	16.0	42.7
Panevėžys	**Heat generation, total:**	**407.2**	**421.8**	**421.6**	**100**	**100**	**100**
	including by power plants	296.9	210.9	203.9	72.9	50.0	48.4
	including by boiler facilities	110.3	210.9	217.8	27.1	50.0	51.6
	including with biofuel	0.2	104.3	138.0	0.1	24.7	32.7
Alytus	**Heat generation, total:**	**231.3**	**240.7**	**161.4**	**100**	**100**	**100**

City	Generati on	Heat generation, GWh			Heat generation, %		
		2011	2012	2013 09	2011	2012	2013 09
	including by power plants	155.3	131.1	106.8	67.2	54.5	66.2
	including by boiler facilities	76.0	109.6	54.6	32.8	45.5	33.8
	including with biofuel	0.0	73.9	81.5	0.0	30.7	50.5
Marijampolė	**Heat generation, total:**	**181.1**	**180.3**	**120.3**	**100**	**100**	**100**
	including by power plants	98.3	98.3	63.8	54.3	54.5	53.0
	including by boiler facilities	82.8	82.0	56.5	45.7	45.5	47.0
	including with biofuel	88.6	90.7	59.8	48.9	50.3	49.7
Kėdainiai	**Heat generation, total:**	**109.67**	**112.10**	**10.10**	**100**	**100**	**100**
	including by power plants				0.0	0.0	0.0
	including by boiler facilities	109.67	112.10	10.10	100.0	100.0	100.0
	including with biofuel				0.0	0.0	0.0
Mažeikiai	**Heat generation, total:**	**154.00**	**162.00**	**105.00**	**100**	**100**	**100**
	including by power plants				0.0	0.0	0.0
	including by boiler facilities	154	162	105	100.0	100.0	100.0
	including with biofuel	123.1	135.0	83.5	79.9	83.4	79.5
Utena	**Heat generation, total:**	**151.10**	**157.80**		**100**	**100**	
	including by power plants	1.60	26.50		1.1	16.8	
	including by boiler facilities	149.50	131.30		98.9	83.2	
	including with biofuel	74.68	114.73		49.4	72.7	
Elektrėnai	**Heat generation, total:**	**150**	**147**	**95**	**100**	**100**	**100**
	including by power plants	149.739	147.373	94.6949	100	100	100
	including by boiler facilities			0	0	0	0
	including with biofuel	0	0	0	0.0	0.0	0.0

Sources: Survey data, LDHA reports [1, 2].

Transmission and consumption links

22. The transportation link (pipelines) of the district heating system and final consumers are as important a system element as heat generation facilities. Focusing attention and investments solely on the renovation of generation equipment without paying sufficient attention to the heat transportation link or consumption efficiency within the final consumption sector, it is impossible to ensure rational, competitive, long-term and sustainable heat supply.

23. District heating networks in Lithuania are well developed but due to the lack of rational planning and a long period of constant investment shortage they cannot adequately respond to consumer needs. The lack of investment not only hinders the implementation of new, more efficient technologies but also fails to ensure the minimal pace of required equipment upgrading guaranteeing that such equipment is upgraded at the end of its technical life cycle. This results in growing routine and emergency repairs costs at the same time endangering energy supply security and reliability. Emergency response usually involves greater expenditure than sufficiently consistent renovation of facilities. Urban DH networks are being renovated too slowly and have capacity excess, especially in industrial parts of cities where the potential is underused, which implies additional heat transmission losses. As little as up to 2% of pipelines are renovated annually, event with the help of EU structural assistance while the minimal required technical recovery level is at least 3.5%. New consumers (shopping centres, sports arenas, etc.) emerge in new locations and need new pipelines.

24. More than 80% of buildings in cities are energy-inefficient while the average age of multi-apartment buildings has gone over the threshold of 40 years (where the technical threshold for the use of buildings between capital repairs is 25 to 30 years), which is why they are in urgent need of modernisation. If the modernisation process does not reach adequate levels, buildings will

become critically depreciated rendering their renovation technically and economically no longer feasible. This would prevent any improvement in heat efficiency. Given low energy efficiency in buildings, energy bills are high creating social tension, adversely affecting the national and municipal budgets because of growing payments for imported fuel and expenditure on social welfare for eligible persons. If heat costs in non-renovated buildings are not substantially reduced, it will be impossible to cut energy bills, which will lead to growing consumer dissatisfaction and debt, increasing costs of compensations to disadvantaged persons and worsening trade balance.

25. More than 80% of the country's multi-apartment buildings (the dominant consumer segment in DH systems) require capital repairs now involving radically improving efficiency of heat consumption for heating purposes. Lithuania has about 34 000 multi-apartment buildings (Renovation of multi-apartment buildings, 2013) that are in need of modernisation. With a view to ensuring that the average age of multi-apartment buildings is reduced at least to 30 years in 2020 (i.e. the average age of multi-apartment buildings does not exceed the threshold for the use of buildings before they undergo major maintenance), there is a need to modernise 6.7% of buildings annually, i.e. 1 876 multi-apartment buildings built before 1993 per year. As this concerns not only aspirations to improve heat consumption efficiency but also the technical condition of buildings and security of residents, the level of modernisation of multi-apartment and public buildings in Lithuania must reach the minimal adequate annual volumes and remain stable for at least 20 years. With the modernisation of multi-apartment buildings taking on such a pace, the average actual heat consumption for heating premises in 2020 should drop to 92 kWh/m^2 per year.

II-3. Trends in heat consumption changes and forecasts of demand

26. During the preparatory stages for the EU integration and becoming a Member State in 2004, the Lithuanian economy was growing rapidly: in spite of a significant recession the national GDP grew on average by 4.45% per year. Such rapid economic growth also led to some obvious increase (Fig. 2) in final energy and its components consumed by industries, and between 2000 and 2012 final energy consumption was growing at the average pace of 2.1% per year. Volumes of fuel consumed in the transport sector and electricity consumed by industries for various needs were growing the fastest: 3.2% and 3.1% per year respectively. Somewhat slower (1.5% per year on average) growth was demonstrated by fuel directly consumed by final consumer facilities in other industries. District heat supply is an integral component of final energy but the growth rates of heat consumption were only 0.8% per year. The share of heat in the final energy structure thus dropped from 22.0% in 2000 to 15.7% in 2012.

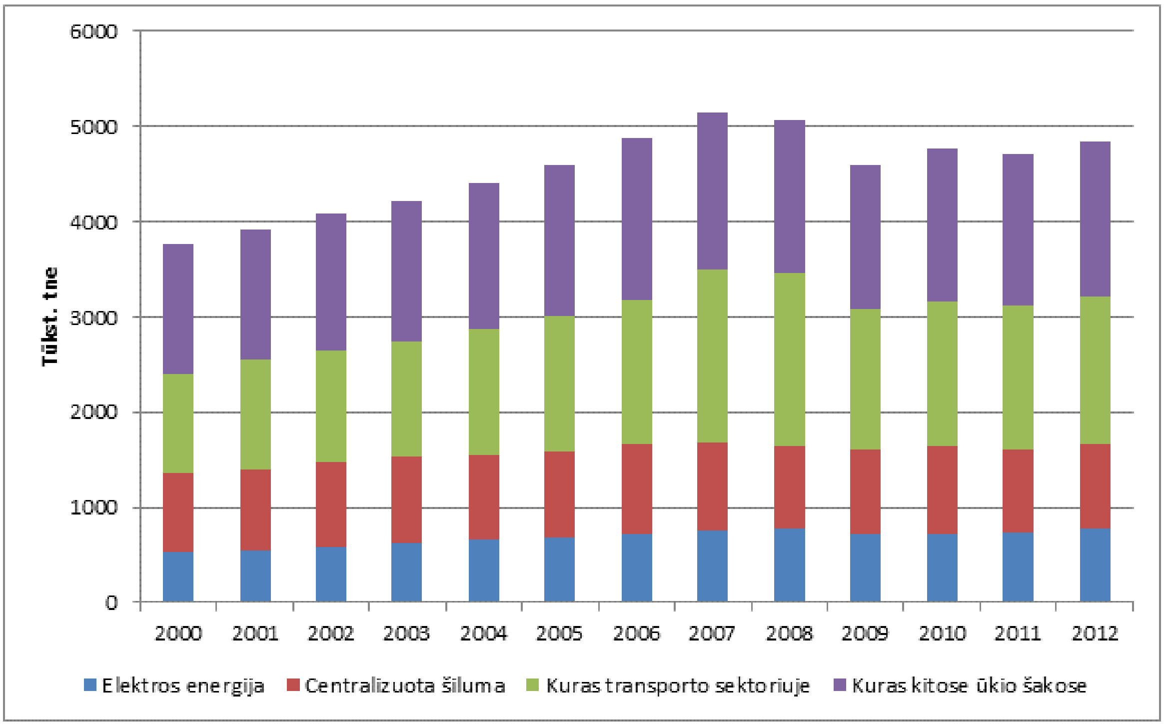


Figure 2. Changes in final energy consumption between 2000 and 2012

Tūkst. Tne	Thousand toe
Elektros energija	Electricity
Centralizuota šiluma	District heating
Kuras transporto sektoriuje	Fuel in the transport sector
Kuras kitose ūkio šakose	Fuel in other industries

27. Changes in the consumption of heat supplied to final consumers between 2000 and 2012 are shown in Figure 3. We see that the actual district heating volumes showed little change during that period – heat consumption dropped in manufacturing, construction and agriculture but that drop had little effect on the overall change in heat consumption because the growth demonstrated by the service sector was higher. The final consumption structure is dominated by household and service sectors the share of which in 2012 was 66.3% and 27.1% respectively. Fluctuations in heat consumption during that period were largely influenced by climate change because, in accordance with the data gathered in the database of the Lithuanian District Heating Association, more than 70% of heat supplied was used to heat premises. The actual heat consumption changes are therefore better reflected by the adjusted data curve shown in Fig. 3. The actual heat consumption volumes recalculated on the basis of a multi-annual (up to 60 years) average degree days are based on the assumption that climate factors directly affect that share of heat supplied to consumers that is used for heating premises. The effect of these factors on heat consumed for preparing hot water and for technological needs is insignificant. Actual and recalculated heat consumption indicators practically coincide only in 2010 when the average air temperature and the annual number of degree days were very close to their multiannual average.

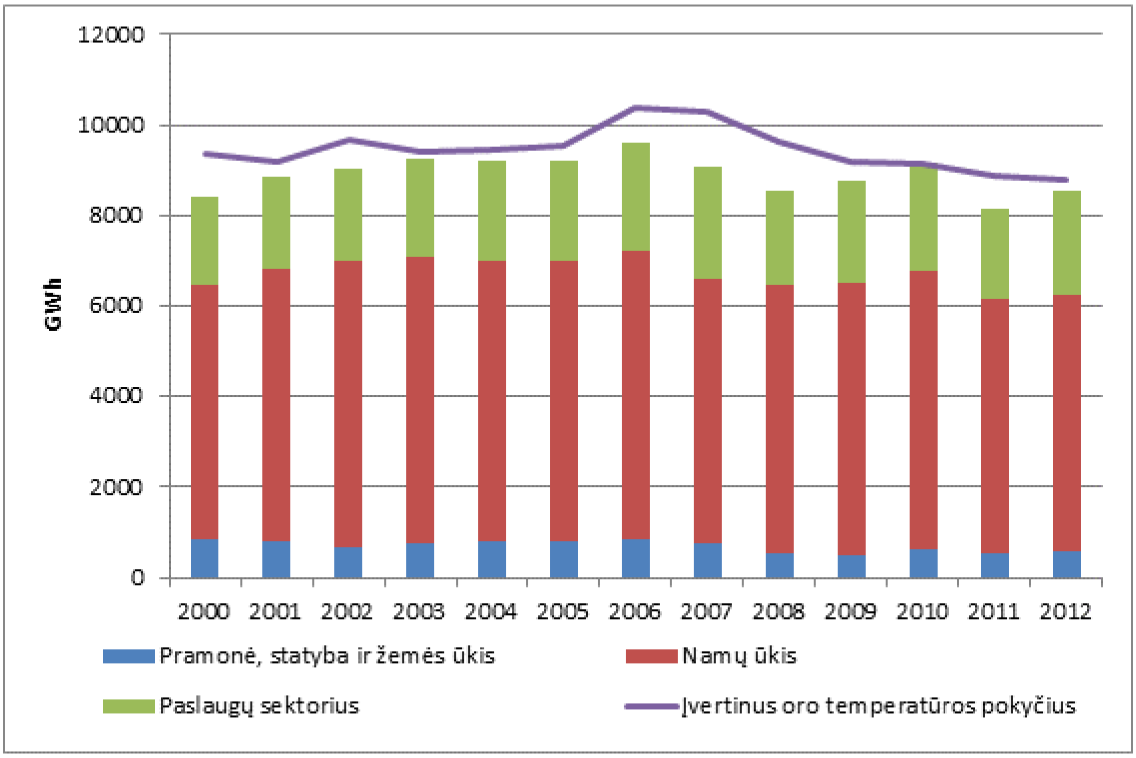


Figure 3. Changes in heat supplied to final consumers

Pramonė, statyba ir žemės ūkis	Manufacturing, construction and agriculture
Paslaugų sektorius	Service sector
Namų ūkis	Households
Įvertinus oro temperatūros pokyčius	Taking into account air temperature fluctuations

28. In the future changes in demand for district heating will be affected both by overall national trends towards the economic growth and by specific changes in consumer structure, the renovation of residential and public buildings and other factors. Having recovered after a dramatic recession, in the future Lithuania's economy should demonstrate stable growth with a view to achieving the objective set in national strategic documents, i.e. gradually bringing the GDP per capita indicator closer to the EU average. A growing economy will ensure bigger incomes of the population, encourage better conditions in the service sector (e.g. in 2000-2012 heat consumption in Estonia's service sector showed the average growth of 3.2% per year) and create prerequisites for greater comfort in the household sector. The forecasts of heat demand are therefore based on the assumption that heat demand as well as the need for other energy types can be linked with economic growth with the help of heat consumption and GDP growth elasticity indicators. On the basis of an analysis of Lithuanian, Latvian and Estonian statistical data, consumer behaviour is not elastic but economic growth does prompt some increase in energy demand. In the case of the main scenario based on the assumption that during the period up to 2030 the country's GDP will show the average annual growth of 3.7%, heat demand for technological needs and hot water will grow on average by 0.4% and demand for heating premises will be increasing annually by 0.37%.

An analysis of data in the database of the Lithuanian District Heating Association shows that heat consumption for hot water and maintaining ambient temperature in residential buildings demonstrate little differences (Fig. 4) but heat volumes for heating premises and the overall demand are very different (Fig. 5) and depend on the quality of buildings.

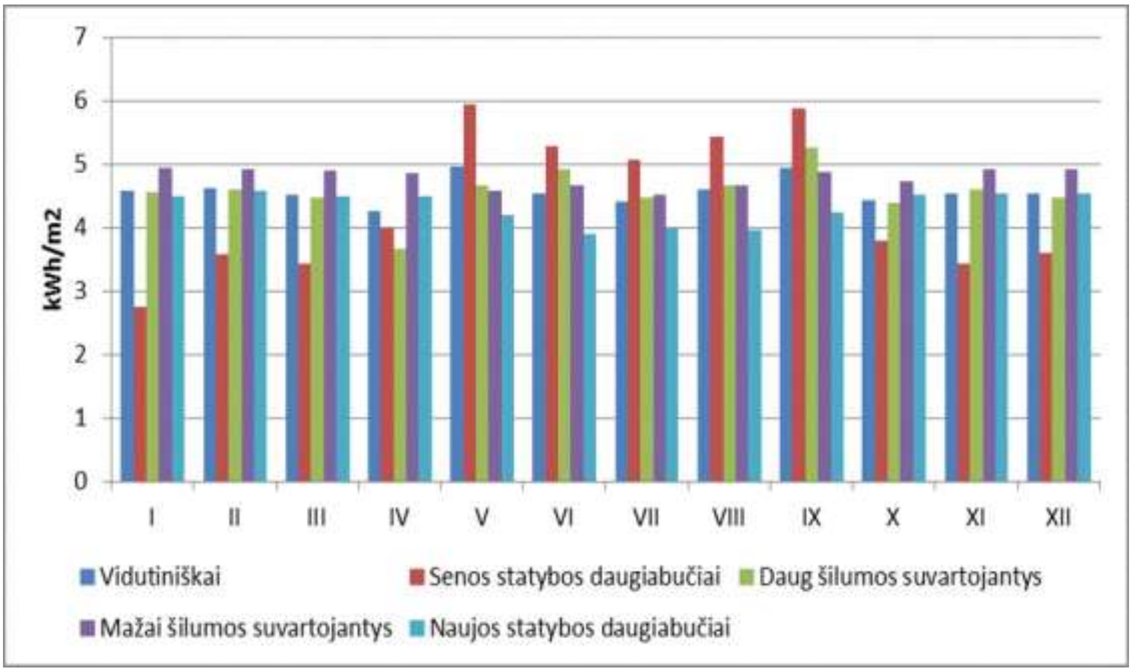


Figure 4. Heat consumption for hot water and temperature maintenance in 2012

Vidutiniškai	Average
Mažai šilumos vartojantys	Consuming little heat
Senos statybos daugiabučiai	Old multi-apartment buildings
Naujos statybos daugiabučiai	New multi-apartment buildings
Daug šilumos vartojantys	Consuming much heat

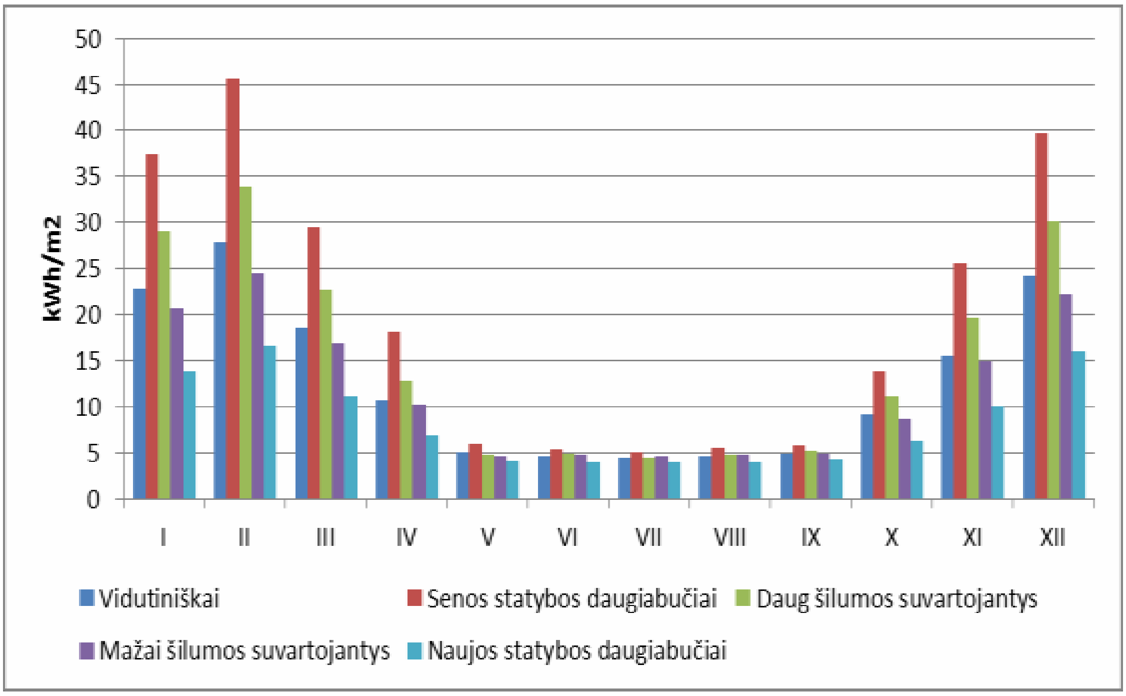


Figure 5. Changes in total heat demand of multi-apartment buildings in 2012

Vidutiniškai	Average
Mažai šilumos vartojantys	Consuming little heat
Senos statybos daugiabučiai	Old multi-apartment buildings

Naujos statybos daugiabučiai	New multi-apartment buildings
Daug šilumos vartojantys	Consuming much heat

29. In the future the evolution of heat demand will be greatly affected by changes in the multi-apartment building sector and in the service sector. Much higher prices of primary energy resources affect high prices of district heating supplied to consumers, thus encouraging residential condominiums to heat-insulate external partitions and renovate heating and hot water systems inside buildings. After buildings are heat-insulated and individual heating adjustment tools are installed in individual dwellings, heat demand for heating premises will decrease respectively. Prerequisites for the renovation of dwellings are illustrated in Fig. 6. The renovation of residential buildings is likely to take place block by block and with all the prerequisites in place about 70% of old buildings, 34% of energy-consuming buildings and 16% of multi-apartment buildings now attributable to the category of buildings consuming little heat are to be renovated by 2025. By 2035, the renovation would cover all old buildings and many heat-consuming buildings as well as about 75% of heat-efficient buildings.

30. For the sake of a rational result, multi-apartment buildings need to be modernised block by block where the renovation of buildings in a block is carried out in parallel with the renovation of pipelines of the block's district heating systems (and other engineering networks), thus reducing heat losses in the transmission link. Assuming that at least 80% of the 35 000 multi-apartment buildings are to be renovated and an average block is about 30 houses, there are approximately 900 block units in the country. To modernise 1 876 multi-apartment buildings per year, annual renovation works are to cover about 60 blocks.

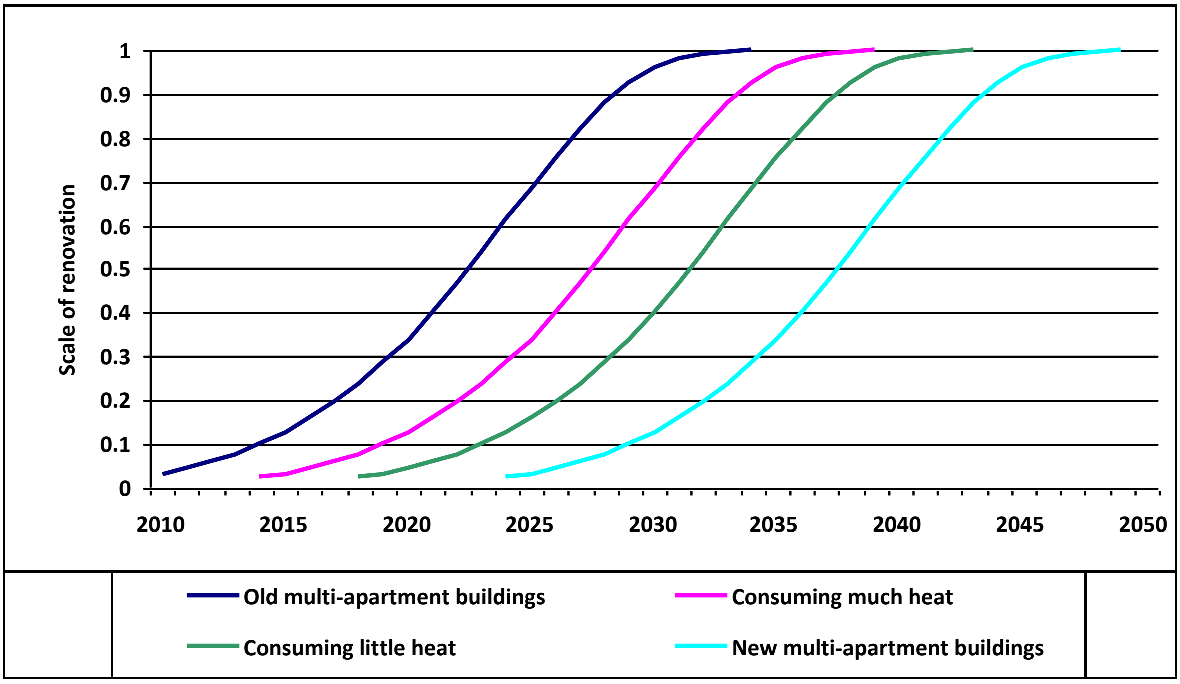


Figure 6. Forecast of renovation progress with multi-apartment residential buildings

31. In implementing Directive 2012/17/EU on energy efficiency, Lithuania has committed to gradually renovating public buildings. Admittedly, the implementation of energy-saving measures in the service sector will make it possible to reduce the volume of heat consumed in this sector by 1.5% per year. Expected volumes of heat savings due to building renovation are illustrated in Fig. 7. It has been found that in 2025, after the renovation of residential and public buildings, heat savings will be 1 TWh and 0.3 TWh respectively. In 2035, heat savings will double: the renovation of residential buildings will save about 2.2 TWh while savings in the service sector will be 0.55 TWh.

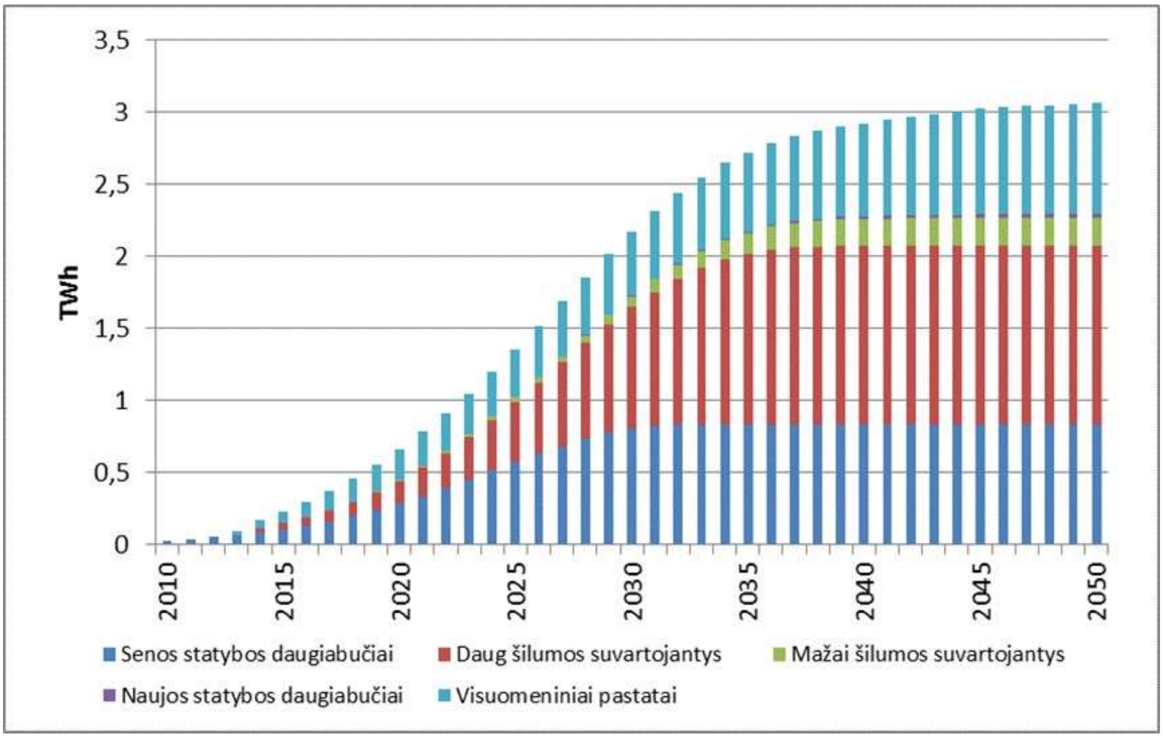


Figure 7. Forecast on effects of the renovation of residential and public buildings

Visuomeniniai pastatai	Public buildings
Mažai šilumos vartojantys	Consuming little heat
Senos statybos daugiabučiai	Old multi-apartment buildings
Naujos statybos daugiabučiai	New multi-apartment buildings
Daug šilumos vartojantys	Consuming much heat

32. The long-term forecast of final heat demand within the district heating system drawn up on the basis of the main scenario assumptions is presented in Fig. 8 and that of heat demand up to 2020 in selected cities – in Table 4.

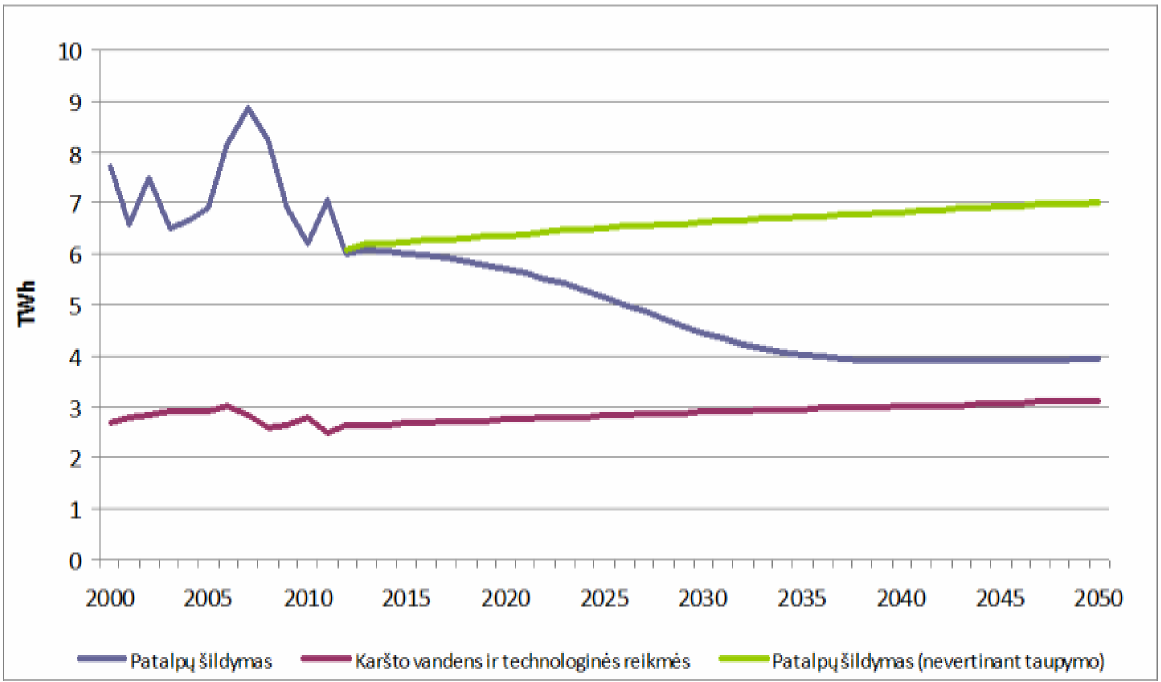


Figure 8. Forecast of final heat demand within district heating systems

Patalpų šildymas	Heating of premises
Karšto vandens ir technologinės reikmės	Hot water and technological needs
Patalpų šildymas (nevertinant taupymo)	Heating of premises (exclusive of saving)

Table 4. Changes in heat demand in selected cities, GWh

	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Vilnius	2480.6	2491.4	2477.1	2468.0	2457.0	2444.0	2427.6	2409.2	2387.6
Kaunas	1185.8	1190.6	1184.0	1180.0	1175.0	1169.0	1161.5	1153.0	1143.0
Klaipėda	832.7	836.4	831.5	828.4	824.6	820.1	814.5	808.3	800.9
Šiauliai	392.7	394.8	392.2	390.4	388.2	385.7	382.7	379.3	375.3
Panevėžys	359.1	361.0	358.6	357.0	355.1	352.8	350.1	347.0	343.5
Alytus	217.8	218.9	217.5	216.5	215.4	214.1	212.5	210.6	208.5
Marijampolė	140.3	141.1	140.2	139.5	138.8	137.9	136.8	135.6	134.2
Kėdainiai	99.8	100.4	99.7	99.2	98.7	98.0	97.2	96.3	95.3
Mažeikiai	145.2	146.0	145.0	144.3	143.6	142.6	141.5	140.2	138.8
Utena	139.3	139.9	139.1	138.5	137.9	137.1	136.1	135.0	133.8
Elektrėnai*	151.1	150.8	150.8	151.0	151.2	151.4	151.4	151.3	151.2
Other cities	2370.1	2380.2	2366.7	2358.1	2347.7	2335.4	2319.9	2302.4	2282.0

*Potentially greater current demand of UAB Kietaviškių gausa compensates for the expected effect of the renovation of buildings.

II-4. Development prospects for the heat supply system. Principles of allocating European Union financial support and amounts of support allocated to certain heat generation technologies

Methodological principles for analysing the evolution of district heating systems

33. Prospective developments and the functioning of the district heating system were analysed with the help of mathematical models. The units analysed (see Fig. 9) along with district heating systems in certain cities included the national power grid, the fuel supply system and final heat and electricity consumers. The most cost-effective heat generation technologies (existing, undergoing modernisation and new) and fuels used were selected for district heating systems of selected cities; heat and electricity production volumes were determined for selected time periods (seasons or specific characteristic day/night time intervals), and fuel consumption levels, standby capacity matters, compliance of energy production technologies with and/or adaptation thereof to

environmental restrictions were also covered. Heat production technologies in each city (within a hydraulically isolated district heating system) are chosen from a large number of existing technologies, technologies undergoing modernisation and new technologies that may at some point be installed in the city in question. The efficiency of technologies is assessed in terms of the scale of investments in installing them, non-variable and variable operational expenditure, fuels that may be used, performance indicators, the duration of the life cycle and construction works, environmental features, etc. The connection with the power grid is analysed taking into account how well cogeneration plants can contribute to meeting ever-changing electricity needs of final consumers and ensuring the required standby capacity at the same time helping to meet variable heat demand.

34. Similar issues of the optimal choice and rational use of electricity generation technologies are being dealt with in the power grid. Some additional analysis here also covers possibilities and the need for exchanging electricity and standby capacity with certain other countries depending on the needs of electricity markets of neighbouring countries (export from Lithuania) or supply possibilities (import to Lithuania), electricity prices, throughput capacity of communications lines, etc.

35. Heat and electricity supply systems are fuelled taking into account existing and prospective supply infrastructures (pipelines, terminal capacity, natural gas storages, etc.) and fuel prices and supply volumes. Matters concerning the feasibility of supplying local and renewable energy resources for certain technologies within the heat and electricity supply system are dealt with taking into account the potential and prices of such resources.

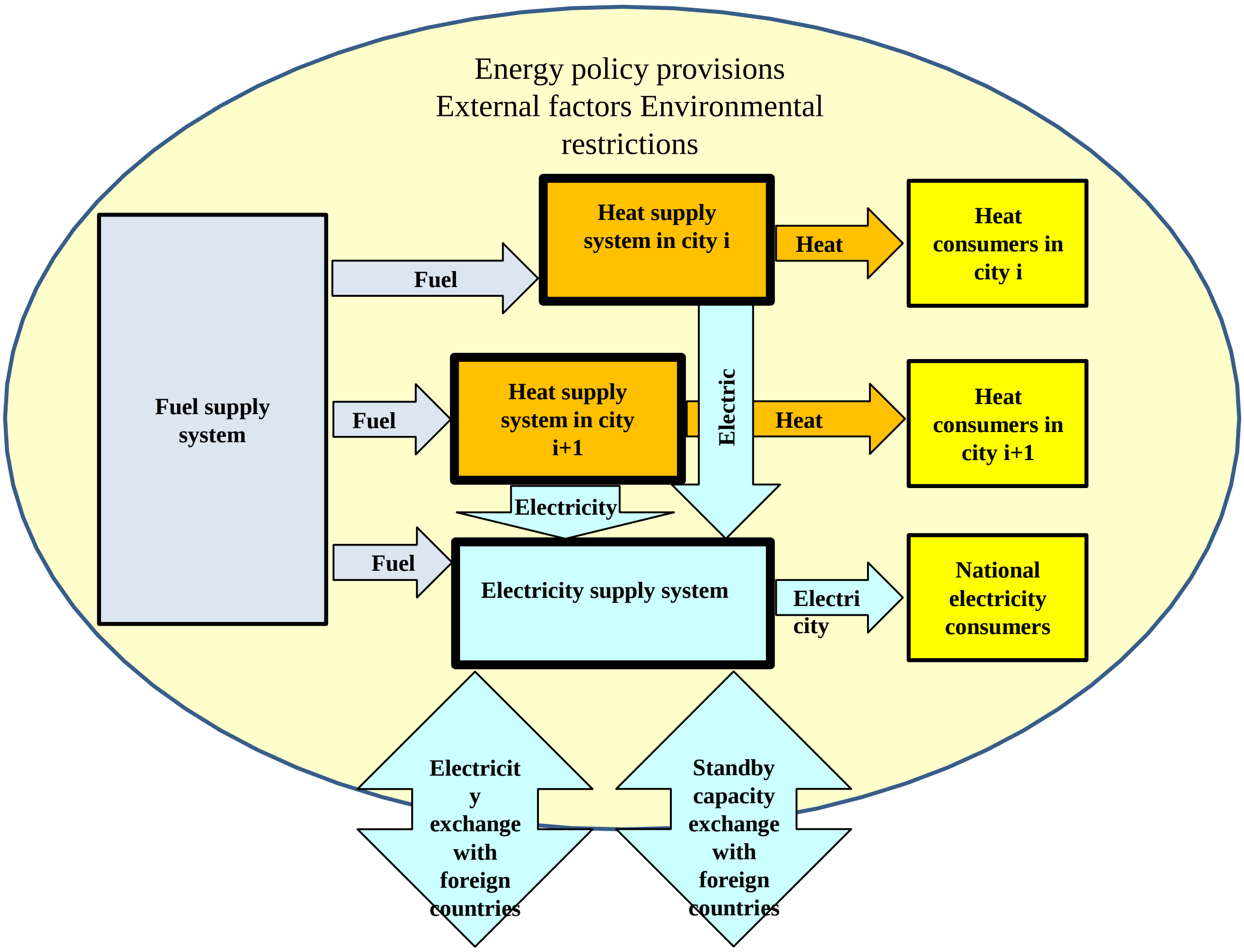


Figure 9. Structure and functional links of the mathematical model for analysing the prospective development and functioning of district heating systems

36. Developments in heat and electricity consumption and availability of renewable energy resources (wind, hydropower and solar energy) are assessed taking into account multiannual observation data on natural processes (outside temperatures, river water levels, solar radiation and variable wind speed). Annual demand for specific energy types on individual markets is in line with the forecast of demand presented in Table 4 (this document only contains forecasts of heat demand).

37. The assessment of all these and other factors and the detailed mathematical description along with the overview of energy policy provisions, environmental and other external factors affecting the energy sector or individual systems therein allow for a rather detailed analysis of the long-term development of the district heating system (also in the context of the development and functioning of other systems in the energy sector). The period in question covers years 2011 to 2065. For the period between 2011 and 2020 the unit of analysis is one year, followed by 5, 10 or 15-year intervals, i.e. 2025, 2030, 2040, 2050 and 2065. The main focus of the analysis is the time interval of 2011-2020-2025-2030 but such a long period has been selected for analysis in order to reflect the specific functionalities and economic attractiveness of long-lived energy technologies. The number of variables defining developments in installed capacities of individual energy system technologies and levels of energy production and fuel consumption at individual intervals of the period in question (at certain typical hours of the day/night) is over 2.4 million. There is a comparable number of equations describing processes with energy systems.

38. The efficiency and competitiveness of heat production technologies depend on technical and economic parameters of technologies and fuel prices. Fuel prices are of utmost importance. Therefore, the assessment of prospective fuel prices has been in the spotlight.

Principles of allocating financial support

39. Financial support for the development of heat production sources to district heating undertakings must enable them to implement and operate energy generation technologies in a competitive environment but such support should not be excessive so as not to create conditions for fraud or irresponsible installation and operation of energy facilities. In other words, the allocation of support should not eliminate the need to operate installations rationally or encourage the implementation of insufficiently efficient technologies.

40. The objective of financial support to heat generation undertakings is to change the established investment policy. Investment support aims at:

a. improving investment opportunities of heat supply undertakings which are currently rather modest and do not encourage undertakings to invest in facilities requiring greater initial investments although their return on investment in the long run would be higher,

b. creating conditions for new heat production technologies to penetrate the country's district heating system,

c. enhancing the contribution of district heating undertakings to dealing with the country's energy security problems (increasing the level of local competitive electricity production),

d. reducing heat prices for final consumers.

41. The penetration of supported technologies into the market and the level of support allocated were simulated on the basis of the assumption that their newly installed capacity is divided

into two components: (a) requiring investments and (b) requiring no investments. So, one technology (e.g. a water heating boiler) is conditionally broken down into two technologies defined by similar technical and economic indicators with only one difference that one of them (where investments are covered by the support fund) does not have any investments as compared to the other one which has real investments. In other words, apart from conventional technologies characterised by the entire set of technical and economic indicators, the mathematical model has also covered similar technologies with investments covered by the support fund and not treated as expenditure. This group of technologies includes heat and electricity production technologies based on renewable resources (boiler facilities and power plants) and efficient cogeneration installations running on fossil fuels (gas). In spite of the fact that investments in these technologies are not treated as expenditure and it may be desirable to present as many of them as possible in simulating the prospective development of the district heating system, this is not the case as the support fund is limited. Given the limitations of the support fund, the most cost-efficient option of supported technologies is looked for with a view to installing the capacity of heat production units supported with assistance funds, i.e. supported technologies (technologies for which investments are not treated as expenditure) are first of all installed where the economic return is the greatest. After the most efficient niche is filled, the search process focuses on another niche that is in turn the most efficient, i.e. this process goes on as long as the support fund is available or until consumer energy needs are met, and there is no further need to install any technology.

42. Each supported technology has an analogy differing only in that it requires investments to be installed and such investments are treated as expenditure of the district heating system. The respective proportionate shares of these two technologies and newly installed capacities are set at the same time offering a possibility to limit the maximum support level to each technology in question. For instance, to ensure that the implementation of a specific technology does not use more than k% of investments from the support fund, the capacity to be installed is limited:

$$\frac{X_r}{X_r + X_n} \leq \frac{k}{100},$$

where: X_r *– newly installed capacity of the technology in question where investments are covered by the support fund;*

X_n *– newly installed capacity of the technology in question where investments are not covered by the support fund;*

k *– maximum allowable investment support intensity for the technology in question (the share of required investments that can be covered by the support fund).*

43. The maximum share of investments that can be covered by the support fund for a specific technology will not necessarily attain its maximum value because given the limitations of the support fund and other technologies eligible for support, it is possible to find a more efficient option for using the support pulling a share of the support funds away from the technology in question. As supported technologies (for which investments are not treated as expenditure) are represented in the mathematical model like all other technologies while the development of the district heating system is analysed dynamically within the pre-determined time period and it is possible to simulate the optimal use of the support fund both to support individual technologies and to distribute the support within a given time period.

44. To get district heating undertakings interested in implementing only cost-effective technologies, not all investments should be covered by the support fund. A share of investments should be co-financed by undertakings proper. However, given that the applicable methodology for allocating the support allows optimising the intensity of the support, the initial phase of the analysis envisaged a possibility to cover quite a large share (up to 80%) of investments from the support

fund (k ≤ 80 %). Later the maximum support intensity was reduced to 50% and 0%. That was done to establish the economic effect of the support on the energy system and to compile information for decision-makers on the support mechanism to be applied.

45. To find out how the support used for heat (and electricity) production technologies in the district heating system can contribute to the implementation of the national energy security objectives, three energy security options were analysed:

a. to develop local electricity generation as far as practicable in accordance with the market conditions (without restricting electricity imports),

b. to seek that as of 2020-2025 the country produces at least 50% of its electricity demand,

c. to seek that around 2020-2025 the country produces at least 50% of its electricity demand and that by 2050 that level is up to 80%.

46. The requirements of paragraphs 40.1 to 40.3 of the mathematical model were implemented by restricting electricity import possibilities accordingly. General electricity import restrictions applied along with more stringent restrictions of imports from non-EU countries. The scenarios analysed are presented in Table 5.

Table 5. Scenarios analysed

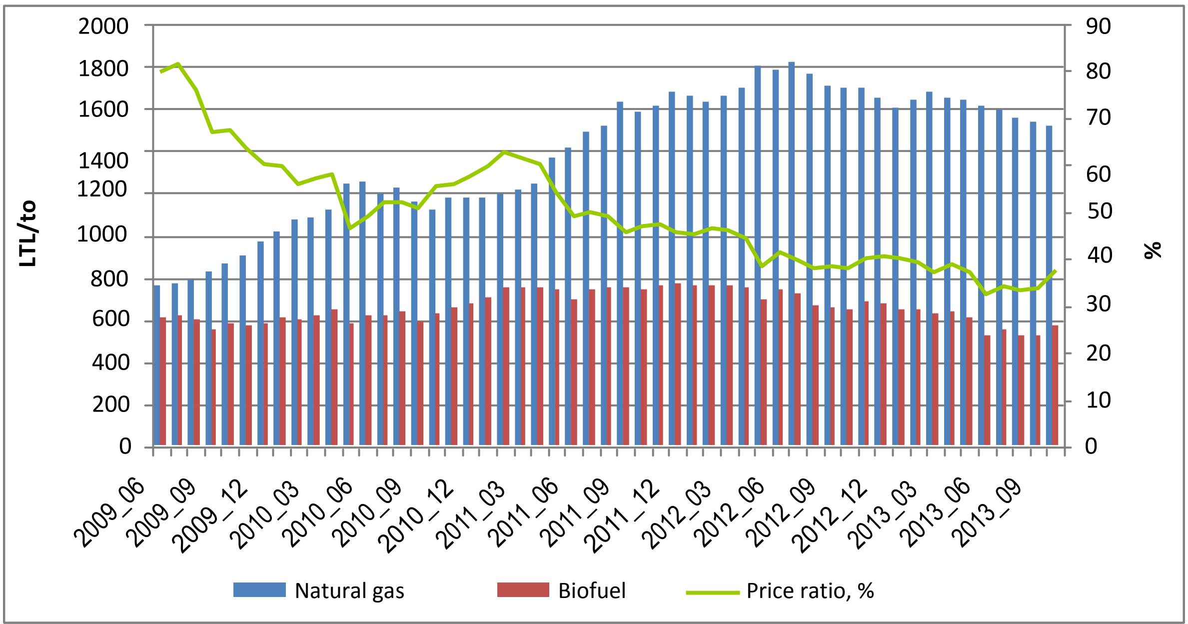
<table>
<tr><th rowspan="2">Scenarios</th><th rowspan="2">Fuel prices</th><th colspan="6">Maximum allowable investment support rate</th><th colspan="2">Support fund</th><th colspan="2">Support allocation between:</th><th colspan="5">Total allowable energy import, % of national demand</th><th colspan="5">Allowable energy import from non-EU countries, % of national demand</th><th rowspan="2">Biofuel import</th></tr>
<tr><th>RER technologies</th><th>Fossil fuel cogeneration plants</th><th>Large onshore wind power plants</th><th>Small onshore wind power plants</th><th>Offshore wind plants</th><th>Solar plants</th><th>2014-2020</th><th>2021-2027</th><th>RER technologies</th><th>Fossil fuel cogeneration plants</th><th>2011</th><th>2020</th><th>2023</th><th>2030</th><th>2050</th><th>2011</th><th>2020</th><th>2023</th><th>2030</th><th>2050</th></tr>
<tr><td>Scenario A</td><td rowspan="9">Moderate growth</td><td colspan="6" rowspan="3">0.8</td><td rowspan="6">1500</td><td rowspan="6">1000</td><td colspan="2" rowspan="9">Free</td><td rowspan="9">Free</td><td colspan="4">Free</td><td rowspan="9">Free</td><td colspan="4">Free</td><td rowspan="9">Not allowed</td></tr>
<tr><td>Scenario B</td><td>50</td><td>50</td><td>30</td><td>20</td><td>30</td><td>30</td><td>15</td><td>10</td></tr>
<tr><td>Scenario C</td><td>70</td><td>50</td><td>50</td><td>50</td><td>35</td><td>30</td><td>15</td><td>10</td></tr>
<tr><td>Scenario D</td><td colspan="6" rowspan="3">0.5</td><td colspan="4">Free</td><td colspan="4">Free</td></tr>
<tr><td>Scenario E</td><td>50</td><td>50</td><td>30</td><td>20</td><td>30</td><td>30</td><td>15</td><td>10</td></tr>
<tr><td>Scenario F</td><td>70</td><td>50</td><td>50</td><td>50</td><td>35</td><td>30</td><td>15</td><td>10</td></tr>
<tr><td>Scenario G</td><td colspan="6" rowspan="3">No support</td><td colspan="2" rowspan="3">No support</td><td colspan="4">Free</td><td colspan="4">Free</td></tr>
<tr><td>Scenario H</td><td>50</td><td>50</td><td>30</td><td>20</td><td>30</td><td>30</td><td>15</td><td>10</td></tr>
<tr><td>Scenario I</td><td>70</td><td>50</td><td>50</td><td>50</td><td>35</td><td>30</td><td>15</td><td>10</td></tr>
</table>

Trends in fuel price fluctuations

47. The overall balance of fuel used for electricity and heat production is dominated by imported fossil fuels: in 2011 and 2012 natural gas accounted for 74.3% and 64.2% and oil products – for 4.1% and 10.2% respectively but the role of renewable energy resources is becoming increasingly important: in 2011 their share was 21.2% and in 2012 increased to 25.2%. Now and in the future economic indicators of many heat supply undertakings, especially in larger cities, will be to a large extent dependent on oil and gas price fluctuations on global energy markets.

48. During the past few years very high gas prices substantially altered economic indicators of district heating undertakings and led to high heat prices and large consumer bills bringing particular problems to low-income families.

49. With gas prices increasing, prices of various biofuels competing in the heating sector were also growing. However prices of the key biofuels used on the largest scale (woodchips, waste wood and biofuel mixtures) remained twice or thrice as low as those of natural gas. This is illustrated in Fig. 10 by changes in average prices of natural gas and of biofuels published by the National Control Commission for Energy and Prices between 2009 and 2013 and the pricing ratio defining the attractiveness of local fuel. It is essential to note that the drop in gas prices by 19.3% from LTL 1816/toe in July 2012 to LTL 1521/toe in October 2013 was largely dependent on the lower value of the dollar (as compared to the euro). If the average LTL to USD ratio remained stable during that period, the gas price would have dropped by a mere 8%. The biofuel price shown in the figure matches the average original price of wood on the heat producer level taking into account costs pertaining to raw biofuel materials and transportation.



10 Figure 10. Prices of natural gas and biofuel and their price ratios

50. In modelling the development options for the heating sector, two scenarios with natural gas prices were selected: (1) a high-price scenario and (2) a moderate price growth scenario. In the high-price scenario long-term fuel price forecasts are based on the oil and oil products price trend described in the main scenario of the Annual Energy Review 2013 drawn up by the US Government's Energy Information Administration

1 EUR 1 = LTL 3.4528. As of 1 January 2015 Lithuania has Euro as its currency.

for the period up to 2040 and price interrelations; using the existing formula the natural gas price was linked with fuel oil and diesel prices. Price trends for woodchips and biofuel were assessed taking into account a number of factors affecting their growth:

- undoubtedly growing demand for various wood types leading to increased prices on the internal market;
- with demand growing, the share of more expensive biofuel requiring infrastructure, proper logistics, etc. will also increase;
- national commitments of many countries to use renewable energy resources more widely will enhance biofuel demand on international markets where it makes sense to export wood pellets even now, even given significant transportation costs.

Price trends for oil products, natural gas and local resources taking into account factors leading to their further growth and a longer period up to 2050 are shown in Fig. 11.

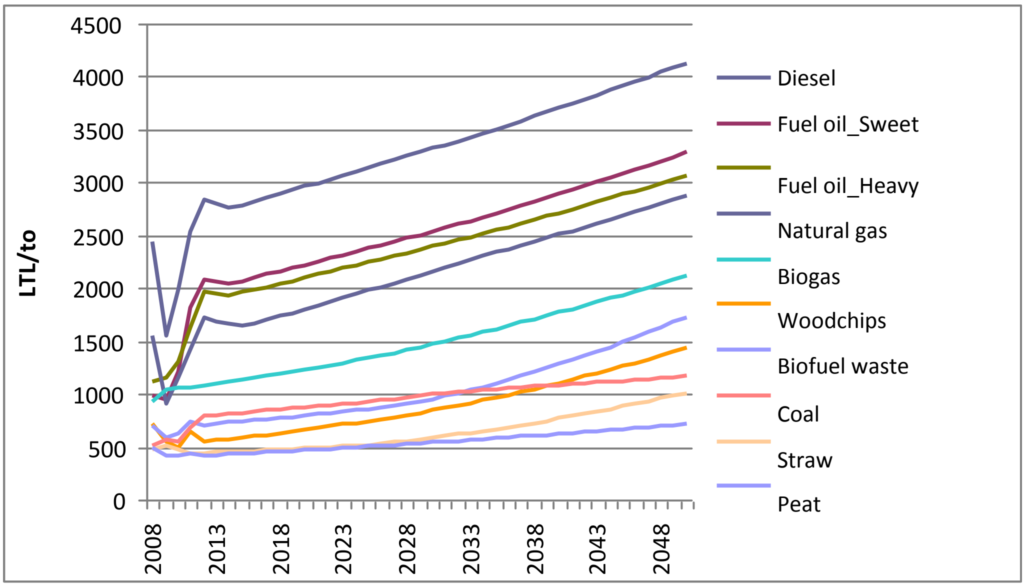


Figure 11. Fuel price forecast (high-price scenario)

51. The latest study Global Energy Outlook 2013 conducted by the experts of the International Energy Agency analyses the scenario of a much slower growth of prices of oil products and, in particular, natural gas. Such trends may to a great extent be a result of expected significant developments on global liquefied natural gas markets:

- in spite of envisaged further growth of demand for natural gas, significant exports of liquefied natural gas from the US are expected; such exports will be encouraged by very big price differences pertaining to this fuel in the US, European and Japanese markets, which will greatly affect the conventional mechanism of linking gas prices with oil and on the global market integration;
- specialists forecast that Australia will become a major player on the global energy market and the world's largest exporter of liquefied natural gas substantially reducing the liquefied gas supply and demand balance in Asia;
- state-of-the-art technologies will significantly reduce gas transportation costs.

52. A moderate growth of natural gas prices (on average by 1% annually) during the period until 2035 is also forecast by Danish experts in their studies in 2013. These developments on global energy markets and the rational operation of the liquefied natural gas terminal in Klaipėda may also be highly important for a slower growth of biofuel prices because lower natural gas prices will undermine the competitiveness of biofuel. Biofuel prices can only grow as long as energy generation installations running on biofuel remain competitive vis-a-vis natural gas. The proposed scenario of a moderate fuel price growth is described in Fig. 12 while related data are presented in Table 6. In this case some additional assessment has been carried out in respect of the prospective stability of natural gas prices due to its supply diversification given the construction of the liquefied natural gas terminal.

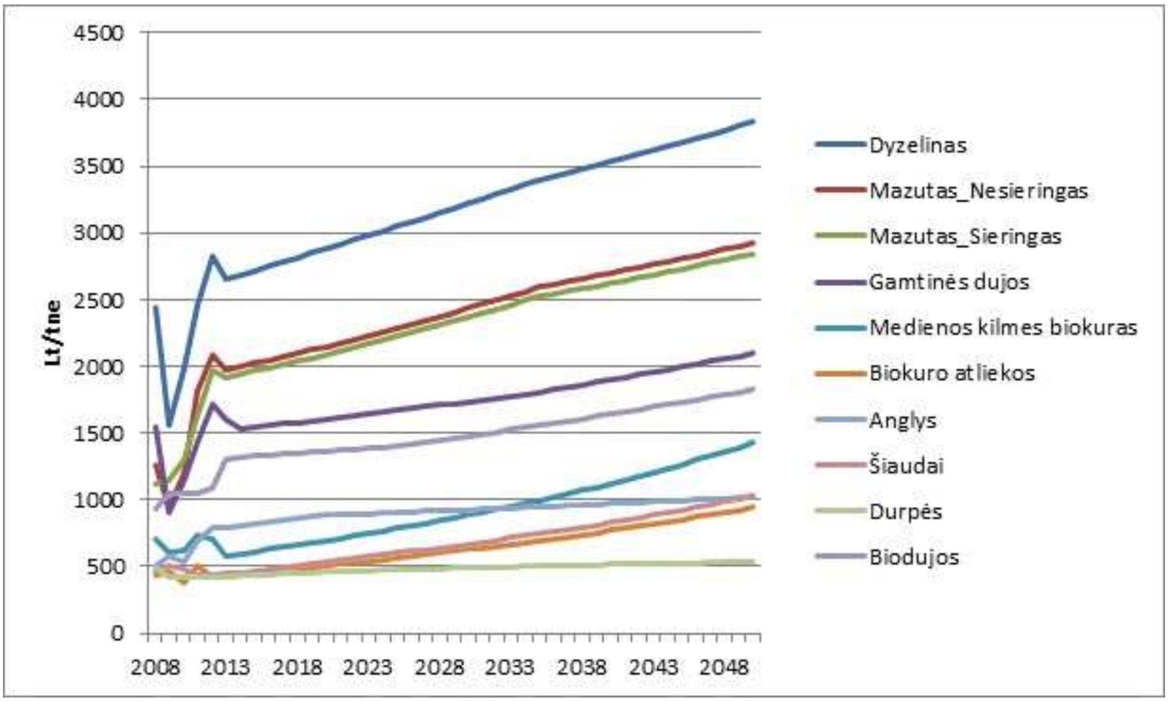


Figure 12. Fuel price forecast (moderate price growth scenario)

Dyzelinas	Diesel
Mazutas_Nesieringas	Fuel oil_Sweet
Mazutas_Sieringas	Fuel oil_Heavy
Gamtinės dujos	Natural gas
Medienos kilmės biokuras	Biofuel of wood origin
Biokuro atliekos	Biofuel waste

Anglys	Coal
Šiaudai	Straw
Durpės	Peat
Biodujos	Biogas

Table 6. Fuel price forecast (moderate price growth scenario), LTL/toe

	2012	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***
Diesel fuel	2828.5	2652.7	2684.8	2717.3	2750.2	2783.4	2817.1	2851.2	2885.7
Sweet fuel oil	2081.7	1973.7	1997.5	2021.7	2046.2	2070.9	2096.0	2121.3	2147.0
Heavy fuel oil	1969.5	1919.2	1942.4	1965.9	1989.7	2013.8	2038.2	2062.8	2087.8
Natural gas	1713.4	1602.6	1533.6	1544.8	1556.0	1567.4	1578.8	1590.4	1602.0
Biofuel of wood origin	706.7	583.6	598.1	613.0	628.3	643.9	660.0	676.4	693.2
Biofuel waste	417.2	426.7	436.9	447.4	458.1	469.1	480.4	491.9	503.7
Coal	793.2	793.4	805.7	818.2	830.9	843.8	856.8	870.1	883.6
Straw	440.4	443.4	454.8	466.4	478.3	490.6	503.1	516.0	529.2
Peat	415.4	423.9	429.0	434.1	439.3	444.6	449.9	455.3	460.8
Fuel wood	446.3	455.1	467.9	481.0	494.4	508.3	522.5	537.1	552.1
Biogas (for boiler facilities)	1086.2	1310.3	1317.6	1325.0	1332.4	1339.9	1347.4	1354.9	1362.5
Shale oil	1955.9	2001.2	2021.2	2041.4	2061.8	2082.4	2103.2	2124.3	2145.5

Prospective development of energy generation technologies in the district heating system

53. The prospective development and functioning of the district heating system are closely linked with the prospective development and functioning of the power grid, which is why an overview of the former is best to commence with an analysis of the latter.

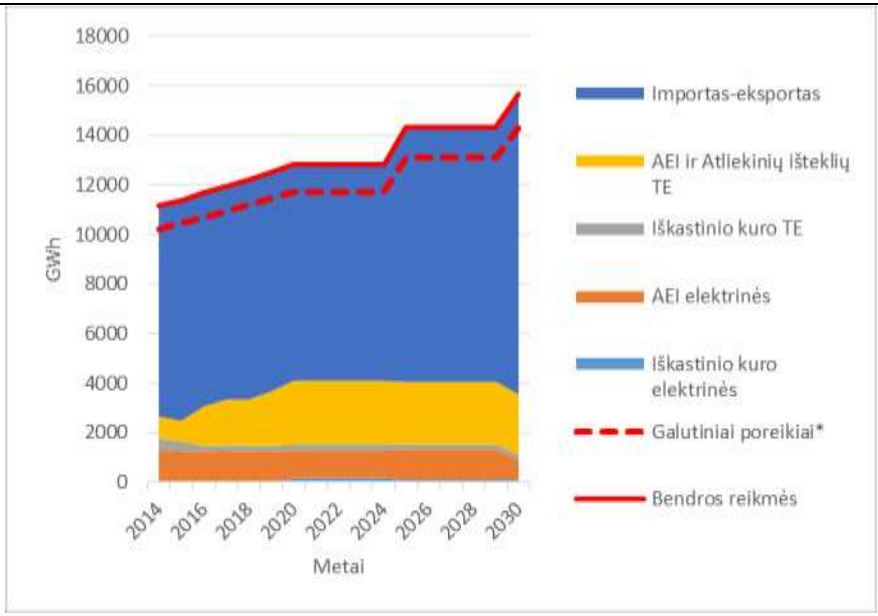
54. The dynamics of energy generation by certain types of power plants under scenarios D, E and F are summarised in Fig. 13 and Tables 7 to 9. These include simulation results under those scenarios where the maximum investment support rate is limited to 50%. A similar situation is also present in other cases where the maximum support rate is set.

55. The reported data show clear differences in imported electricity volumes and production levels of cogeneration plants based on fossil fuels (gas). The country's energy system freely competing on the free market (Scenario D) would only produce about 30% of the required volume of electricity. The rest of the required volume of electricity would be imported (see Fig. 14). In the case of the other scenarios local electricity production is following the pre-determined energy policy objective but, as will be shown later, there are some grounds for believing that power plants will have to be subsidised when operating them in order to achieve that objective. Otherwise they may be unable to compete on the free market and put on standby.

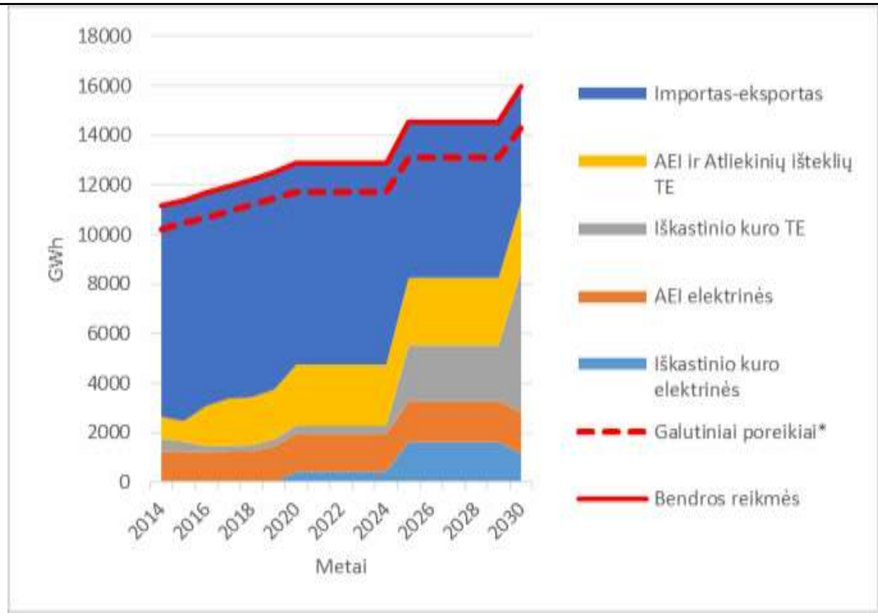
56. Electricity production volumes of cogeneration plants running on renewable energy resources are practically independent of the country's energy policy objectives relating to energy security. By 2020 electricity generation at such cogeneration plants should be increased to 2000 to 2100 GWh/year, irrespective of the energy policy objectives. This would account for about 44 to 49% of electricity generated nationally. During the later period between 2020 and 2030 the development of these plants would be slightly affected by the country's energy policy objectives in the field of energy security. In order to produce at least 50% of electricity in the country, the annual production of biofuel-based cogeneration plants should be increased by another ~200 to 300 GWh.

57. The share of power plants running on renewable energy resources in meeting the total national electricity demand under scenarios D, E and F is shown in Fig. 15. By 2020 the contribution of these power plants in meeting the total national electricity demand should be increased to 25 to 29% (see Fig. 15). It would stay at that level until about 2030. Given rather different local electricity generation volumes under the scenarios in question, the contribution of

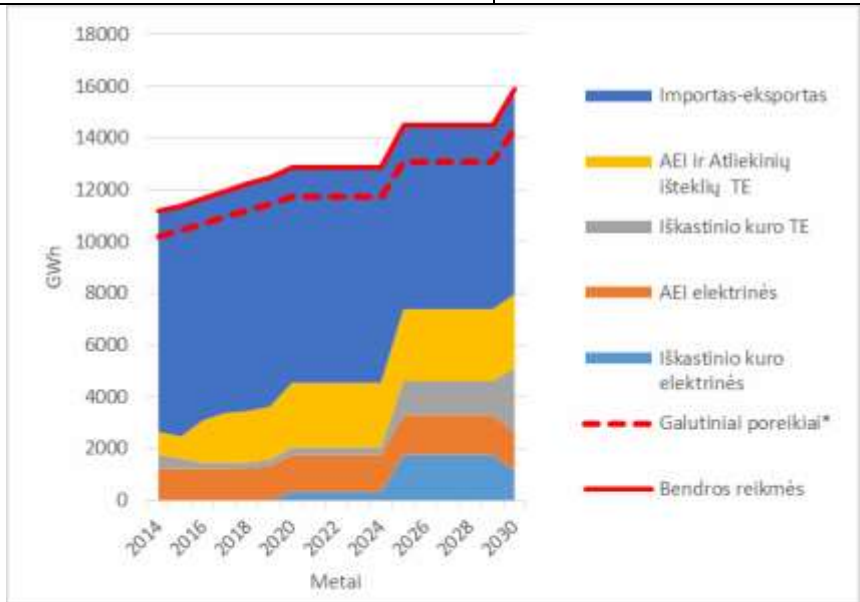
plants running on renewable energy resources in the national electricity production would be quite different already as of 2025. The largest share of these power plants (~85%) would be attained at the lowest national electricity production rate (see Fig. 16). Under the other scenarios it would decrease to 50 to 55%.



(a) without limiting import



(b) producing at least 50% of electricity nationally



(c) producing at least 80% of electricity nationally

Figure 13. Electricity generation with the help of RER technologies and efficient cogeneration with up to 50% investment support. (***Note:*** Final demand here includes electricity consumption by AB Orlen and boiler facilities)

Metai	Year
Importas-eksportas	Import/export
AEI ir atliekinių išteklių TE	RER and waste cogeneration plants
Iškastinio kuro TE	Fossil fuel cogeneration plants
AEI elektrinės	RER power plants
Iškastinio kuro elektrinės	Fossil fuel power plants
Galutiniai poreikiai*	Final demand*
Bendros reikmės	Total demand

Table 7. Electricity generation by technology group under Scenario D (without limiting electricity import and providing support to no more than 50% of required investment), GWh

Technologies	***2014***	2015	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Fossil fuel plants	0	0	0	0	0	0	177	177	177	177	177	100	100	100	100	100	116
RER plants	1250	1239	1227	1250	1257	1251	1111	1111	1111	1111	1111	1227	1227	1227	1227	1227	786
Fossil fuel cogeneration plants	517	403	239	228	216	210	249	249	249	249	249	205	205	205	205	205	201
RER and waste-based cogeneration	890	840	1597	1860	1872	2207	2560	2560	2560	2560	2560	2523	2523	2523	2523	2523	2443
Import/export	8513	8913	8610	8611	8874	8843	8746	8746	8746	8746	8746	10253	10253	10253	10253	10253	12117
Energy system demand	946	934	973	1001	1017	1049	1113	1113	1113	1113	1113	1215	1215	1215	1215	1215	1300
Final demand*	10224	10459	10701	10948	11202	11463	11729	11729	11729	11729	11729	13093	13093	13093	13093	13093	14364
Total demand	11170	11394	11674	11949	12219	12511	12842	12842	12842	12842	12842	14307	14307	14307	14307	14307	15664

****Note:*** Final demand here includes electricity consumption by AB Orlen and boiler facilities.

Table 8. Electricity generation by technology group under Scenario E (seeking that by 2050 the country produces at least 80% of its electricity demand providing support to no more than 50% of required investment), GWh

Technologies	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Fossil fuel plants	0	0	0	0	0	0	430.9	430.9	430.9	430.9	430.9	1624	1624	1624	1624	1624	1140
RER plants	1237	1226	1214	1237	1243	1437	1529	1529	1529	1529	1529	1644	1644	1644	1644	1644	1668
Fossil fuel cogeneration plants	516.9	402.5	238.4	235.9	257.4	279.1	321.9	321.9	321.9	321.9	321.9	2260	2260	2260	2260	2260	5732
RER and waste-based cogeneration	890	840	1628	1904	1932	2013	2459	2459	2459	2459	2459	2719	2719	2719	2719	2719	2780
Import/export	8527	8926	8595	8574	8786	8772	8112	8112	8112	8112	8112	6260	6260	6260	6260	6260	4640
Energy system demand	946.4	934.9	975.1	1003	1017	1038	1124	1124	1124	1124	1124	1414	1414	1414	1414	1414	1597
Final demand*	10224	10459	10701	10948	11202	11463	11729	11729	11729	11729	11729	13093	13093	13093	13093	13093	14364
Total demand	11170	11394	11676	11951	12219	12501	12853	12853	12853	12853	12853	14507	14507	14507	14507	14507	15961

****Note:*** Final demand here includes electricity consumption by AB Orlen and boiler facilities.

Table 9. Electricity generation by technology group under Scenario F (seeking that as of 2025 the country produces at least 50% of its electricity demand providing support to no more than 50% of required investment), GWh

Technologies	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Fossil fuel plants	0	0	0	0	0	0	335.1	335.1	335.1	335.1	335.1	1762	1762	1762	1762	1762	1176
RER plants	1250	1239	1227	1250	1257	1331	1424	1424	1424	1424	1424	1544	1544	1544	1544	1544	1472
Fossil fuel cogeneration plants	516.9	404.2	238.5	227.4	227.4	249	291.9	291.9	291.9	291.9	291.9	1315	1315	1315	1315	1315	2478
RER and waste-based cogeneration	890	840	1641	1909	1971	2052	2495	2495	2495	2495	2495	2765	2765	2765	2765	2765	2843
Import/export	8513	8911	8570	8565	8766	8870	8301	8301	8301	8301	8301	7109	7109	7109	7109	7109	7902
Energy system demand	945.7	934.4	975.9	1003	1019	1040	1119	1119	1119	1119	1119	1402	1402	1402	1402	1402	1509
Final demand*	10224	10459	10701	10948	11202	11463	11729	11729	11729	11729	11729	13093	13093	13093	13093	13093	14364
Total demand	11170	11394	11677	11952	12222	12503	12848	12848	12848	12848	12848	14495	14495	14495	14495	14495	15872

****Note:*** Final demand here includes electricity consumption by AB Orlen and boiler facilities.

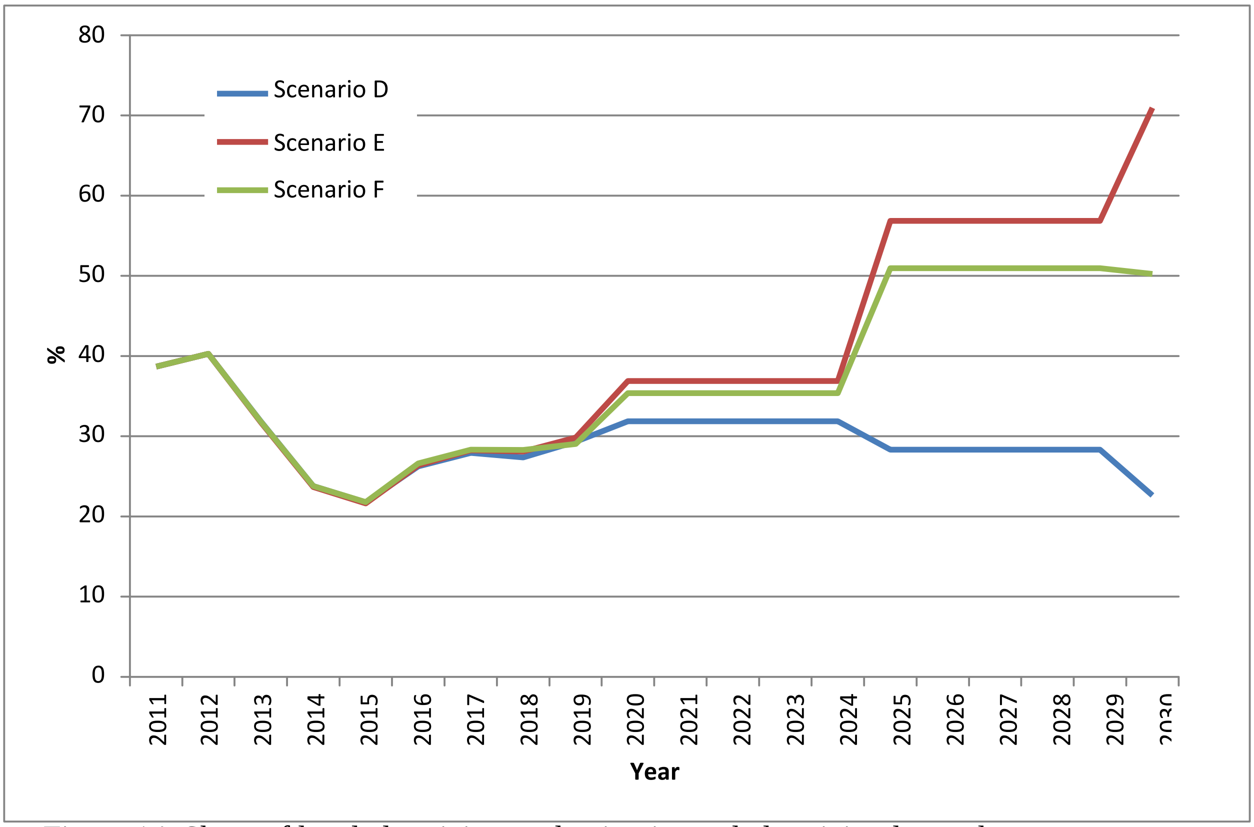


Figure 14. Share of local electricity production in total electricity demand

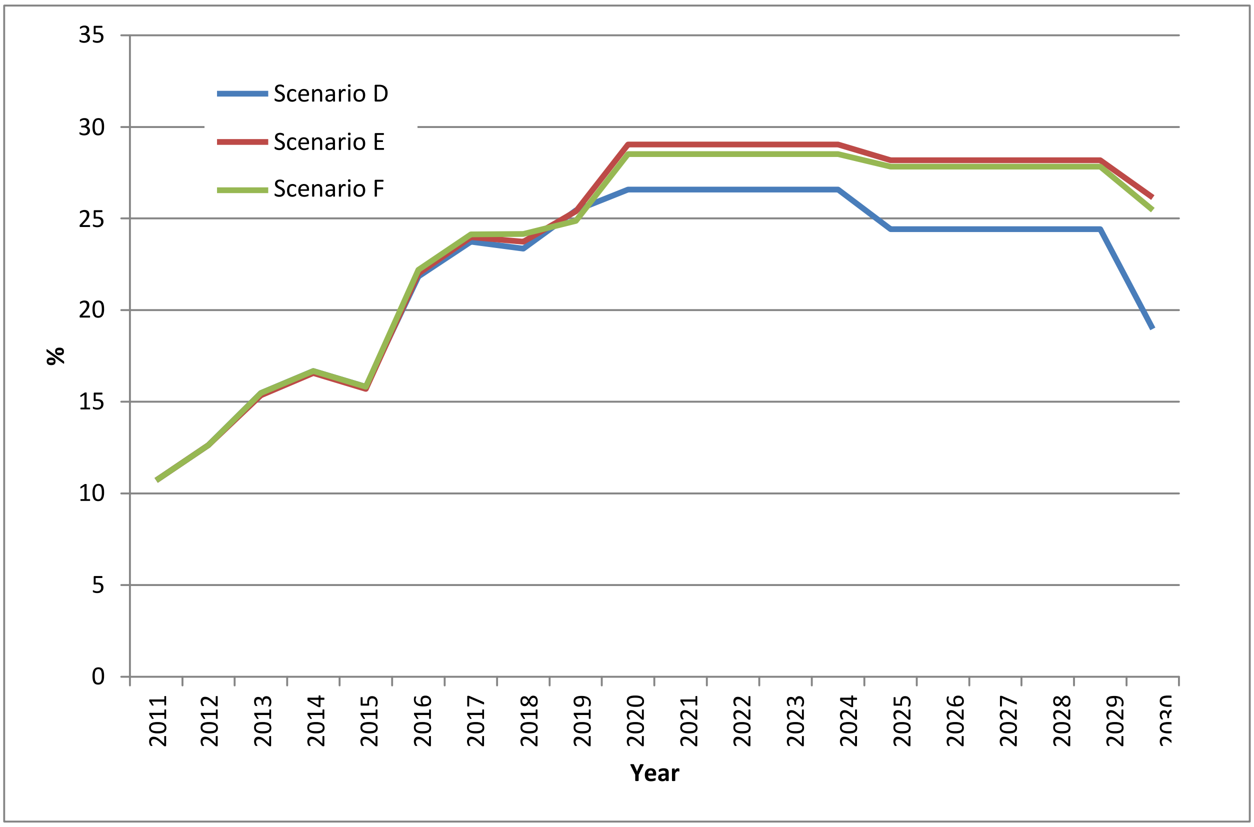


Figure 15. Contribution of RER technologies to meeting total national electricity demand

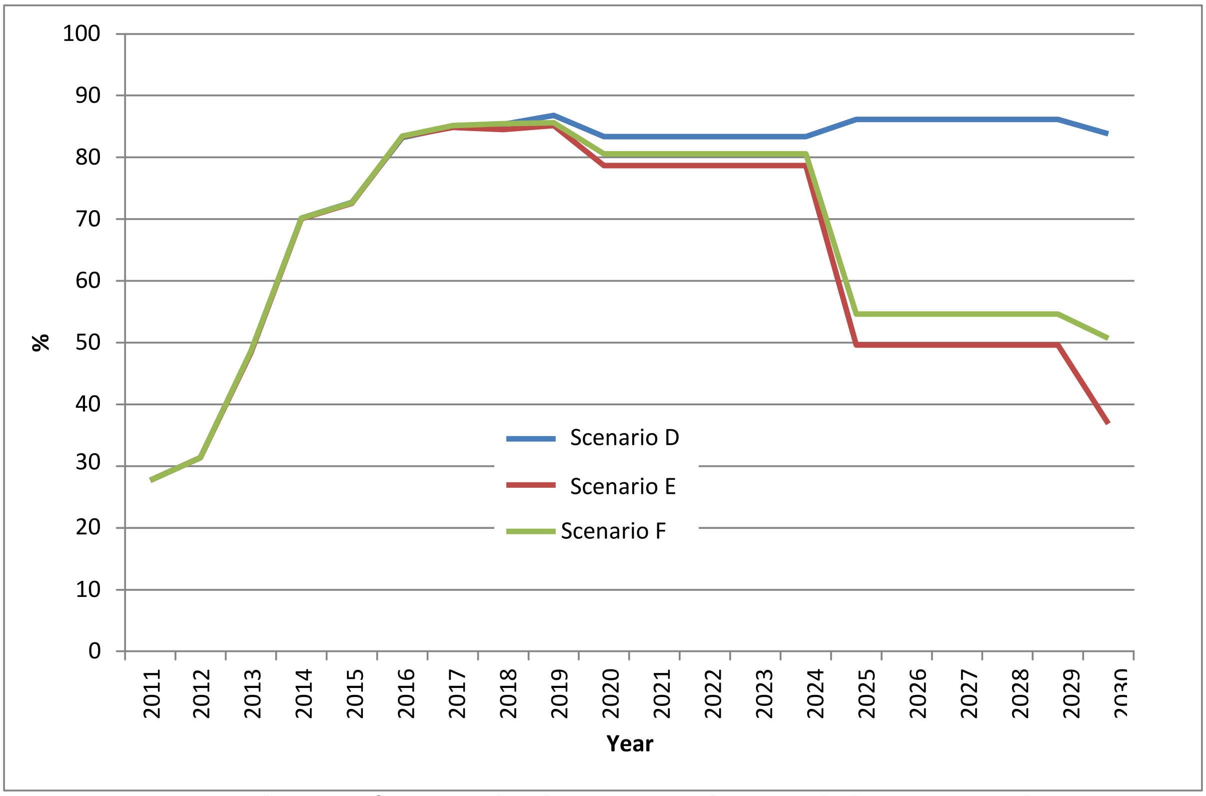
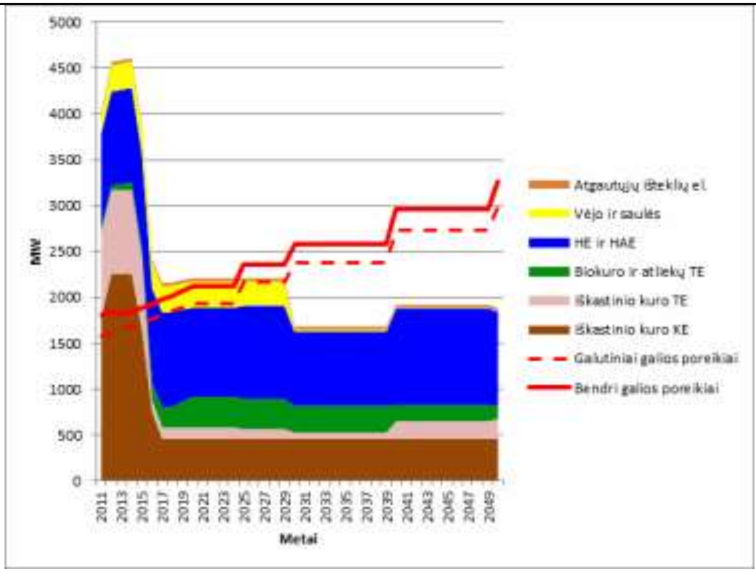


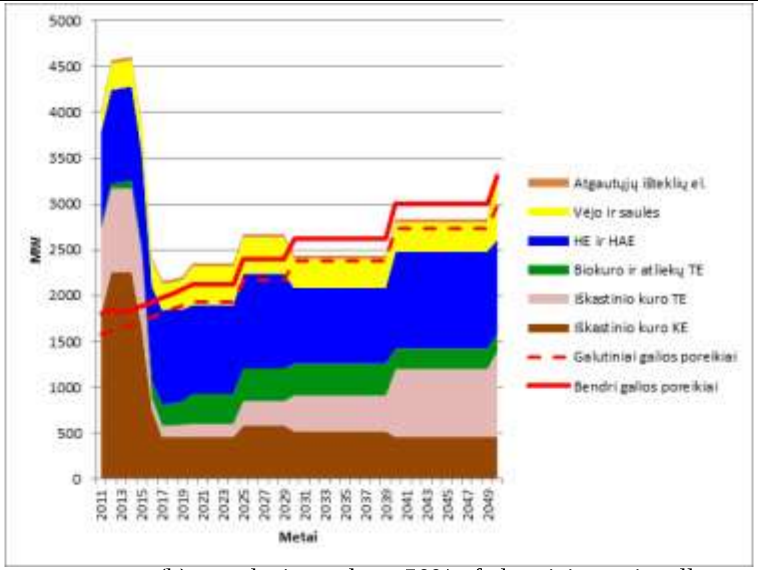
Figure 16. Contribution of RER technologies to total national electricity production

58. One of the key roles in enhancing the country's energy security should be given to the most efficient cogeneration plants running on fossil fuels. Given the greater scale of local electricity production, its role is increasing. In certain cases pertaining to electricity production they can partially replace cogeneration plants running on renewable energy resources because they generate the same heat volume but at the same time a much larger amount of electricity (higher Cb factor). Where under Scenario D the share of cogeneration plants using fossil fuels in meeting total national electricity demand should be reduced to 2 to 3% as soon as possible, under Scenario F the share of such plants between 2016 and 2020 should be increased from 2 to 3% to around 10% by 2025. Around 2030 their contribution to meeting total national electricity demand could account for about 15%, and in 2040 – as much as 27 to 30%. Under Scenario E such cogeneration plants should meet 15 to 16% of the country's total electricity demand already in 2025. By 2030 their contribution should be increased to 35 to 36% while around 2040 their electricity generation should cover over 50% of the country's total electricity demand.

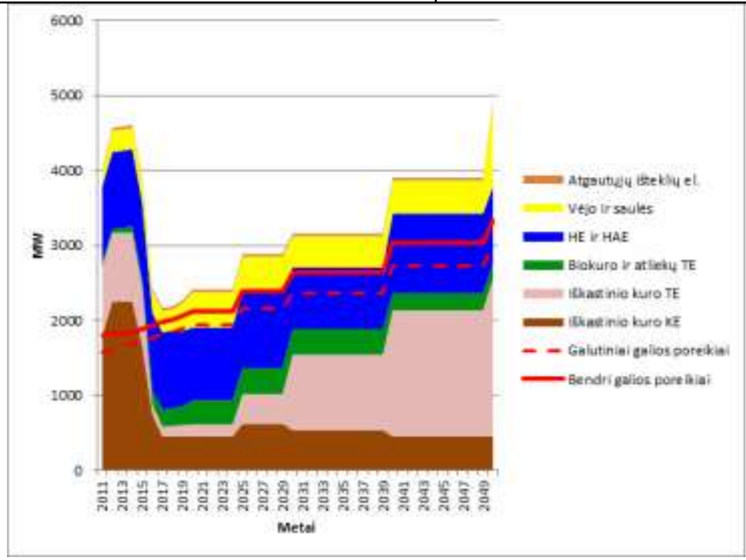
59. The dynamics of installed capacity of the country's power plants are shown in Fig. 17 while new, modernised or recovered capacities under the scenarios in question are summarised in Table 10. It essentially repeats the trends dominating electricity production.



(a) without limiting import



(b) producing at least 50% of electricity nationally



(c) producing at least 80% of electricity nationally

Fig. 17. Installed capacities of power plants under Scenarios D, E and F. (***Note:*** Final demand here includes electrical capacity needs of AB Orlen and boiler facilities).

Metai	Year
Atgautųjų išteklių el.	Recovered resource energy
Vėjo ir saulės	Wind and solar
HE ir HAE	Hydropower
Biokuro ir atliekų TE	Biofuel and waste cogeneration plants

Iškastinio kuro TE	Fossil fuel cogeneration plants
Iškastinio kuro KE	Fossil fuel condensing plants
Galutiniai galios poreikiai	Final capacity demand
Bendri galios poreikiai	Total capacity demand

Table 10. New, modernised or recovered capacities of the country's power plants, MW

Power plant type	***Without limiting import (Scenario D)***				***Producing at least 50% of electricity nationally***				***Seeking to produce at least 80% of electricity nationally (Scenario E)***			
	2014-	***2016-***	***2020-***	***2025-***	***2014-***	***2016-***	***2020-***	***2025-***	***2014-***	***2016-***	***2020-***	***2025-***
Gas-based condensing							130.5				168.7	
Gas-based cogeneration plants				39.9				39.9				39.9
Gas turbine cogeneration				16.8				15.8				169.5
Gas engine cogeneration plants						20.0	34.5	25.5		33.9	34.9	25.5
Biofuel and waste-based	95.8	118.9	2.1	52.6	103.2	98.9	37.7	88.4	101.9	95	36.9	75.9
Biogas-based cogeneration	15.3	26.4	3.5	12.2	14.0	27.7	3.7	12.5	14.3	27.4	3.7	20.0
Small hydropower plants	0.9	1.8	2.3	15.0	0.9	1.8	2.3	15.0	0.9	1.8	2.3	15.0
Wind power plants						134.4	1.5	161.7		185.4		210.5
Straw-based cogeneration		7.3				10.8	0.2	0.2		10.8	0.4	0.2
CCGT cogeneration plants							100.0	137.7			216.7	469.5
Total:	**111.9**	**154.3**	**7.9**	**136.5**	**118.1**	**293.6**	**310.3**	**496.5**	**117.1**	**354.3**	**463.6**	**1025.9**

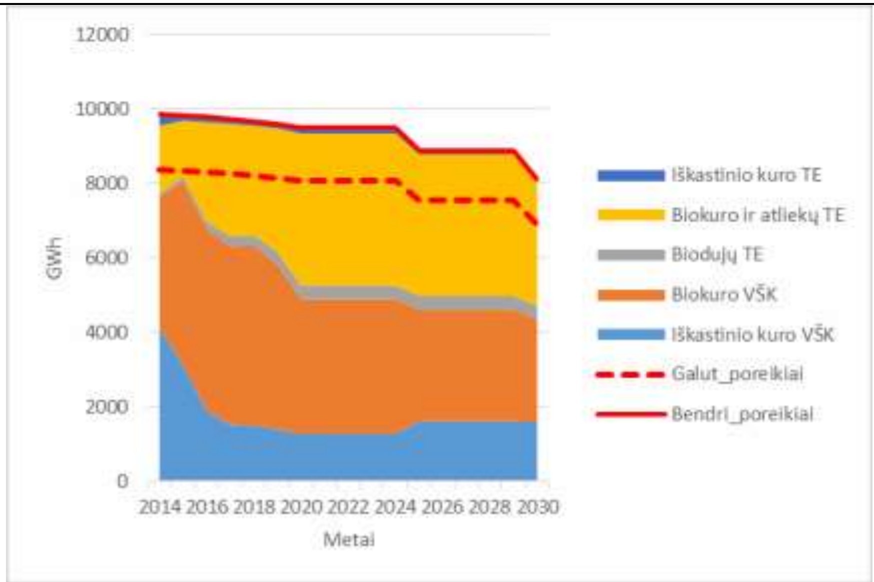
Note: Installed capacities of power plants should in practice be selected as close as possible to calculation results but taking into account discrete sizes of power plant equipment and specific construction features.

60. Without limiting electricity imports in the country between 2014 and 2030, it would be reasonable to install cogeneration plants running on biofuel and municipal waste of the electric capacity of about 270 MW, biogas-based cogeneration plants of about 60 MW, gas cogeneration plants of about 60 MW and small cogeneration plants of about 20 MW. (Biogas-based cogeneration plants may also be installations where biogas generation and heat and electricity production happen in different places). With a view to producing at least 50% of electricity demand nationally, the installed electric capacity of biofuel and municipal waste-based cogeneration plants would increase up to around 340 MW while the total capacity of gas-based cogeneration plants (including gas engine plants) would grow up to 500 MW. With a view to producing at least 80% of electricity nationally as of 2050, by 2030 the new installed capacity of biofuel and municipal waste-based cogeneration plants would drop to 320 MW but that of gas cogeneration plants would have to be increased to 1160 MW.

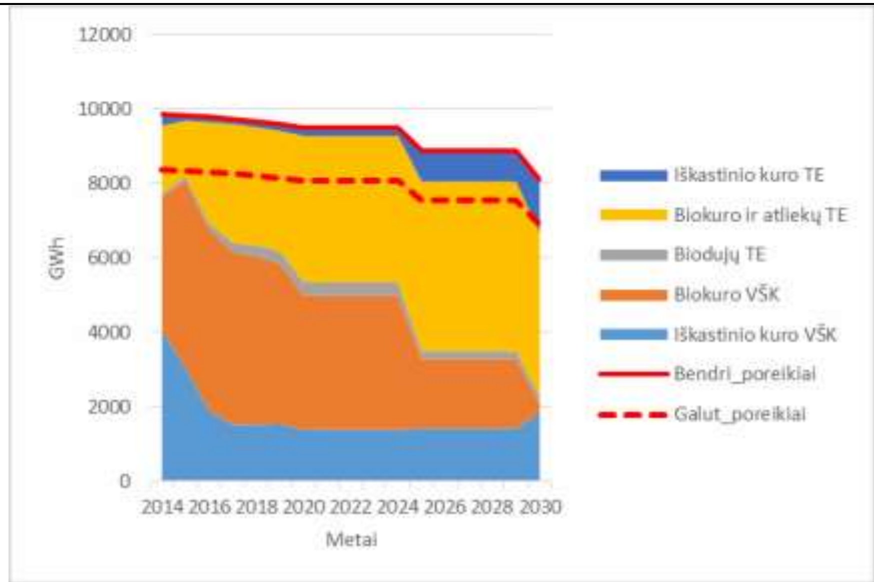
61. Given favourable electricity import conditions and no artificial restrictions in this area, a significant share of heat supplied as district heating should be produced using water heating boilers running on biofuel. The maximum heat generation by such water heating boilers would be achieved by around 2015-2018. During this period the annual heat generation by such boilers should reach about 4.4 to 4.8 TWh. Between 2019 and 2025 heat production by water heating boilers running on biofuel will decrease because of the growing heat production by municipal waste-based cogeneration plants and decreasing heat demand. Between 2025 and 2040 or even 2050 heat production by such boilers would remain rather stable and vary between 2.7 and 3.1 TWh.

District heating production under scenarios D, E and F is summarised in Fig. 18 and Tables 11 to 13.

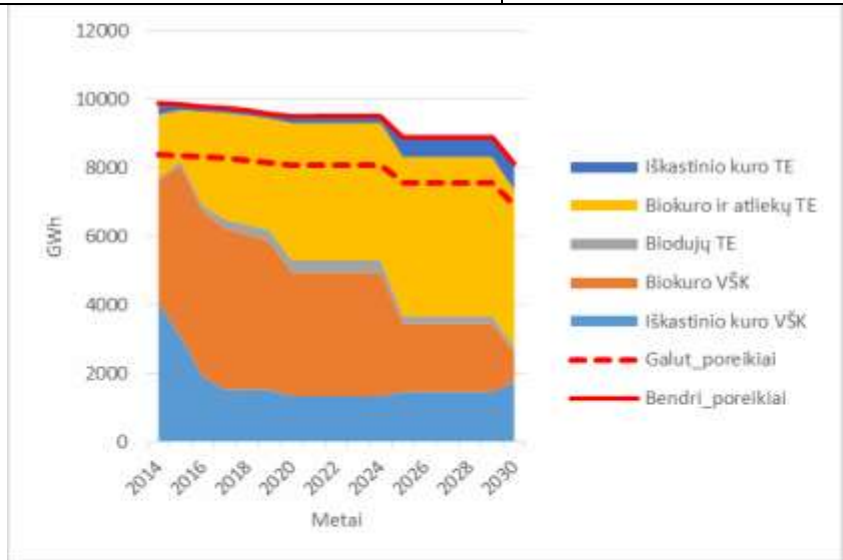
62. Heat generation by cogeneration plants running on biofuel and municipal waste under Scenario D should be increased to 4.1 TWh already by 2020. Later the absolute contribution of this technology to the total district heating production would start to decrease mainly due to decreasing heat demand, the end of the life cycle and emerging cogeneration plants running on fossil fuels the economic attractiveness of which will be enhanced by the shrinking difference between prices of biofuel and natural gas. Annual production of cogeneration plants based on biofuel and municipal waste in 2030 and 2040 would reach around 3.3 TWh and 2.2 TWh respectively. The most significant drop within this technology group would be associated with biofuel-based cogeneration plants. Production levels of cogeneration plants running on municipal waste would remain rather stable.



(a) without limiting import



(b) producing at least 50% of electricity nationally



(c) producing at least 80% of electricity nationally

Fig. 18. Rational heat generation in the country's DH systems by technology with up to 50% of support allocated for investment

Metai	Year
Iškastinio kuro TE	Fossil fuel cogeneration plants

Biokuro ir atliekų TE	Biofuel and waste cogeneration plants
Biodujų TE	Biogas cogeneration plants
Biokuro VŠK	Biogas water heating boilers
Iškastinio kuro VŠK	Fossil fuel water heating boilers
Galut_poreikiai	Final demand
Bendri_poreikiai	Total demand

Table 11. Rational heat generation in the country's district heating systems under Scenario D by group of technologies (without limiting electricity import and providing support to no more than 50% of required investment), GWh

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
Water heating boilers on fossil fuels	4122	3129	1900	1525	1500	1396	1281	1281	1281	1281	1281	1613	1613	1613	1613	1613	1603
Biofuel-based water heating boilers	3527	4951	4890	4797	4826	4440	3619	3619	3619	3619	3619	3003	3003	3003	3003	3003	2741
Biogas-based cogeneration plants	72.3	118.9	187.3	260.9	294.4	328	361.1	361.1	361.1	361.1	361.1	364.3	364.3	364.3	364.3	364.3	366.9
Biofuel and waste cogeneration plants	1836	1495	2672	3024	2934	3321	4088	4088	4088	4088	4088	3808	3808	3808	3808	3808	3317
Fossil fuel cogeneration plants	322.2	148.2	146.4	133.1	119.1	112.2	157	157	157	157	157	109.2	109.2	109.2	109.2	109.2	91.6
Production_total	9880	9842	9796	9741	9673	9597	9506	9506	9506	9506	9506	8898	8898	8898	8898	8898	8120
Network_losses	1492	1485	1476	1465	1453	1439	1421	1421	1421	1421	1421	1330	1330	1330	1330	1330	1213
Final_demand	8388	8357	8320	8276	8221	8158	8085	8085	8085	8085	8085	7568	7568	7568	7568	7568	6907
Total_demand	9880	9842	9796	9741	9673	9597	9506	9506	9506	9506	9506	8897	8897	8897	8897	8897	8120

Table 12. Rational heat generation in the country's district heating systems under Scenario E by group of technologies (seeking to produce at least 80% of electricity nationally as of 2050 and providing support to no more than 50% of required investment), GWh

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
Water heating boilers on fossil fuels	4044	3044	1884	1524	1530	1541	1389	1389	1389	1389	1389	1422	1422	1422	1422	1422	1854
Biofuel-based water heating boilers	3606	5037	4875	4617	4523	4309	3599	3599	3599	3599	3599	1864	1864	1864	1864	1864	217.4
Biogas-based cogeneration plants	72.3	118.9	178.5	259.5	293.1	326.6	359.9	359.9	359.9	359.9	359.9	212.8	212.8	212.8	212.8	212.8	218.6
Biofuel and waste cogeneration plants	1836	1495	2712	3200	3167	3242	3934	3934	3934	3934	3934	4556	4556	4556	4556	4556	4377
Fossil fuel cogeneration plants	322.1	148.1	145.6	140.4	159.8	179.4	224.3	224.3	224.3	224.3	224.3	842.1	842.1	842.1	842.1	842.1	1453
Production_total	9880	9842	9796	9741	9673	9597	9506	9506	9506	9506	9506	8897	8897	8897	8897	8897	8120
Network_losses	1492	1485	1476	1465	1453	1439	1421	1421	1421	1421	1421	1330	1330	1330	1330	1330	1213
Final_demand	8388	8357	8320	8276	8221	8158	8085	8085	8085	8085	8085	7568	7568	7568	7568	7568	6907
Total_demand	9880	9842	9796	9741	9673	9597	9506	9506	9506	9506	9506	8897	8897	8897	8897	8897	8120

Table 13. Rational heat generation in the country's district heating systems under Scenario F by group of technologies (seeking to produce at least 50 % of electricity demand nationally as of 2025 and providing support to no more than 50% of required investment), GWh

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
Water heating boilers on fossil fuels	4068	3078	1905	1543	1528	1532	1346	1346	1346	1346	1346	1470	1470	1470	1470	1470	1763
Biofuel-based water heating boilers	3581	4999	4823	4695	4531	4324	3602	3602	3602	3602	3602	1999	1999	1999	1999	1999	848.8
Biogas-based cogeneration plants	72.3	118.9	175.7	259.1	292.7	326.2	359.5	359.5	359.5	359.5	359.5	211.7	211.7	211.7	211.7	211.7	163.9
Biofuel and waste cogeneration plants	1836	1495	2746	3111	3189	3263	4002	4002	4002	4002	4002	4636	4636	4636	4636	4636	4583
Fossil fuel cogeneration plants	322.1	151.3	145.6	132.8	132.8	152.2	197.3	197.3	197.3	197.3	197.3	581	581	581	581	581	759.9
Production_total	9880	9842	9795	9741	9673	9597	9506	9506	9506	9506	9506	8897	8897	8897	8897	8897	8119
Network_losses	1492	1485	1476	1465	1453	1439	1421	1421	1421	1421	1421	1330	1330	1330	1330	1330	1213
Final_demand	8388	8357	8320	8276	8221	8158	8085	8085	8085	8085	8085	7568	7568	7568	7568	7568	6907
Total_demand	9880	9842	9796	9741	9673	9597	9506	9506	9506	9506	9506	8897	8897	8897	8897	8897	8120

63. Under Scenario E heat production by cogeneration plants running on biofuel and municipal waste should be increased to 3.9 TWh by 2020. The maximum heat production levels of these cogeneration plants would be reached between 2025 and 2040 amount to 4.4 to 4.6 TWh per year. Between 2040 and 2050 annual production of these plants is estimated at around 3.2 TWh. Decline in production for this type of heat generation technologies is attributable to decreasing heat demand and growing production by cogeneration plants running on fossil fuels. Rapidly growing heat production by cogeneration plants based on fossil fuels is in this case mainly attributable to the even-big difference between biofuel and gas prices but the national energy policy provisions seek to produce a significant share of electricity demand (over 80% after 2050) inside the country. Scenario E is also characterised by the fact that heat production by technology running on municipal waste is at the lowest level as compared between Scenarios D, E and F in question and water heating boilers running on biofuel are almost entirely pushed out of heat production.

64. With a view to producing at least 50% of electricity demand nationally as of 2025, production levels of cogeneration plants producing heat from biofuel and municipal waste should be increased to 4 TWh by 2020. These technologies would reach their peak between 2025 and 2035 at the production level of about 4.6 TWh. After that their production would be gradually declining by lower heat demand and growing heat generation by cogeneration plants running on fossil fuels. Around 2050 cogeneration plants based on biofuel and municipal waste should produce about 3.1 to 3.3 TWh of heat annually. Annual heat generation by cogeneration plants using fossil fuels would reach 1.4 to 1.5 TWh. A rational level of heat production by biofuel-based water heating boilers would be about 3.6 TWh in 2020, 2 TWh in 2025 and 0.8 to 1 TWh between 2030 and 2050.

65. There is a need to ensure that by 2020 the production share of cogeneration plants under competitive conditions within total heat supplied as district heating would be 48-49% and under favourable electricity import conditions stay at that level until around 2035 to 2040.

66. With a view to producing at least 50% of electricity demand nationally after 2025, the share of heat production by cogeneration plants in total district heating production should be increased to 61-63% in 2025 and to around 68% in 2030. In implementing the energy policy objective to produce at least 80% of electricity demand nationally as of 2050, the share of heat produced by cogeneration plants in total district heating production should be increased to about 75% by 2030.

The share of heat generated by cogeneration plants in total national district heating production under the scenarios in question is shown in Fig. 19. Figure 20 illustrates the share of heat generated by biofuel-based water heating boilers in total district heating production on the national level.

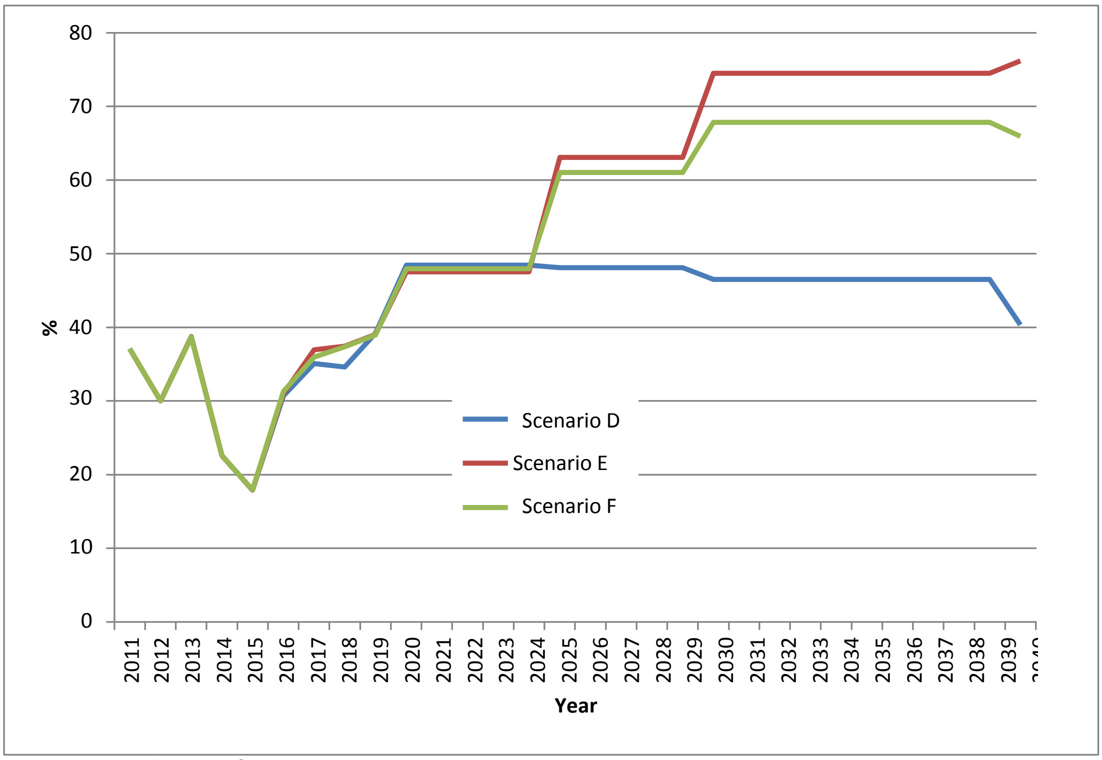


Fig. 19. Share of heat generated by cogeneration plants in total national district heating production

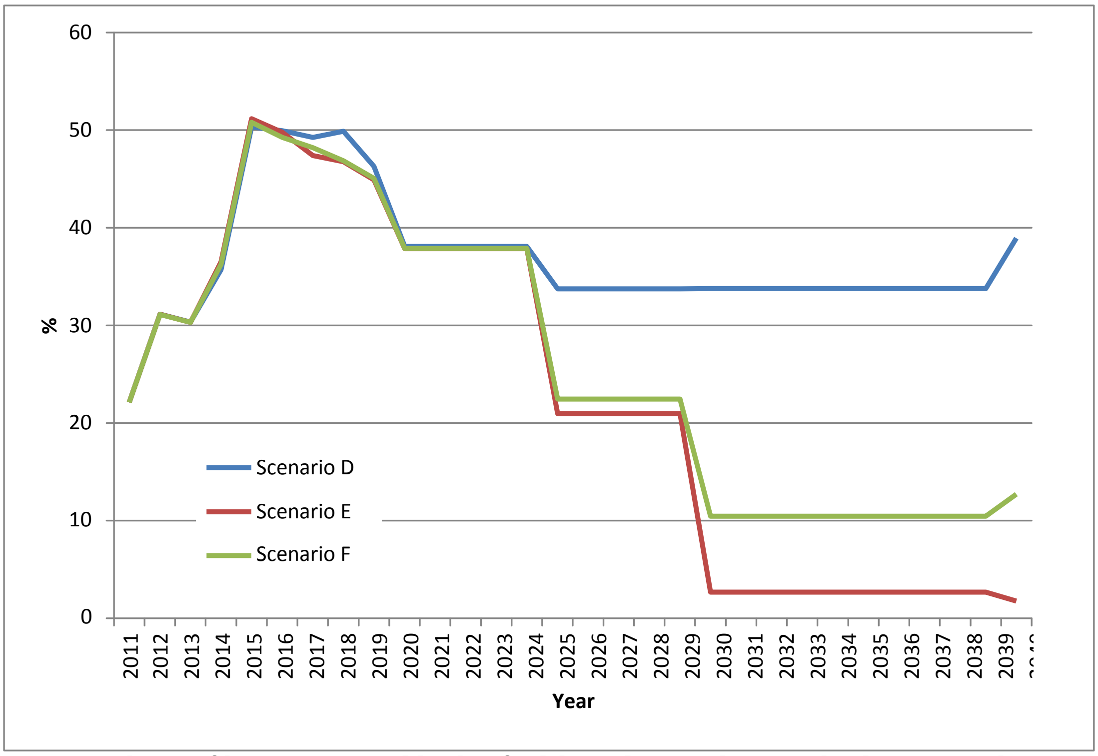
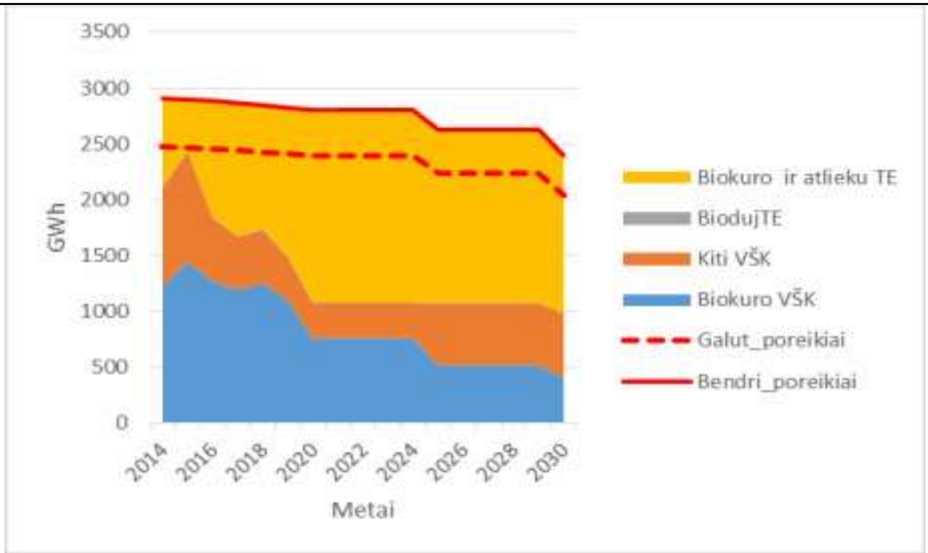


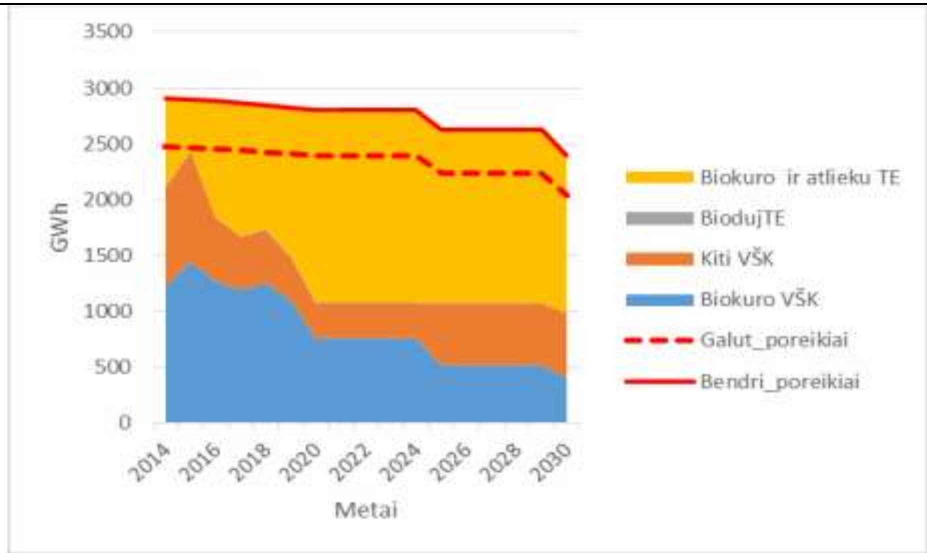
Fig. 20. Share of heat generated by biofuel-based water heating boilers in total national heat production

67. The objective to increase local electricity production significantly increase the contribution of cogeneration plants running on fossil fuels to district heating production and respectively diminishes the role water heating boilers including biofuel-based boilers. A much broader trend for using cogeneration plants in order to reach the objective of producing more electricity locally remains rather obvious and stable under all of the scenarios analysed.

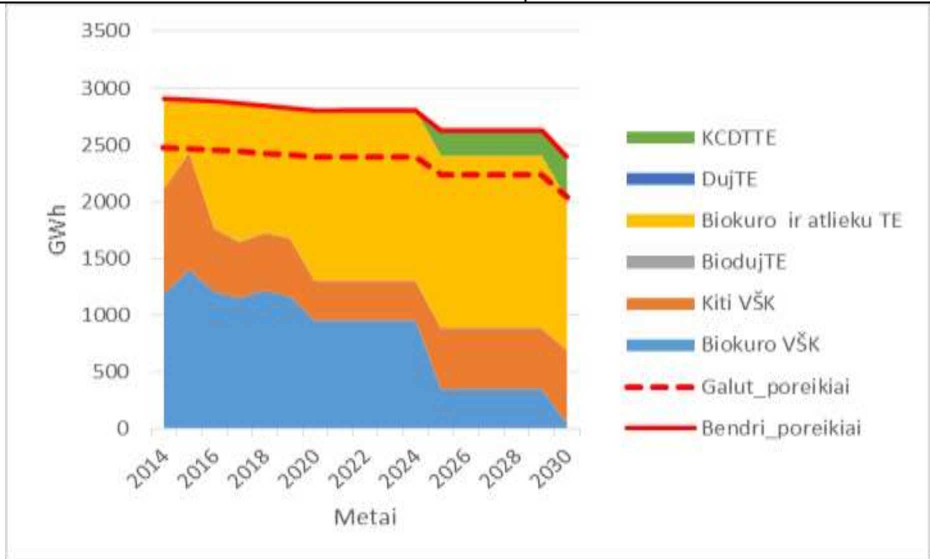
68. Development trends for cogeneration plants are even better reflected in heat production. This is shown in Fig. 21 and Tables 14 to 16 through the dynamics of heat generation in Vilnius district heating system. The data presented show that the objective to increase local electricity production significantly increase the contribution of cogeneration plants running on fossil fuels to district heating production and respectively diminishes the role water heating boilers including biofuel-based boilers. For example, in Vilnius district heating system the share of cogeneration plants in heat production between 2020 and 2030 is estimated at 59-62% while electricity import possibilities are unlimited. By 2040 this share is to drop to 44%. At the same time, with local electricity production levels increasing to 50% and 80%, in 2020 to 2030 the share of cogeneration plants in district heating production increases to 54 to 71% and 51 to 83% respectively. In 2040 the share of cogeneration plants in total heat production in these cities under Scenarios E and F is estimated at 68% and 90% respectively. These data are summarised in Fig. 22. A drop in heat production at cogeneration plants in 2014-2015 is associated with the high price of gas used by power plants and a relatively low ratio of electricity and heat generated (Cb factor) characteristic of existing cogeneration plants currently using fossil fuels.



(a) without limiting import



(b) producing at least 50% of electricity nationally



(c) producing at least 80% of electricity nationally

Fig. 21. Rational heat generation in Vilnius DH system by technology with up to 50% of support allocated for investment

Metai	Year
Biokuro ir atliekų TE	Biofuel and waste cogeneration plants
BiodujTE	Biogas cogeneration plants
Kiti VŠK	Other WHBs

Biokuro VŠK	Biofuel WHBs
Galut_poreikiai	Final demand
Bendri_poreikiai	Total demand
KCDTTE	CCGT CHPs
DujTE	Gas CHPs

Table 14. Rational heat generation in Vilnius district heating system under Scenario D by group of technologies (without limiting electricity import and providing support to no more than 50% of required investment), GWh

Technologies	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Biofuel-based water heating boilers	1226	1442	1273	1189	1255	1098	759.1	759.1	759.1	759.1	759.1	521	521	521	521	521	404.1
Other water heating boilers	892.3	991.5	563.2	480.2	476.7	387.9	310.7	310.7	310.7	310.7	310.7	547.5	547.5	547.5	547.5	547.5	582.4
Biogas-based cogeneration plants	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0
Biofuel and waste cogeneration plants	780	455	1039	1191	1109	1334	1724	1724	1724	1724	1724	1546	1546	1546	1546	1546	1408
Total production	2907	2897	2884	2869	2849	2828	2802	2802	2802	2802	2802	2623	2623	2623	2623	2623	2394
Network losses	430.3	428.7	426.8	424.5	421.7	418.5	414.8	414.8	414.8	414.8	414.8	388.2	388.2	388.2	388.2	388.2	354.3
Final demand	2477	2468	2457	2444	2428	2409	2388	2388	2388	2388	2388	2235	2235	2235	2235	2235	2040
Total demand	2907	2897	2884	2869	2849	2828	2802	2802	2802	2802	2802	2623	2623	2623	2623	2623	2394

Table 15. Rational heat generation in Vilnius district heating system under Scenario E by group of technologies (seeking to produce at least 80% of electricity nationally as of 2050 and providing support to no more than 50% of required investment), GWh

Technologies	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Biofuel-based water heating boilers	1253	1475	1285	1218	1284	1229	1033	1033	1033	1033	1033	330.6	330.6	330.6	330.6	330.6	4.2
Other water heating boilers	865.1	958.2	508.5	469.5	482.5	491.5	344.5	344.5	344.5	344.5	344.5	891.9	891.9	891.9	891.9	891.9	1235.8
Biogas-based cogeneration plants	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0
Biofuel and waste cogeneration plants	780.4	455.3	1082	1173	1074	1099	1416	1416	1416	1416	1416	1392	1392	1392	1392	1392	1154
Gas cogeneration plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53
CCGT cogeneration plants	0	0	0	0	0	0	0	0	0	0	0	414.5	414.5	414.5	414.5	414.5	794.9
Total production	2907	2897	2884	2869	2849	2828	2802	2802	2802	2802	2802	2623	2623	2623	2623	2623	2394
Network losses	430.3	428.7	426.8	424.5	421.7	418.5	414.8	414.8	414.8	414.8	414.8	388.2	388.2	388.2	388.2	388.2	354.3
Final demand	2477	2468	2457	2444	2428	2409	2388	2388	2388	2388	2388	2235	2235	2235	2235	2235	2040
Total demand	2907	2897	2884	2869	2849	2828	2802	2802	2802	2802	2802	2623	2623	2623	2623	2623	2394

Table 16. Rational heat generation in Vilnius district heating system under Scenario F by group of technologies (seeking to produce at least 50 % of electricity demand nationally as of 2025 and providing support to no more than 50% of required investment), GWh

Technologies	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Biofuel-based water heating boilers	1188	1400	1207	1152	1219	1164	952.9	952.9	952.9	952.9	952.9	350.3	350.3	350.3	350.3	350.3	45.1
Other water heating boilers	930.2	1030	554.9	491.4	503.9	512.4	343.6	343.6	343.6	343.6	343.6	532.8	532.8	532.8	532.8	532.8	647.7
Biogas-based cogeneration plants	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0
Biofuel and waste cogeneration plants	780	455	1113	1217	1118	1143	1497	1497	1497	1497	1497	1513	1513	1513	1513	1513	1335
Gas cogeneration plants	0	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCGT cogeneration plants	0	0	0	0	0	0	0	0	0	0	0	218.4	218.4	218.4	218.4	218.4	367
Total production	2907	2897	2884	2869	2849	2828	2802	2802	2802	2802	2802	2623	2623	2623	2623	2623	2394
Network losses	430.3	428.7	426.8	424.5	421.7	418.5	414.8	414.8	414.8	414.8	414.8	388.2	388.2	388.2	388.2	388.2	354.3
Final demand	2477	2468	2457	2444	2428	2409	2388	2388	2388	2388	2388	2235	2235	2235	2235	2235	2040
Total demand	2907	2897	2884	2869	2849	2828	2802	2802	2802	2802	2802	2623	2623	2623	2623	2623	2394

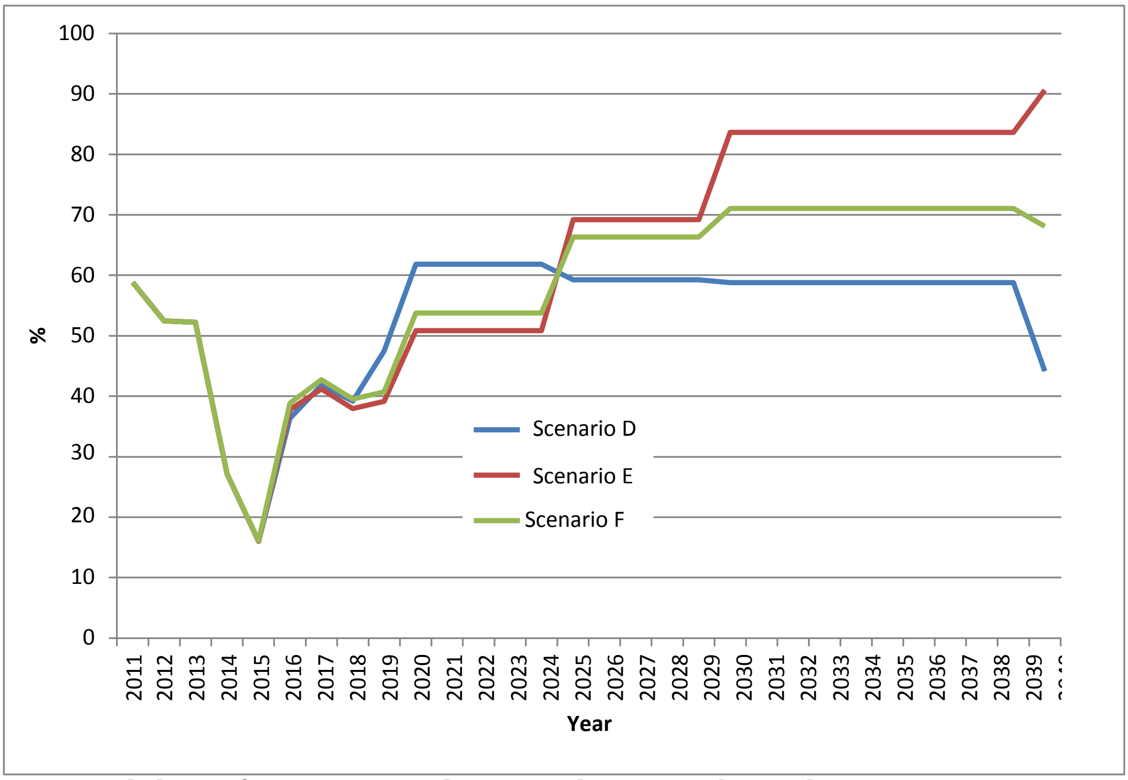
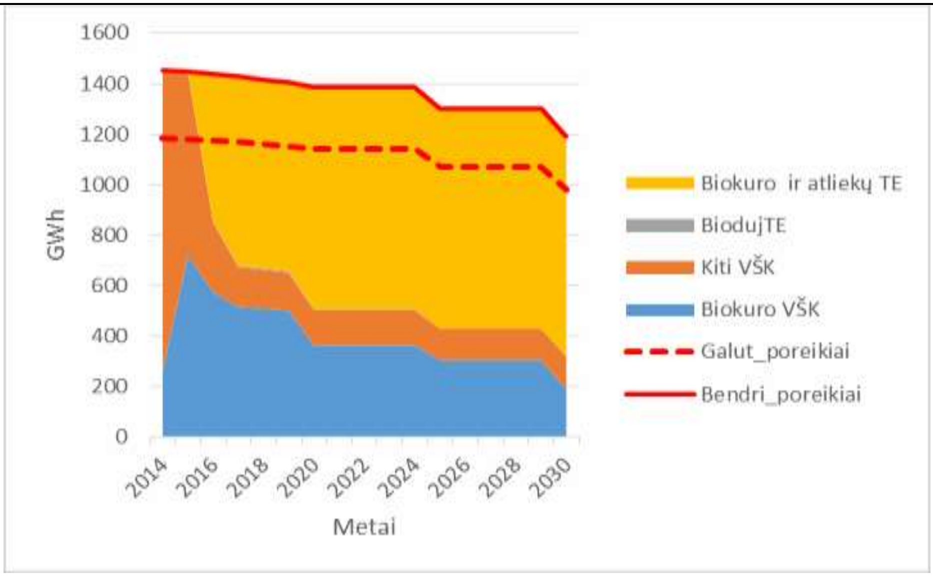


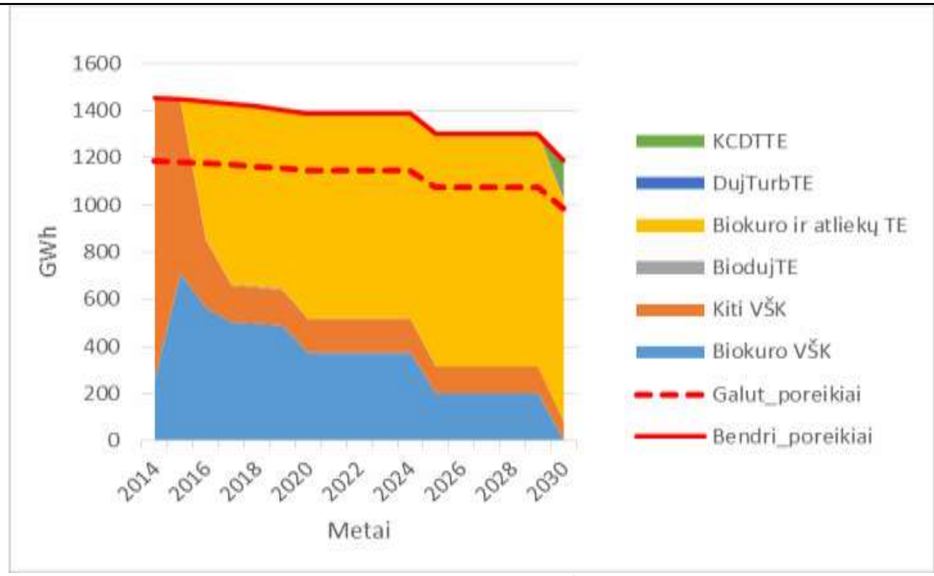
Fig. 22. Rational share of cogeneration plants in Vilnius City district heating system

69. Kaunas district heating system shows similar processes (see Fig. 23 and Tables 17 to 19). However Kaunas district heating system also demonstrates another possible process: with the increasing electricity demand (and local production levels going up) cogeneration plants running on biofuels may become more economically attractive than cogeneration plants based on municipal waste. In such a case greater electricity demand will pre-determine the choice of a technology that requires less investment and runs on more expensive fuel so that it is possible to install greater capacities of a biofuel-based cogeneration plant. Admittedly, this phenomenon is highly dependent on comparative investment in one and the other technologies. With a slight increase of investment in biofuel-based cogeneration plants or less investment in cogeneration plants running on municipal waste, the biofuel-based cogeneration plant may fail to gain economic advantage as compared to cogeneration plants running on municipal waste. However a much broader trend for using cogeneration plants in order to reach the objective of producing more electricity locally remains rather obvious and stable.

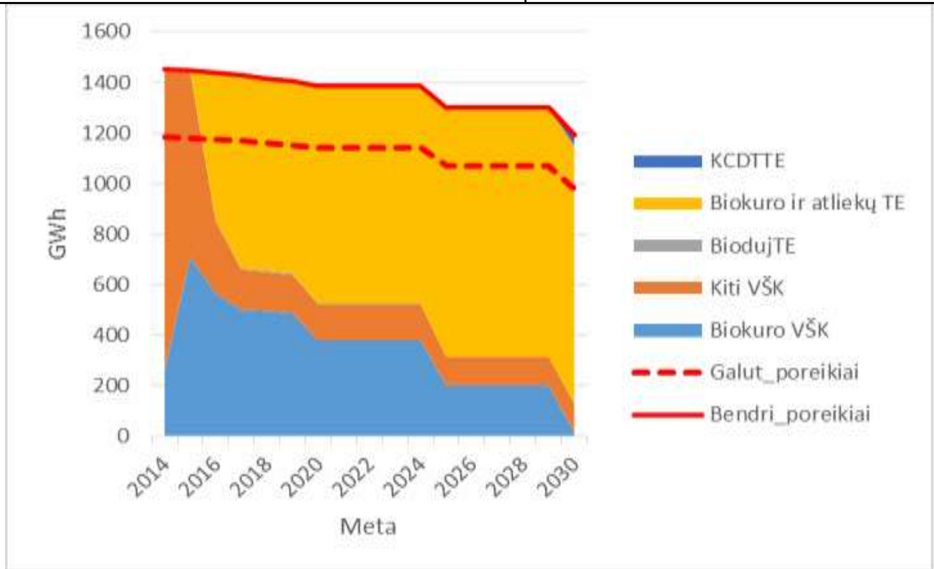
70. Rational heat production by cogeneration plants as the share in total production is presented in Fig. 24. Under Scenario D the share of rational heat production by cogeneration plants between 2020 and 2030 is estimated to be between 62 and 73%. By 2040 this indicator still grows slightly and reaches 76%. Under Scenarios E and F the share of production by cogeneration plants between 2020 and 2030 is estimated to be between 62 to 93% and 62 to 89%. Until 2040 these indicators change but slightly.



(a) without limiting import



(b) producing at least 50% of electricity nationally



(c) producing at least 80% of electricity nationally

Fig. 23. Rational heat generation in Kaunas DH system by technology with up to 50% of support allocated for investment

Metai	Year
Biokuro ir atliekų TE	Biofuel and waste cogeneration plants
BiodujTE	Biogas cogeneration plants

Kiti VŠK	Other WHBs
Biokuro VŠK	Biofuel WHBs
Galut_poreikiai	Final demand
Bendri_poreikiai	Total demand
KCDTTE	CCGT CHPs
DujTE	Gas CHPs
DujTurbTE	Gas turbine CHPs

Table 17. Rational heat generation in Kaunas district heating system under Scenario D by group of technologies (without limiting electricity import and providing support to no more than 50% of required investment), GWh

Technologies	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
Biofuel-based water heating boilers	262.1	720.5	573.8	514.7	509	500.7	362.9	362.9	362.9	362.9	362.9	304.6	304.6	304.6	304.6	304.6	190.2
Other water heating boilers	1185	720	276.8	157.9	153.5	150.8	139.9	139.9	139.9	139.9	139.9	125.9	125.9	125.9	125.9	125.9	128.9
Biogas cogeneration plants	5.2	5.2	5.2	5.2	5.2	5.2	3.1	3.1	3.1	3.1	3.1	0	0	0	0	0	0
Biofuel and waste cogeneration plants	0	0	581.2	749.3	747.6	745.7	879.5	879.5	879.5	879.5	879.5	868.9	868.9	868.9	868.9	868.9	870.1
Total production	1452	1446	1437	1427	1415	1402	1385	1385	1385	1385	1385	1299	1299	1299	1299	1299	1189
Network losses	268	265.8	262.1	258.2	253.9	249.5	242.5	242.5	242.5	242.5	242.5	227.4	227.4	227.4	227.4	227.4	208.1
Final demand	1184	1180	1175	1169	1162	1153	1143	1143	1143	1143	1143	1072	1072	1072	1072	1072	981
Total demand	1452	1446	1437	1427	1415	1403	1386	1386	1386	1386	1386	1300	1300	1300	1300	1300	1189

Table 18. Rational heat generation in Kaunas district heating system under Scenario E by group of technologies (seeking to produce at least 80 % of electricity demand nationally as of 2050 and providing support to no more than 50% of required investment), GWh

Technologies	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
Biofuel-based water heating boilers	262.1	708.2	565	502.4	496.7	488.4	373.8	373.8	373.8	373.8	373.8	201.8	201.8	201.8	201.8	201.8	3.5
Other water heating boilers	1185	732.4	285.5	157.8	153.5	150.8	143.1	143.1	143.1	143.1	143.1	113.7	113.7	113.7	113.7	113.7	81.8
Biogas cogeneration plants	5.2	5.2	5.2	5.2	5.2	5.2	3.1	3.1	3.1	3.1	3.1	0	0	0	0	0	0
Biofuel and waste cogeneration plants	0	0	581.2	761.7	760	758.1	865.3	865.3	865.3	865.3	865.3	984	984	984	984	984	948.4
Gas turbine cogeneration plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.9
CCGT cogeneration plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	134.5
Total production	1452	1446	1437	1427	1415	1403	1385	1385	1385	1385	1385	1300	1300	1300	1300	1300	1189
Network losses	268	265.8	262.1	258.2	253.9	249.5	242.5	242.5	242.5	242.5	242.5	227.4	227.4	227.4	227.4	227.4	208.1
Final demand	1184	1180	1175	1169	1162	1153	1143	1143	1143	1143	1143	1072	1072	1072	1072	1072	981
Total demand	1452	1446	1437	1427	1415	1403	1386	1386	1386	1386	1386	1300	1300	1300	1300	1300	1189

Table 19. Rational heat generation in Kaunas district heating system under Scenario F by group of technologies (seeking to produce at least 50 % of electricity demand nationally as of 2025 and providing support to no more than 50% of required investment), GWh

Technologies	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Biofuel-based water heating boilers	262.1	708.2	565.2	502.4	496.7	488.4	379.6	379.6	379.6	379.6	379.6	202.5	202.5	202.5	202.5	202.5	17.8
Other water heating boilers	1185	732.3	285.8	157.9	153.5	150.8	143.9	143.9	143.9	143.9	143.9	114.2	114.2	114.2	114.2	114.2	113.4
Biogas cogeneration plants	5.2	5.2	5.2	5.2	5.2	5.2	3.1	3.1	3.1	3.1	3.1	0	0	0	0	0	0
Biofuel and waste cogeneration plants	0	0	580.8	761.6	759.8	758	858.8	858.8	858.8	858.8	858.8	982.7	982.7	982.7	982.7	982.7	1018.9
CCGT cogeneration plants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39
Total production	1452	1446	1437	1427	1415	1402	1385	1385	1385	1385	1385	1299	1299	1299	1299	1299	1189
Network losses	268	265.8	262.1	258.2	253.9	249.5	242.5	242.5	242.5	242.5	242.5	227.4	227.4	227.4	227.4	227.4	208.1
Final demand	1184	1180	1175	1169	1162	1153	1143	1143	1143	1143	1143	1072	1072	1072	1072	1072	981
Total demand	1452	1446	1437	1427	1415	1403	1386	1386	1386	1386	1386	1300	1300	1300	1300	1300	1189

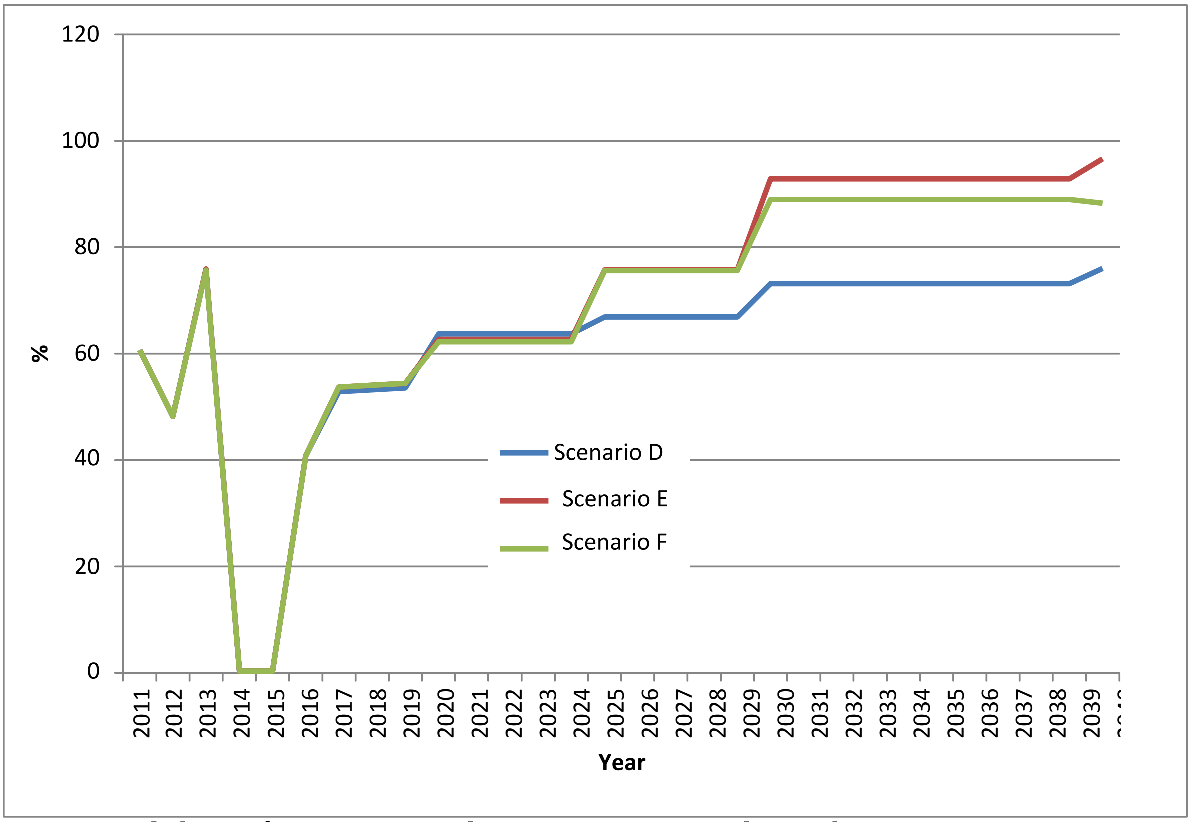


Fig 24. Rational share of cogeneration plants in Kaunas City district heating system

71. Heat production by cogeneration plants using biofuel in total heat generated by cogeneration plants should account for a major share. On the national scale the rational share of such cogeneration plants in total heat production by cogeneration plants (see Fig. 25) should reach about 75-85% within the next few years and stay at that level at least until 2040.

72. In 2014-2030 heat produced from biofuel by Vilnius and Kaunas City district heating systems is estimated at 60 to 100% of total heat generated by cogeneration plants (see Fig. 26 and 27) A larger share is attributable to the beginning of the period and a smaller one – to the end. A relative decline of heat production by cogeneration plants running on biofuels may be substantially affected by the energy policy objective chosen on the national level to increase local electricity generation encouraging faster development of cogeneration plants using fossil fuels. This is best shown by the data presented in Fig. 26.

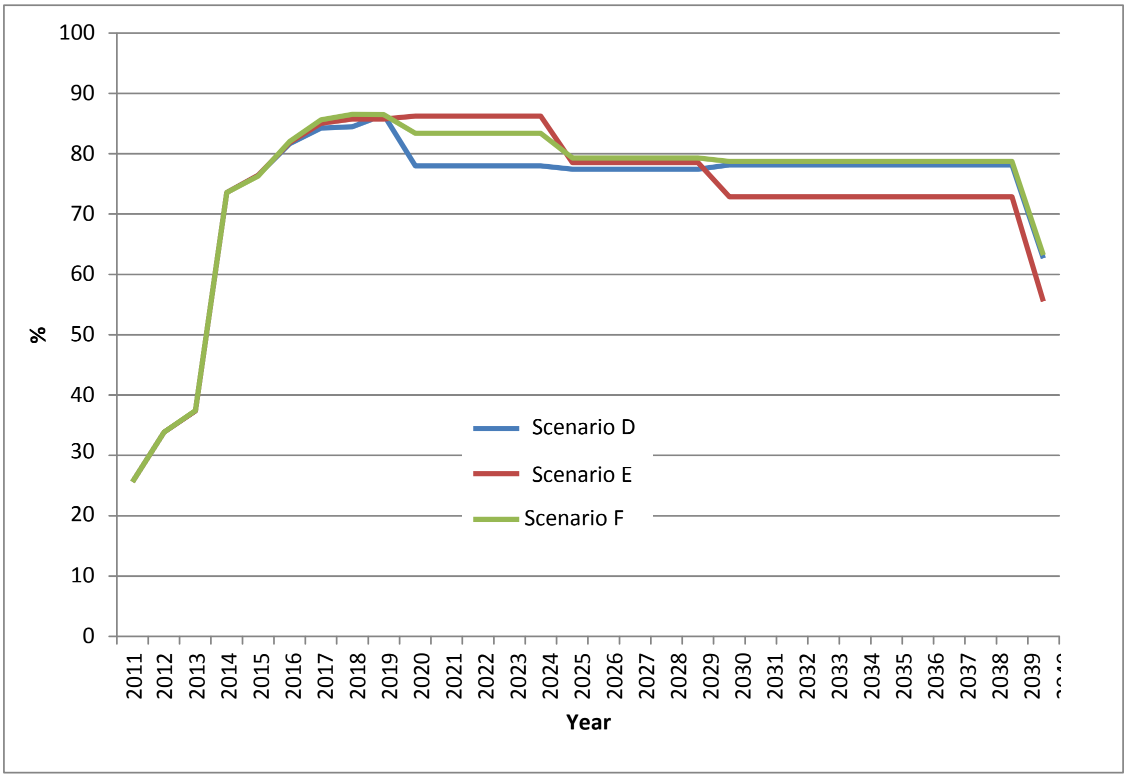


Fig. 25. Share of heat produced nationally by biofuel-based cogeneration plants in total heat generation by cogeneration plants

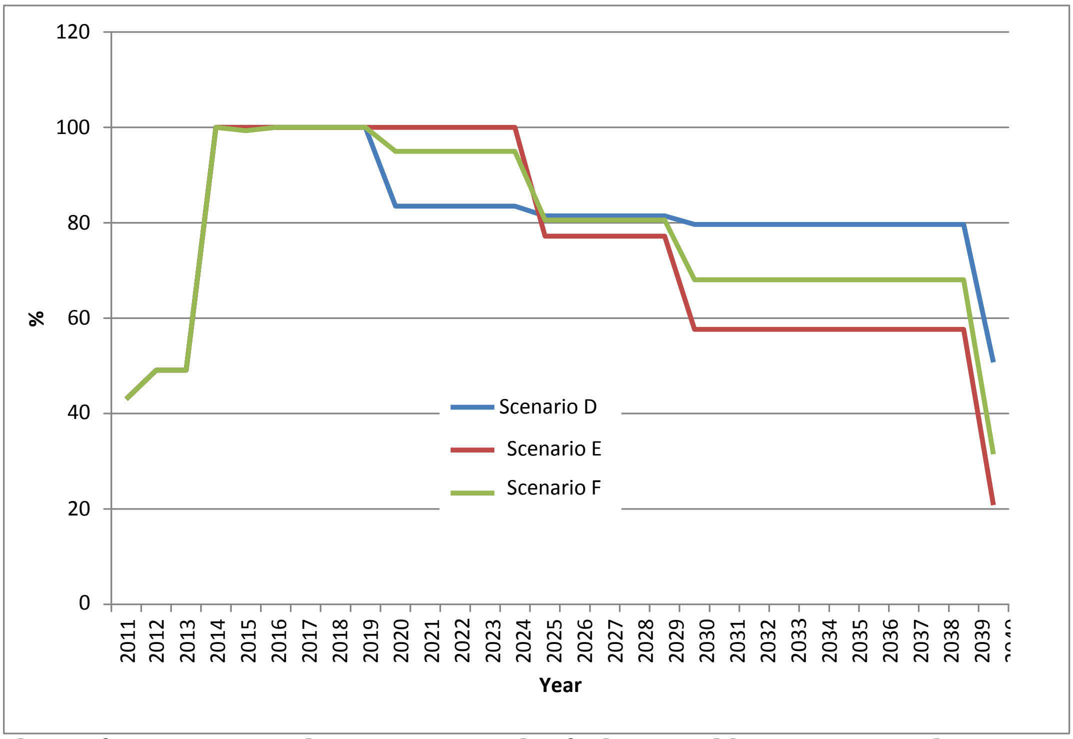


Fig. 26. Share of cogeneration plants running on biofuels in total heat generation by cogeneration plants within Vilnius district heating system (assuming that 40% of heat produced by cogeneration plants using municipal waste comes from biodegradable waste)

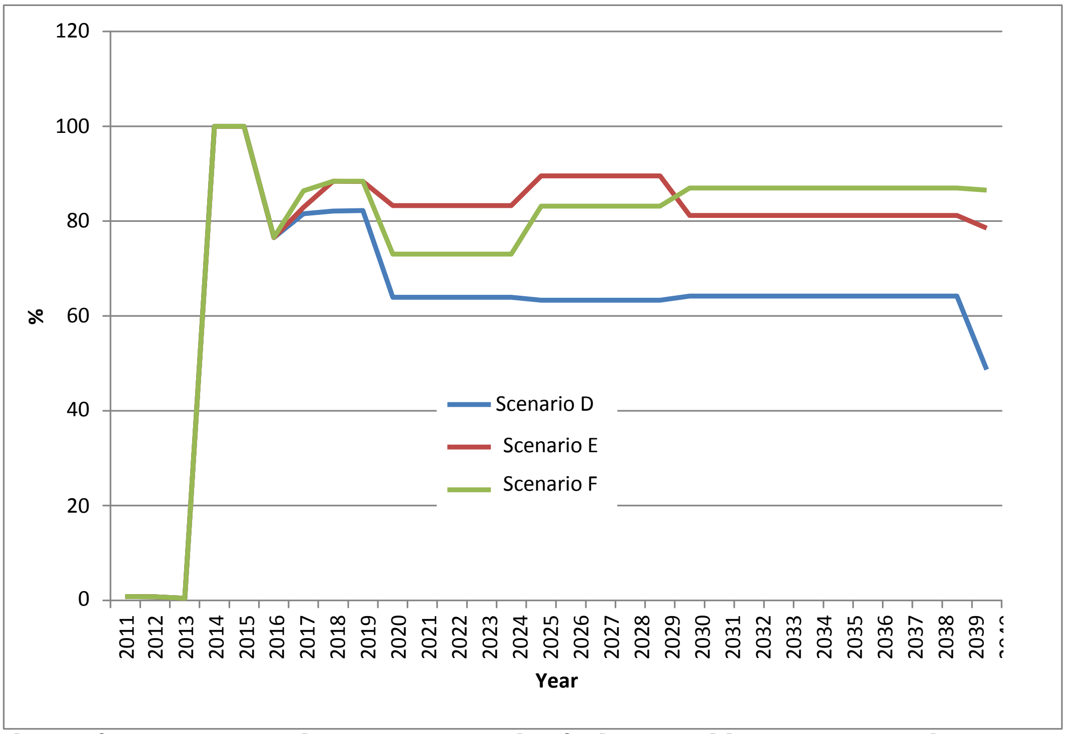


Fig. 27. Share of cogeneration plants running on biofuels in total heat generation by cogeneration plants within Kaunas district heating system (assuming that 40% of heat produced by cogeneration plants using municipal waste comes from biodegradable waste)

73. Given different work modes of various heat production technologies to meet basic heat needs, it is best to choose cogeneration plants running on municipal waste, cogeneration plants running on biofuels and biofuel-based water heating boilers. The current trend that district heating systems almost exclusively have only biofuel-based water heating boilers installed needs to be reversed. Biofuel-based cogeneration facilities where it is technically possible to install them should be given priority as compared to biofuel-based water heating boilers. New biofuel-based cogeneration facilities should cover basic needs and partially the demand during the heating season pushing biofuel-based water heating boilers more towards peak load periods. Peak loads and standby heating needs should be met by using water heating boilers running on fossil fuels. This is demonstrated in Figures 28 to 30. This structure of generation capacities would provide for a more flexible response to fuel market developments.

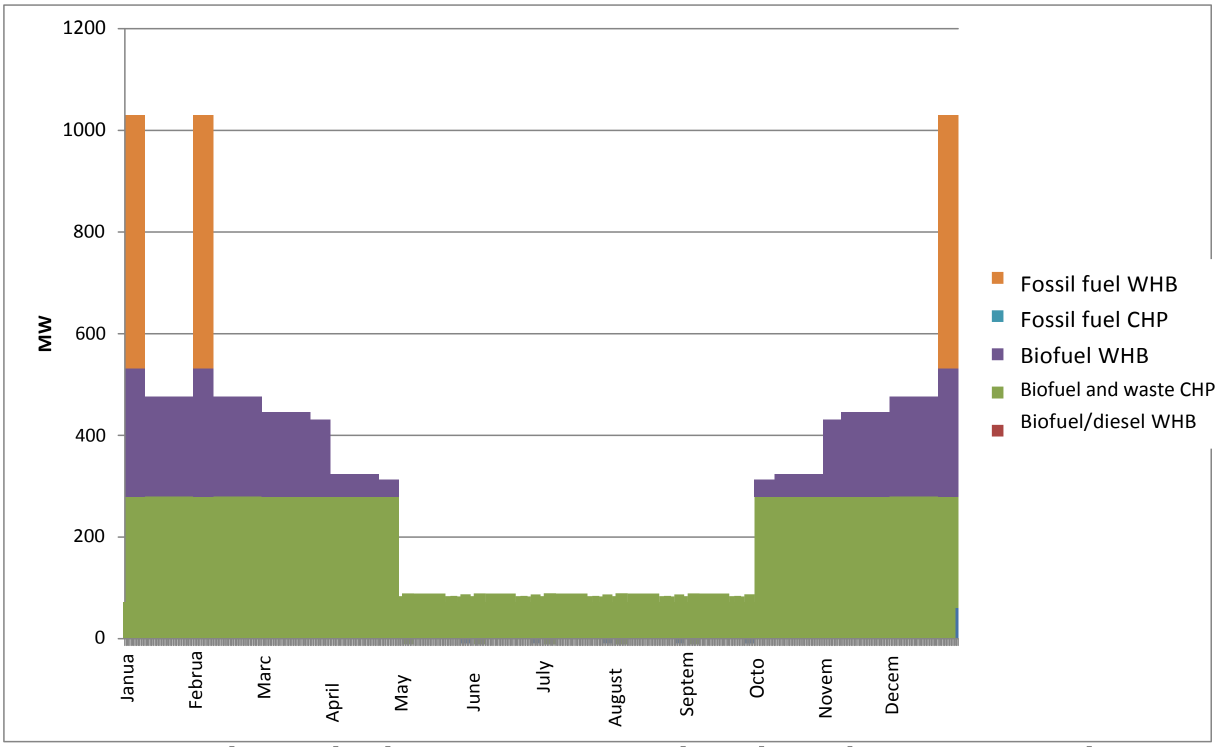


Fig. 28. Heat production developments in 2020 in Vilnius district heating system under Scenario D

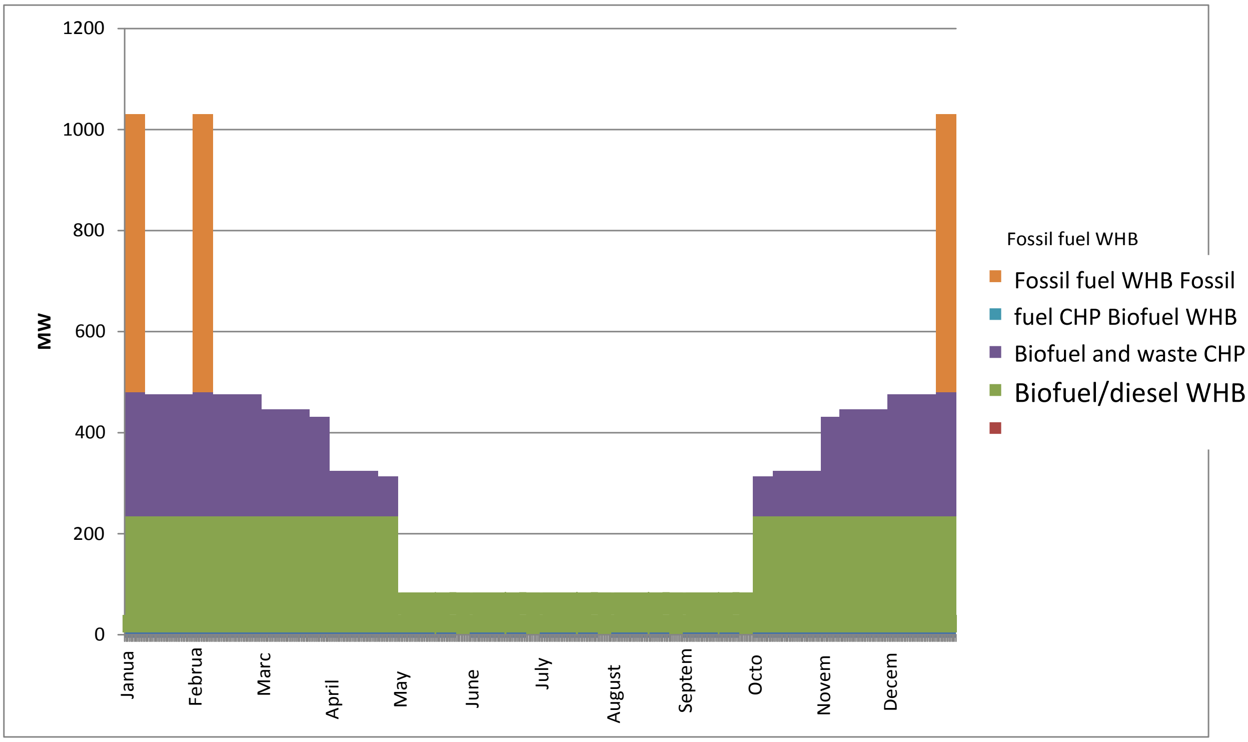


Fig. 29. Heat production developments in 2020 in Vilnius district heating system under Scenario F

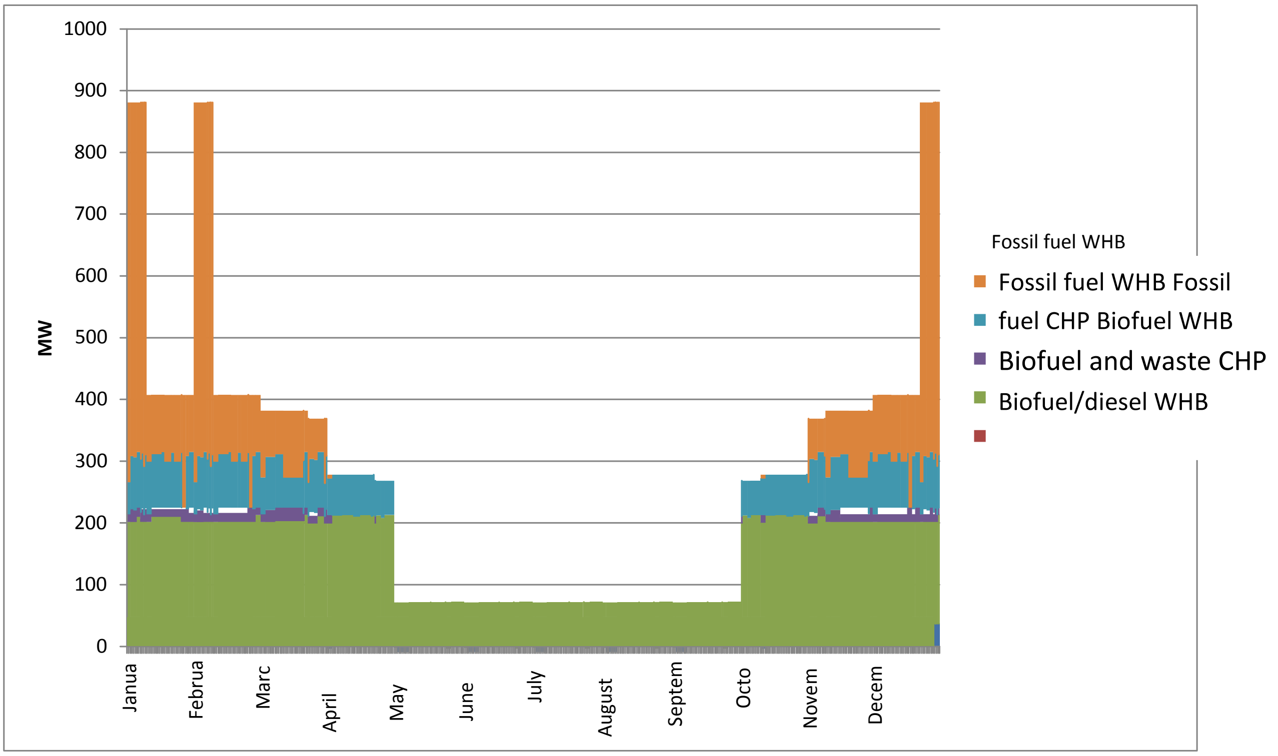


Fig. 30. Heat production developments in 2030 in Vilnius district heating system under Scenario F

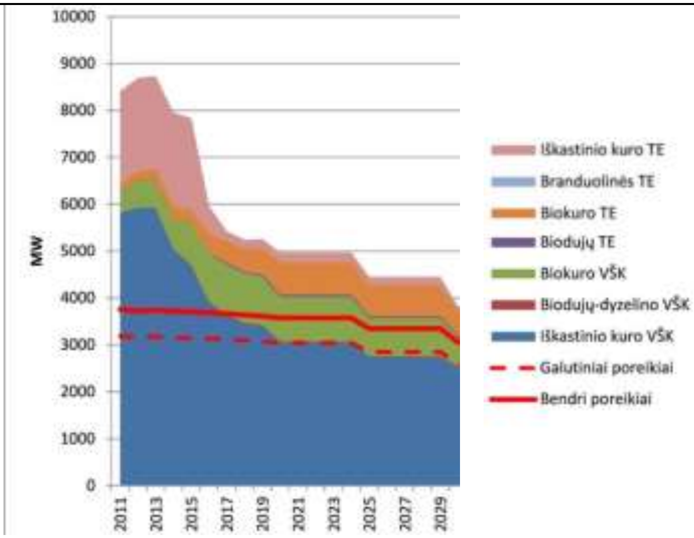
74. The rational structure of generation capacities of heat generation sources within the national, Vilnius and Kaunas DH systems by technology type under Scenarios D, E and F is presented in Figures 31 to 33. What is typical is that both nationally and in individual cities it would be best to significantly reduce the installed capacity of heat production sources that is never used. Another intrinsic feature is that on the national level a major share of installed capacities is water heating boilers running on fossil fuels (gas) used to meet peak demand and provide standby services. Their heat production level, as shown above, is rather low.

75. Heat generation in national district heating systems by fuel type is shown in Fig. 34 and 35 and Tables 20 to 22. The data presented show that during the period in question the main fuel in district heating production should be biofuel. Given favourable electricity import conditions, district heating supply of heat produced on the basis of biofuel would account for 64% in 2015, 65% in 2020, 55% in 2025 and 50% in 2030. To ensure that as of 2025 at least 50% of electricity demand are produced nationally (Scenario F), the share of heat produced using biofuel in 2015 would be 64%, 68% in 2020, 59% in 2025 and 49% in 2030. To ensure that as of 2050 at least 80% of electricity demand are produced nationally (Scenario E), the share of heat produced using biofuel in 2015 would be 65%, 70 % in 2020, 60 % in 2025 and 44% in 2030.

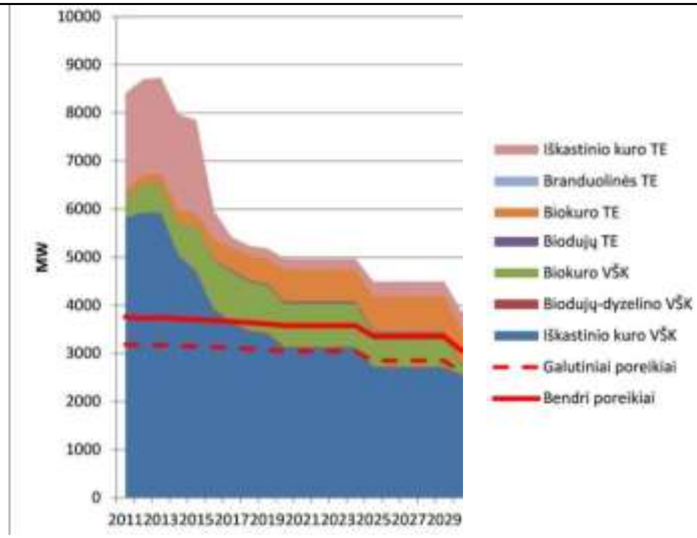
76. Natural gas would remain in the second position. Given favourable electricity import conditions, district heating supply of heat produced on the basis of gas would account for 28% in 2015, 13 % in 2020, 12 % in 2025 and 12% in 2030. To ensure that as of 2025 at least 50% of electricity demand are produced nationally (Scenario F), the share of heat produced using gas in 2015 would be 27%, 14 % in 2020, 16 % in 2025 and 19% in 2030. To ensure that as of 2050 at least 80% of electricity demand are produced nationally (Scenario F), the share of heat produced using gas in 2015 would be 27%, 14% in 2020, 19% in 2025 and 27% in 2030.

77. Heat generation from peat and municipal waste would be comparable. Given favourable electricity import conditions, the share of district heating production from municipal waste would be bigger. The share of heat produced from peat is almost fully independent of the national energy policy provision in the field of energy security. There is a need to seek that in 2015-2030 heat produced from peat reaches 5 to 11% of total heat production. The remaining share of heat would be produced from biofuel and other fuels.

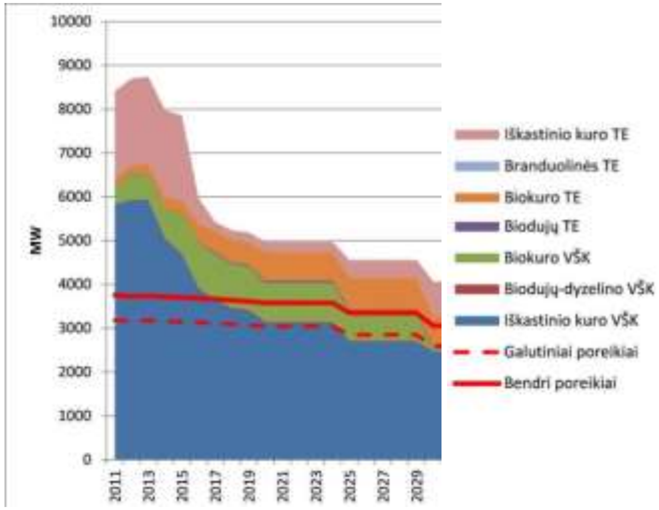
78. The allocation of investment support between heat and/or electricity producing technology groups under all of the scenarios in question is shown in Table 23. In 2014-2020 the amount to be distributed among all technologies was LTL 1 285 million while in 2021-2027 there is an additional LTL 930 million. Support could be used for all water heating boilers and cogeneration plants running on biofuel including municipal waste and efficient cogeneration plants using fossil fuels.



(a) without limiting import



(b) producing at least 50% of electricity nationally

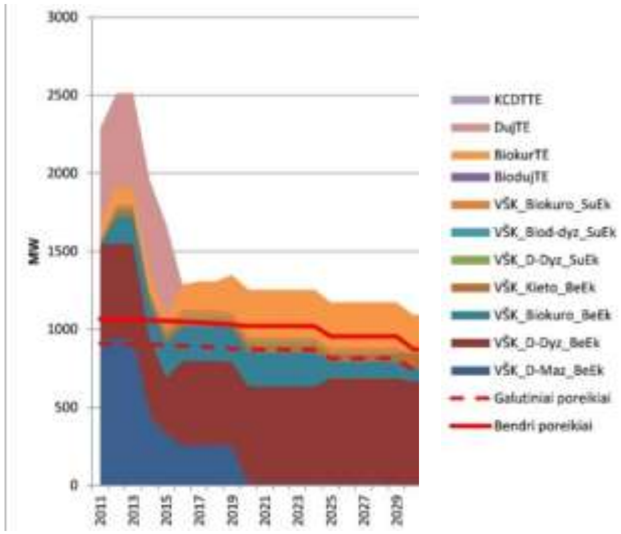


(c) producing at least 80% of electricity nationally

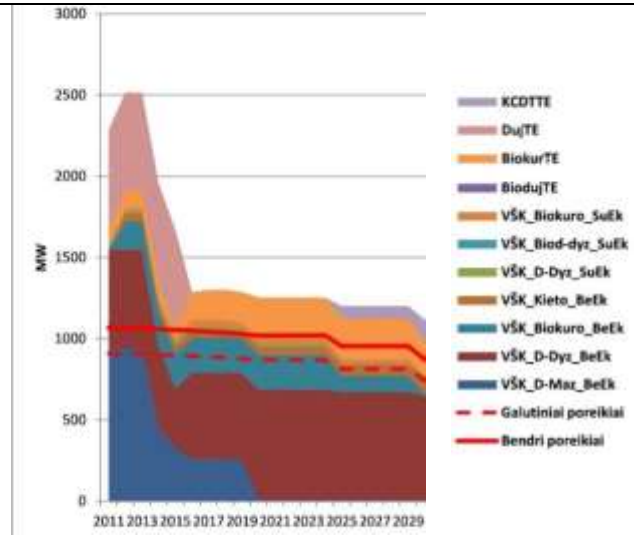
Fig. 31. Rational structure of generating capacities of heat production facilities within national DH systems by technology type with up to 50% investment support

Iškastinio kuro TE	Fossil fuel CHPs
Branduolinio kuro TE	Nuclear fuel CHPs
Biokuro TE	Biofuel CHPs
Biodujų TE	Biogas CHPs
Biokuro VŠK	Biofuel WHBs
Biodujų-dyzelinio VŠK	Biogas/diesel WHBs

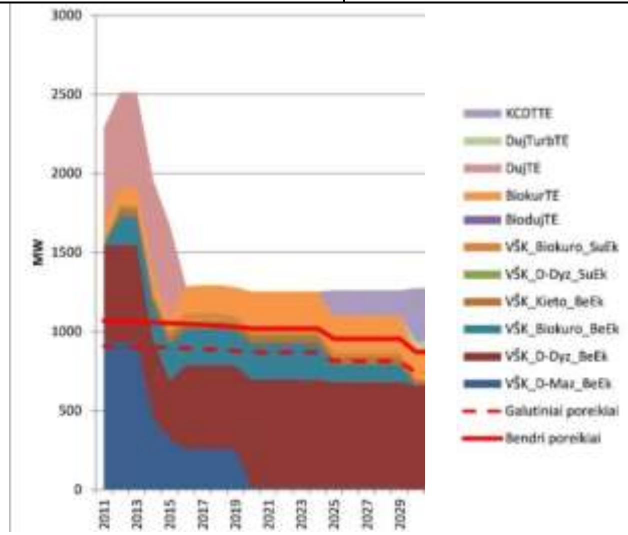
Iškastinio kuro VŠK	Fossil fuel WHBs
Galutiniai poreikiai	Final demand
Bendri poreikiai	Total demand



(a) without limiting import



(b) producing at least 50% of electricity nationally

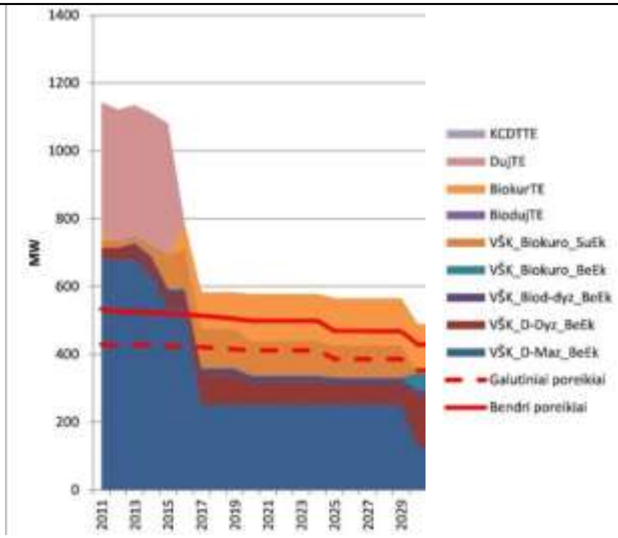


(c) producing at least 80% of electricity nationally

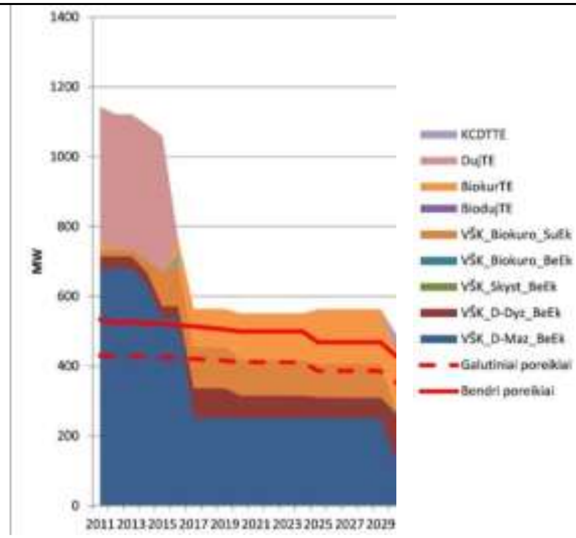
Fig. 32. Rational structure of generating capacities of heat production facilities within Vilnius DH system by technology type with up to 50% investment support

KCDTTE	CCGT CHPs
DujTurbTE	Gas turbine CHPs
DujTE	Gas CHPs
BiokurTE	Biofuel CHPs
BiodujTE	Biogas CHPs
VŠK_Biokuro_SuEk	WHB_Biofuel_With economiser

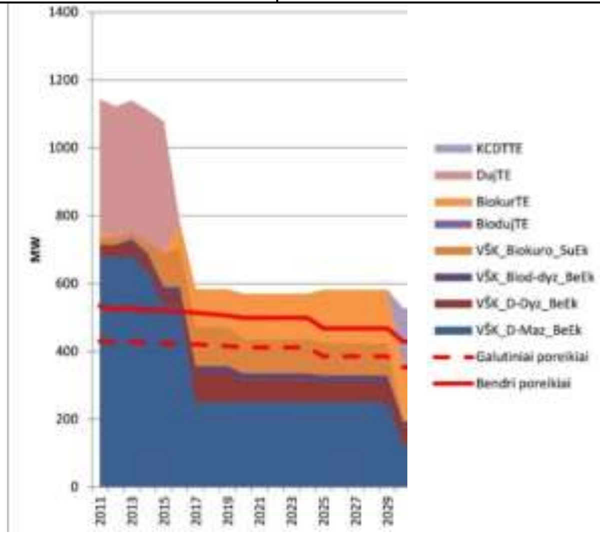
VŠK_D-Dyz_SuEk	WHB_Gas/diesel_With economiser
VŠK_Kieto_BeEk	WHB_Solid fuel_Without economiser
VŠK_Biokuro_BeEk	WHB_Biofuel_Without economiser
VŠK_D-Dyz_BeEk	WHB_Gas/diesel_Without economiser
VŠK_D-Maz_BeEk	WHB_Gas/fuel oil_Without economiser
Galutiniai poreikiai	Final demand
Bendri poreikiai	Total demand



(a) without limiting import



(b) producing at least 50% of electricity nationally

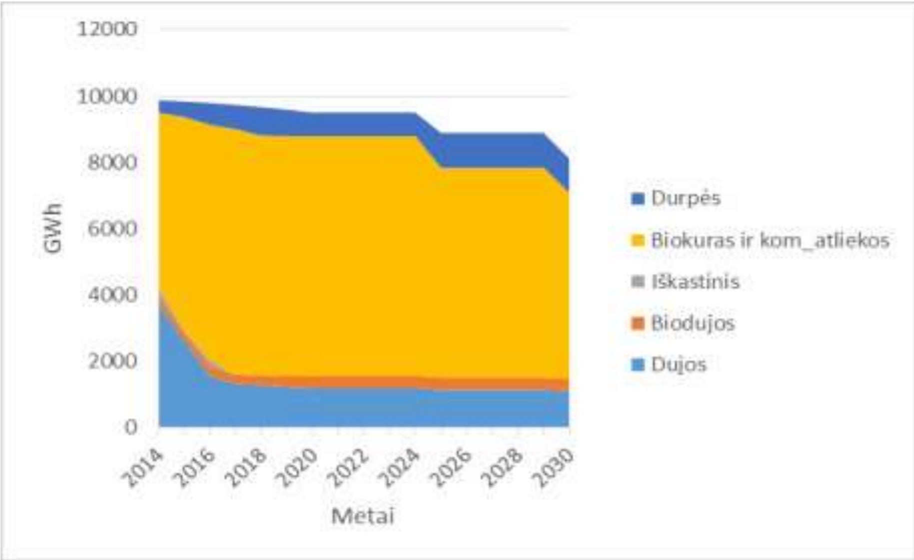


(c) producing at least 80% of electricity nationally

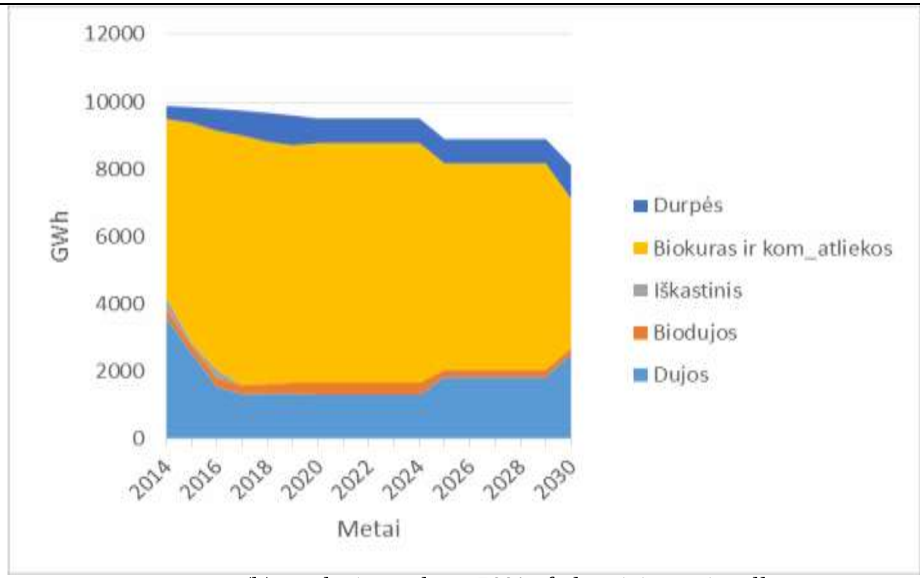
Fig. 33. Rational structure of generating capacities of heat production facilities within Kaunas DH system by technology type with up to 50% investment support

KCDTTE	CCGT CHPs
DujTE	Gas CHPs
BiokurTE	Biofuel CHPs
BiodujTE	Biogas CHPs
VŠK_Biokuro_SuEk	WHB_Biofuel_With economiser
VŠK_Biod-Dyz_SuEk	WHB_Biogas/diesel_With economiser

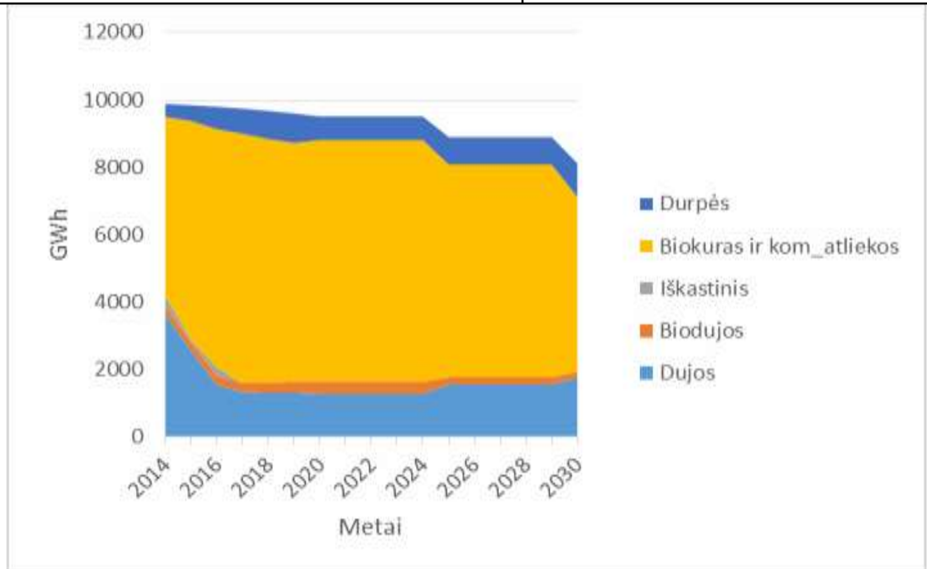
VŠK_D-Dyz_BeEk	WHB_Gas/diesel_Without economiser
VŠK_D-Maz_BeEk	WHB_Gas/fuel oil_Without economiser
Galutiniai poreikiai	Final demand
Bendri poreikiai	Total demand



(a) without limiting import



(b) producing at least 50% of electricity nationally



(c) producing at least 80% of electricity nationally

Fig. 34. Rational heat generation in the country's DH systems by fuel type with up to 50% of support allocated for investment

Durpės	Peat
Biokuras ir kom_atliekos	Biofuel and municipal waste
Iškastinis	Fossil fuels
Biodujos	Biogas

Dujos	Gas
Metai	Year

Table 20. Heat production within national district heating systems by fuel type under Scenario D, MWh

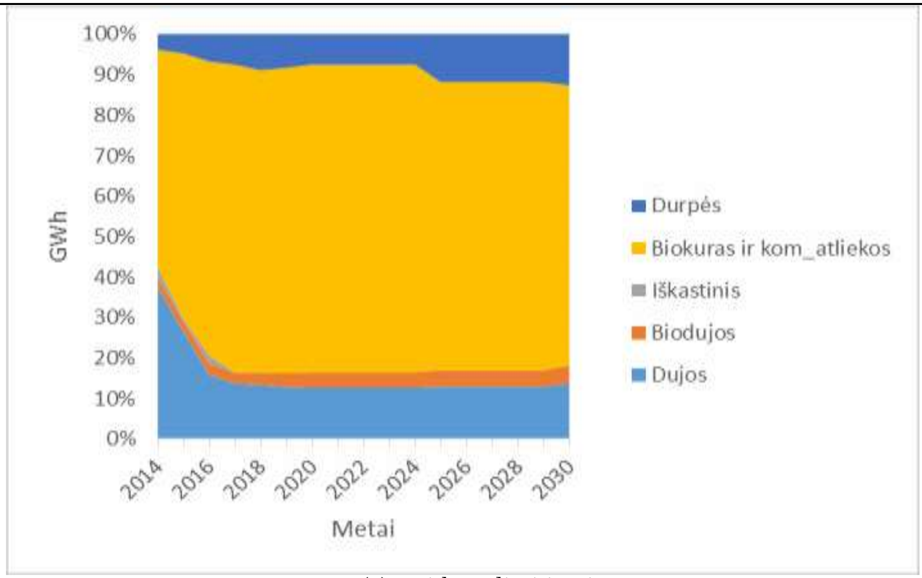
	2014	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Gases	3699	2612	1557	1335	1294	1236	1208	1208	1208	1208	1208	1151	1151	1151	1151	1151	1110
Biogas	250.1	244.3	273.1	260.8	294.4	328	361.1	361.1	361.1	361.1	361.1	364.1	364.1	364.1	364.1	364.1	366.7
Fossil fuels	246.2	73.5	192.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuel and municipal waste	5309.2	6443.8	7115.6	7410.9	7226	7237.1	7226	7226	7226	7226	7226	6329	6329	6329	6329	6329	5620.2
Peat	372.6	465.6	655.8	731.9	856.1	793.7	708.8	708.8	708.8	708.8	708.8	1052	1052	1052	1052	1052	1021

Table 21. Heat production within national district heating systems by fuel type under Scenario E, MWh

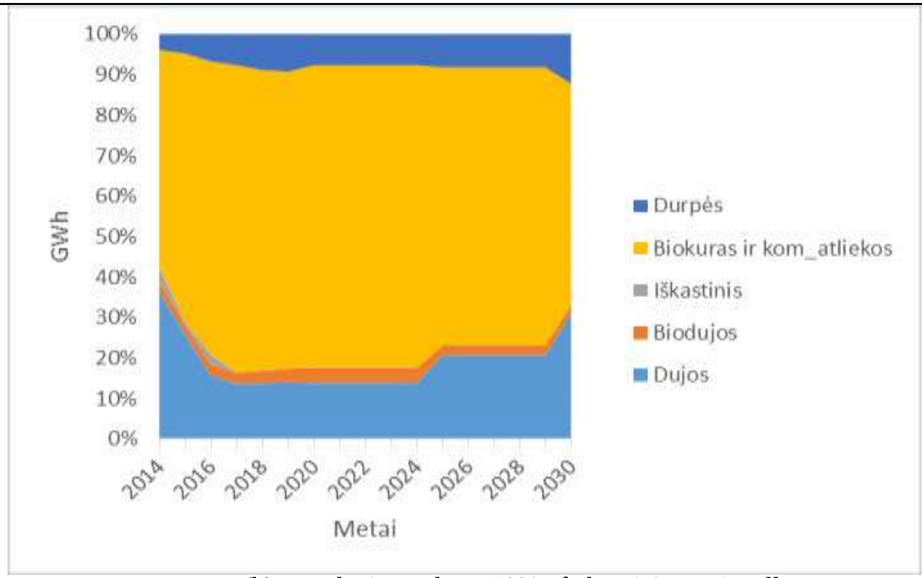
	2014	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Gases	3601	2541	1540	1333	1336	1343	1313	1313	1313	1313	1313	1841	1841	1841	1841	1841	2522
Biogas	249.7	231.9	260.4	259.5	293	326.7	359.9	359.9	359.9	359.9	359.9	212.8	212.8	212.8	212.8	212.8	177
Fossil fuels	325.8	72.5	242	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuel and municipal waste	5316	6530	7098	7404	7190	7043	7106	7106	7106	7106	7106	6119	6119	6119	6119	6119	4427
Peat	384.8	465.5	654	742	852.2	882	727	727	727	727	727	723.7	723.7	723.7	723.7	723.7	993.8

Table 22. Heat production within national district heating systems by fuel type under Scenario F, MWh

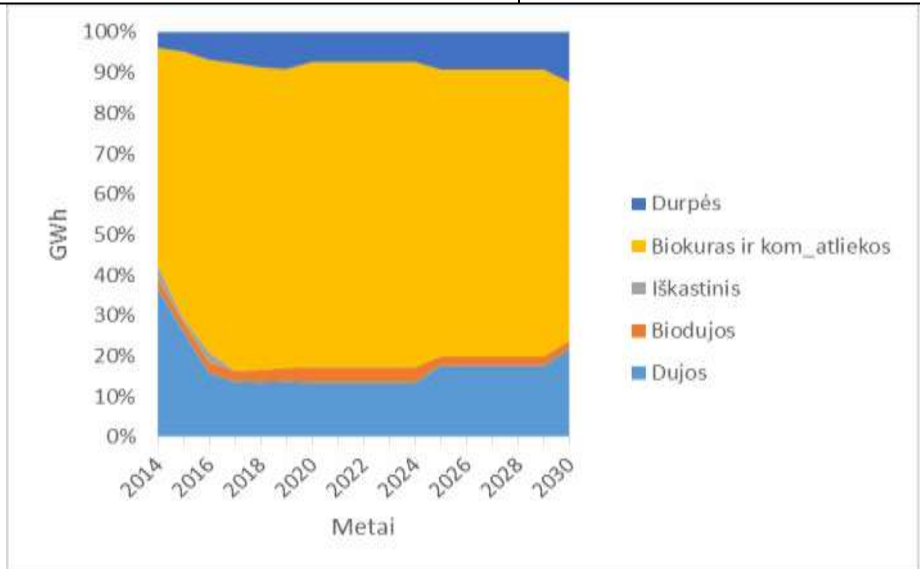
	2014	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***
Gases	3621	2558	1551	1337	1310	1316	1281	1281	1281	1281	1281	1563	1563	1563	1563	1563	1768
Biogas	250.1	237.9	259.7	259	292.6	326.3	359.5	359.5	359.5	359.5	359.5	211.7	211.7	211.7	211.7	211.7	163.8
Fossil fuels	306.8	86.2	245.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biofuel and municipal waste	5315	6492	7072	7396	7232	7080	7167	7167	7167	7167	7167	6305	6305	6305	6305	6305	5190
Peat	383.7	465.6	665	746.9	836.3	873.1	697.8	697.8	697.8	697.8	697.8	816.9	816.9	816.9	816.9	816.9	996.5



(a) without limiting import



(b) producing at least 50% of electricity nationally



(c) producing at least 80% of electricity nationally

Fig. 35. Rational structure of heat generation in the country's DH systems by fuel type with up to 50% of support allocated for investment (***Note:*** Figures should be showing percentage instead of GWh)

Durpės	Peat
Biokuras ir kom_atliekos	Biofuel and municipal waste
Iškastinis	Fossil fuels

Biodujos	Biogas
Dujos	Gas
Metai	Year

Table 23. Support distribution among technology groups under all scenarios analysed, LTL million 2011

	Technology	2014	2015	2016	2017	2018	2019	2020	2021-2025	2026-2030	Total
Scenario A	Biofuel water heating boilers			1.6	14.2						15.8
	Biogas-based CHPs	47	36.9	116.7	108.2	56.6	53.7				419.1
	Biofuel and waste CHP	0.1	344.6	95.8	89.6	155.5	160.5	42.9	314.3	571.5	1774.8
	Fossil fuel CHPs										
	Onshore wind power plants										
	Total	47.1	381.5	214.1	212	212.1	214.2	42.9	314.3	571.5	2209.7
Scenario B	Biofuel water heating boilers				1.5						1.5
	Biogas cogeneration plants	47	62.7	129.7	101.5	63.6	53.4				457.9
	Biofuel and waste CHPs	0.1	318.8	84.6	89.6	129.1	139.3				761.5
	Fossil fuel CHPss				21.6	21.6	21.6	42.9	279.3	431.6	818.6
	Onshore wind power plants								35	139.8	174.8
	Total	47.1	381.5	214.3	214.2	214.3	214.3	42.9	314.3	571.4	2214.3
Scenario C	Biofuel water heating boilers				7.4						7.4
	Biogas-based CHPs	47	62.7	133.8	97.4	63.6	53.4				457.9
	Biofuel and waste CHPs	0.1	318.8	80.5	108.4	129.1	139.3				776.2
	Fossil fuel CHPs					21.6	21.6	42.9	279.3	431.6	797
	Onshore wind power plants								35	139.8	174.8
	Total	47.1	381.5	214.3	213.2	214.3	214.3	42.9	314.3	571.4	2213.3
Scenario D	Biofuel water heating boilers		9.4	27.5	13		3.7	27.6	110.4		191.6
	Biogas-based CHPs	47	72.5	81.2	37.1	34.2	48	6.9	41.4	54.9	423.2
	Biofuel and waste CHPs		298.1	101.1		128.5	369.7		129.1	516.6	1543.1
	Fossil fuel CHPs										
	Onshore wind power plants										
	Total	47	380	209.8	50.1	162.7	421.4	34.5	280.9	571.5	2157.9
Scenario E	Biofuel water heating boilers		1.7	16.6	0.8						19.1
	Biogas-based CHPs	47	65	89.4	37.1	39.6	48.6				326.7
	Biofuel and waste CHPs		314.6	89		22	217.1				642.7
	Fossil fuel CHPs			8.5	21.6	21.6	21.6	42.9	171.4		287.6
	Onshore wind power plants					102	119		142.9	571.4	935.3
	Total	47	381.3	203.5	59.5	185.2	406.3	42.9	314.3	571.4	2211.4
Scenario F	Biofuel water heating boilers		0.8	23.1	1.1		0.1				25.1
	Biogas-based CHPs	47	62.7	91.9	37.1	39.6	48.6				326.9
	Biofuel and waste CHPs		318	95.6		22.1	290.9				726.6
	Fossil fuel CHPs					21.6	21.6	41.1	164.4		248.7
	Onshore wind power plants					41.1	119	1.8	149.9	571.4	883.2
	Total	47	381.5	210.6	38.2	124.4	480.2	42.9	314.3	571.4	2210.5

79. The data included in the table show that under all of the scenarios analysed it is best to allocate a large share of support to cogeneration plants running on biofuel including municipal waste. The share of support to this technology group is estimated between 43 and 99% of all the support funds. The biggest share of support to cogeneration plants running on biofuel is provided under Scenario A, i.e. where an individual technology may be given a large share (up to 80%) of support and there are no energy policy provisions limiting electricity imports. In this case all support is allocated to the most competitive market technologies (biofuel boilers and cogeneration plants) and in particular cogeneration plants running on municipal waste and bringing the biggest return on support. When reducing the share of support

allocated to an individual technology (support intensity) and with other conditions remaining the same (Scenario D), support is distributed among a bigger number of beneficiaries because its amount is to be reduced for the most efficient technologies, i.e. cogeneration plants using municipal waste. Thus, more support (about 9%) is allocated to biofuel-based water heating boilers.

80. Where the energy policy provisions on energy security are made more rigid but a large share of required investment support is allocated to individual technologies (Scenarios C and B), it would be best to concentrate the support on cogeneration plants using biofuel and fossil fuels. Technologies running on biofuel and municipal waste would receive about 55% while fossil fuel-based technologies would be given about 36% of the support funds.

81. The above developments within the heat and electricity system are reflected in system development and functioning costs. The level of expenditure pertaining to the development and functioning of electricity and district heating systems under all of the scenarios analysed is summarised in Table 24. Expenditure is shown in stable money in 2011.

Table 24. Development and functioning costs of energy supply systems, LTL million

Scenario	***Development and functioning costs of electricity and district heating systems in 2011-2065 (discounted), LTL million***	***Investment support in 2014-2027 (discounted), LTL million***	***Non-discounted support in 2014-2027, LTL million***
Scenario A	68156	1139	2210
Scenario B	72043	1141	2214
Scenario C	70275	1141	2213
Scenario D	68256	1098	2158
Scenario E	72159	1123	2211
Scenario F	70306	1119	2211
Scenario G	69045	0	0
Scenario H	72953	0	0
Scenario I	71180	0	0

82. The national energy policy objective to enhance energy security has a price of its own. The data presented show that during the period in question expenditure is increasing by about 3.0-5.7% because of the objective to enhance electricity security. Expenditure increases by about 3.0-3.1% where, as compared to the scenario with unlimited imports, local electricity generation is to be increased to 50%. The increase of local electricity generation as of 2025 up to at least 50% of total electricity demand increases average electricity costs depending on support rates to new technologies throughout the period in question (2011-2065) by 12.8-13.4 LTL/MWh. The objective to produce locally at least 80% of electricity demand of the country by 2050 increases average electricity costs by 24.3-24.5 LTL/MWh while expenditure increases by 5.7-5.8%. This is an average increase of electricity costs between 2011 and 2065. In fact, at the beginning of the reporting period, up until around 2020 there are just minor differences in costs because local electricity generation levels start to stand out at a later stage. The different of electricity costs in 2025 depending on local electricity generation levels is already estimated at 48 to 70 LTL/MWh, in 2030 – 70 to 120 LTL/MWh and in 2040 – 78 to 133 LTL/MWh. The larger figures are associated with the objective to produce at least 80% of electricity nationally by 2050,

and the smaller ones concern the objective to produce at least 50% of electricity as of 2025. This needs to be taken into account when making a final decision on energy policy objectives in the field of energy security.

83. The efficiency of the support can also be assessed through changes in heat and electricity costs given the same levels of electricity production (energy security). The effects of the support on decreasing heat and electricity production costs may be direct or indirect. Direct effects are those manifested through declining investment in the installation of technologies and the capital cost component in production costs. Indirect effects are those caused by changes in generating capacities, fuels used for energy production and the very energy production structure that would not take place if it were not for the support allocated to the implementation of technologies. For example, where under the normal market conditions a biofuel water heating boiler (both with or without support) is installed instead of a water heating boiler running on fossil fuels, the effect of the support on declining heat production costs would only be attributable to smaller investment support (the investment component in the cost structure) in the biofuel boiler. This is a direct effect. However if the said biofuel-based boiler replaces a boiler using fossil fuels only where support is allocated, the effect is caused by changes in the structure of generating capacities and the fuel balance. So the effect of direct support would be felt together with the indirect effect of the support on the drop in heat production costs.

84. Differences in electricity generation costs under Scenarios C, F and I are shown in Fig. 36. Differences in electricity generation costs under Scenarios A, D and G are shown in Fig. 37. Differences in costs demonstrate a direct effect of support to the implementation of technologies on electricity production costs. The data presented show that:

85. With a view to producing at least 50% of electricity demand nationally as of 2025 providing required investment support of up to 50% to heat and electricity production technologies, electricity production costs (the direct effect of the support) between 2016 and 2020 could be reduced by 0.4-1 LTL ct/kWh and between 2021 and 2030 – by 1.1-2.0 LTL ct/kWh. The effect of the support is maintained in the long run. In 2031-2040 the expected decrease of costs stays on the level of 0.4-1.5 LTL ct/kWh while in 2040-2050 it is between 0.1 and 0.6 LTL ct/kWh. Given the same energy policy provision in the field of energy security but with investment support to heat and electricity production technologies reaching 80%, electricity production costs could be reduced by 1.3-2.2 LTL ct/kWh, 1.8-2.4 LTL ct/kWh, 0.3-1.8 LTL ct/kWh and 0.1-0.3 LTL ct/kWh respectively.

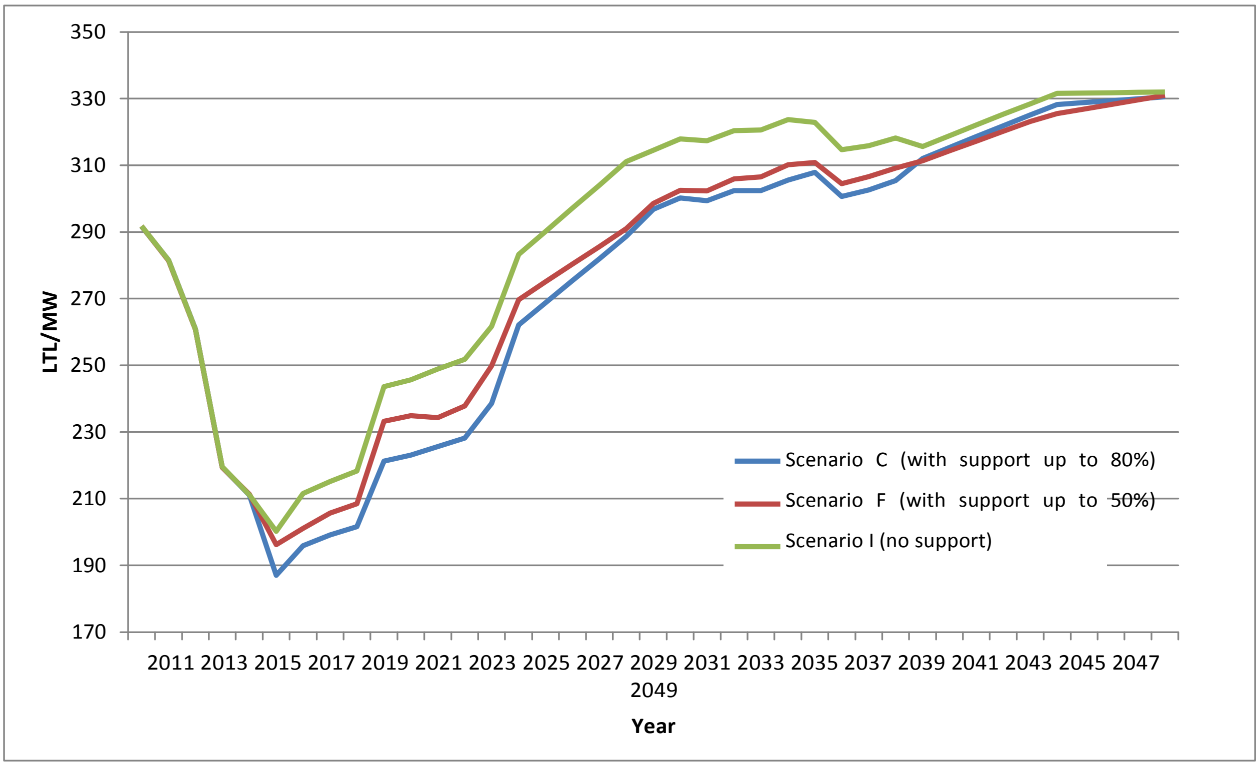


Fig. 36. Electricity production costs with varying support levels allocated to technologies in order to produce at least 50% of electricity demand nationally as of 2025

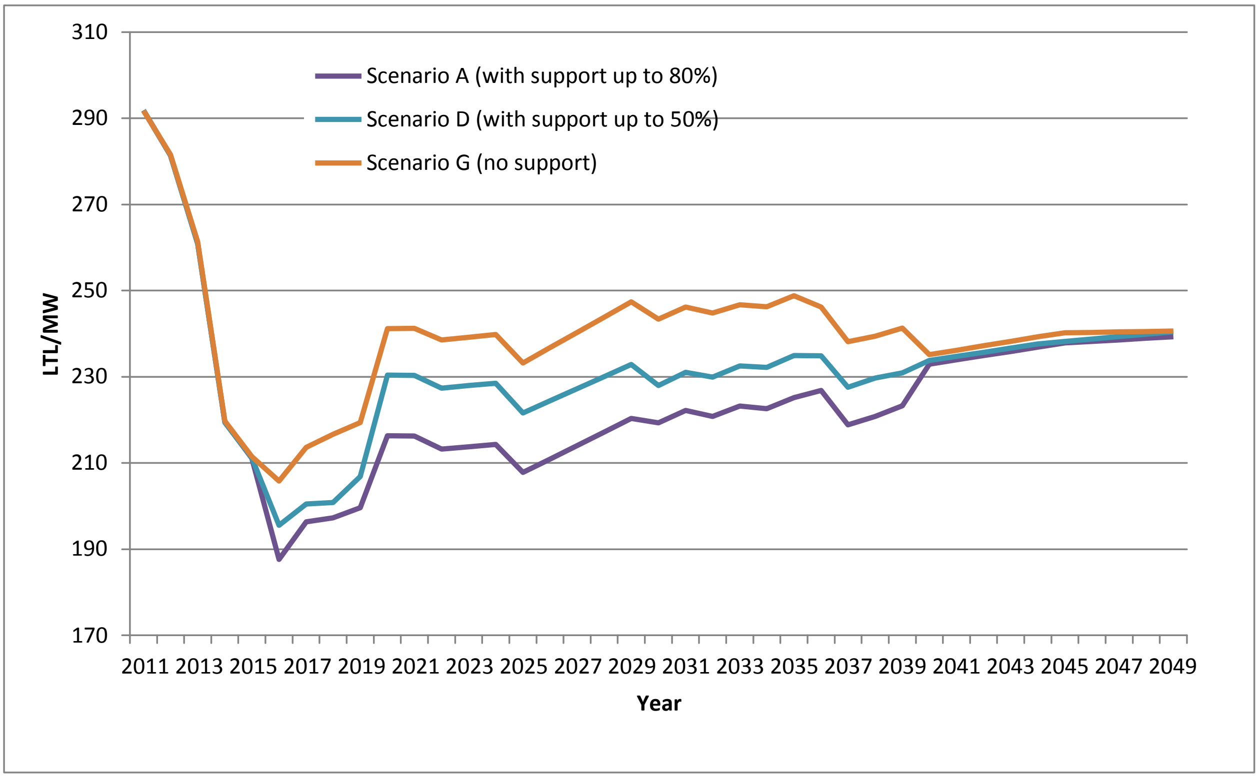


Fig. 37. Electricity production costs with varying support levels allocated to technologies given favourable electricity import conditions

86. Given favourable electricity import conditions without any artificial restrictions imposed and the investment support of up to 50% allocated to heat and electricity production technologies, electricity production costs (the direct effect of the support) between 2016 and 2020 could be reduced by 1.0-1.6 LTL ct/kWh and between 2021 and 2030 – by 1.0-1.5 LTL ct/kWh. In 2031-2040 the expected reduction of costs remains within 0.1-1.5 LTL ct/kWh, and in 2040-2050 it stays between 0 and 0.2 LTL ct/kWh. Given the same electricity import conditions and with investment support to heat and electricity production technologies reaching 80%, electricity production costs could be reduced by 0-2.5 LTL ct/kWh, 2.4-2.7 LTL ct/kWh, 0.2-2.4 LTL ct/kWh and 0.1-0.2 LTL ct/kWh respectively.

87. The direct effect of support to technologies on heat production costs is not as clear when seeking mutual benefits within systems, and electricity production problems (including the reduction of production costs) may partially be dealt with on the account of heat production costs. On the other hand, as shown above, where a large share of support is allocated to cogeneration plants, the support effects are scattered between electricity and heat production costs. Given that in many cases cogeneration plants receiving support produce more heat than electricity, the support funds invested as compared with electricity are distributed between a larger volume of heat generated, and the support effect on heat costs is accordingly less prominent. However the biggest effect of the support on the reduction of heat production costs may be manifested in indirect effects of the support. In other words, where changes in the structure of generating capacities and the fuel balance in the district heating system may be expected only because of the support, the total reduction of heat production costs could be conditionally linked with the support. The dynamics of heat production costs under Scenario F are show in Fig. 38. These changes in heat production costs are similar under all of the scenarios analysed.

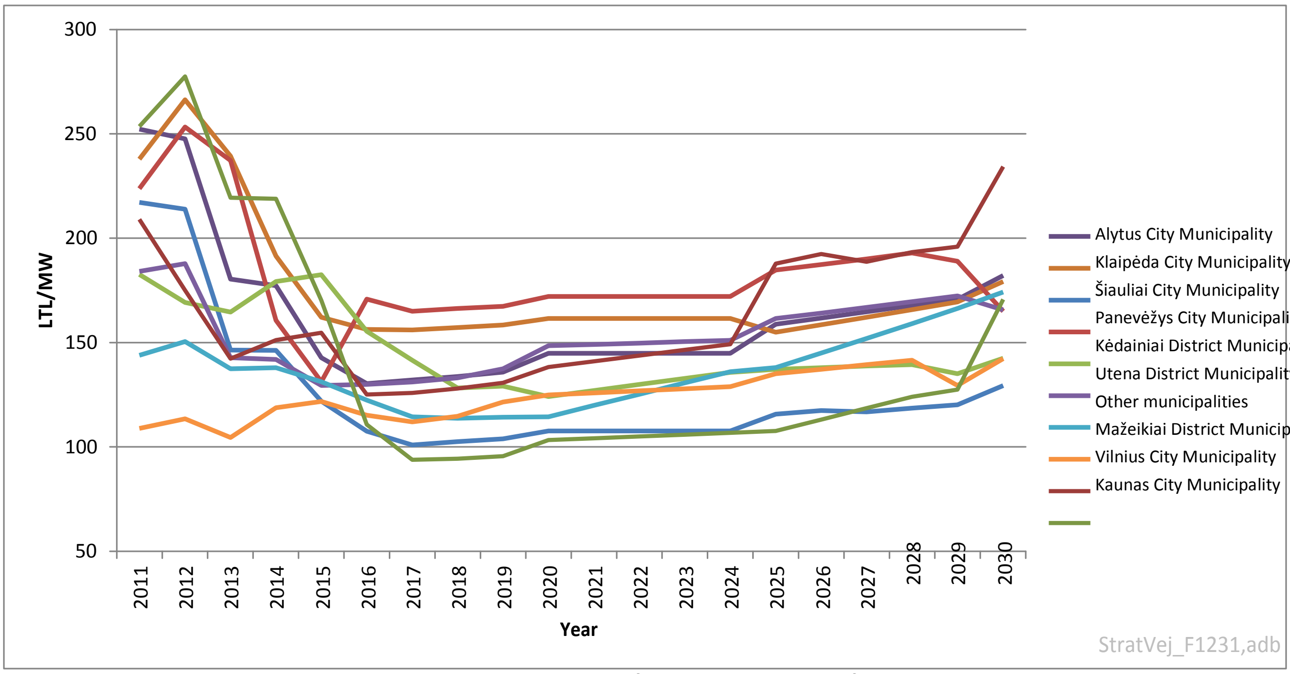


Fig. 38. Heat production costs under Scenario F (50% of support and 50% of local electricity production)

88. The data presented show that structural changes in generating capacities and the fuel balance may result in significant reductions of heat production costs in district heating systems. This depends on the situation in a specific district heating system. For example, in Mažeikiai district heating system a major share of heat production comes from biofuel already now. So no further

reduction of heat production costs is expected. However the biggest reduction of heat production costs may be expected in Kaunas following the installation of cogeneration plants running on municipal waste and biofuel. Other district heating systems (not identified individually) may expect a reduction in heat production costs by about 2-3 LTL ct/kWh, with the national average estimated at about 4-5 LTL ct/kWh.

<u>Support level issue and reservation conditions</u>

89. In dealing with the energy security problem, i.e. with a view to increasing local electricity generation levels, it is important to establish how varying support levels may affect the competitiveness of technologies on international electricity markets and local heat markets. This matter is very topical where the purpose of allocating support to technologies is not only to improve investment conditions for investors and reduce electricity generation costs and energy prices for final consumers but also to ensure that such technologies become competitive and can help to achieve the objective of the energy policy. In other words, where a certain level of national electricity production is sought, we must ensure that energy production technologies can compete on the free market. Without ensuring that, the technologies implemented may remain unused (incapable of competing) when operated.

90. In order to establish competitiveness prospects for technologies and determine the required support level, there is a need to analyse processes ongoing or probable on district heating and electricity markets.

91. At present the most attractive one among heat production technologies in district heating systems is water heating boilers running on biofuel. Comparative investment in biofuel-based water heating boilers is estimated to be between 900 and 1465 LTL/kW. In individual cases investments may reach 1600 LTL/kW (fluidised bed boilers). This range of comparative investments is established on the basis of data of applications approved or submitted to receive support in Lithuania (EU support website 2013) and replies to the survey questionnaires submitted by heat supply undertakings. Economic indicators of other water heating boilers are collected from individual catalogues (Technology Data, etc. 2012), research reports (Galinis et al. 2009, Galinis et al. 2011) and others. These data are summarised in Table 5.

Table 25. Economic indicators of water heating boilers

Type of boiler	***Investment***	***Standing operational costs***	***Variable operational costs***
	LTL/kW	***LTL/kW***	***LTL/MWh***
Liquid fuel WHB without economiser	220	19.7	3.22
Gas/diesel WHB without economiser	210	19.8	3.23
Gas/fuel oil WHB without economiser	311	21.1	4.38
Solid fuel boilers without economiser	1100	50.4	5.56
Granulated biofuel boilers without economiser	1000	48.0	5.29
Biogas/diesel WHB without economiser	252	23.7	3.88
Firewood WHB without economiser	1100	50.4	5.56
Liquid fuel WHB with economiser	297.5	20.1	4.22
Gas/diesel WHB with economiser	287.5	20.1	4.23
Gas/fuel oil WHB with economiser	388.5	21.5	5.38
Solid fuel boilers with economiser	1465	54.1	8.56
Granulated biofuel boilers with economiser	1365	51.7	8.29
Biogas/diesel WHB with economiser	329.5	24.1	4.88
Firewood WHB with economiser	1465	54.1	8.56

92. Biofuel-based water heating boilers are a more attractive alternative for investors as compared to biofuel-operated cogeneration plans because of much more modest investments. This may lead to a situation where heat production is almost exclusively dominated by water heating boilers possibly occupying the niche of cogeneration plants too. Under the current conditions biofuel-based water heating boilers lose to water heating boilers running on natural gas in terms of heat production costs only in the very peak load zone. Such load is present for about 1000 to 1500 hours per year. Heat production costs of existing gas-based water heating boilers is about LTL 200/MWh. So, during peak heat demand the cost threshold for district heating would be the same. Heat prices on the market would not be lower than production costs. Thus, biofuel-based cogeneration plants producing heat at peak loads would be competitive on the market if their heat production costs do not exceed LTL 200/MWh. This can be the case for 1000 to 1500 hours per year. During summer peaks biofuel-based cogeneration plants would have to compete with biofuel-based water heating boilers. If there is no payback on investment yet, their heat production costs would be LTL 100/MWh. If investments in such boilers are already paid back, heat production costs would be about LTL 80/MWh. So during summer peaks (about 4000 hours per year) biofuel-operated cogeneration plants would be competitive on the market if their heat production costs do not exceed LTL 80/MWh. During other seasons (about 3260-3760 hours per year) biofuel-based cogeneration plants would have to compete with biofuel-operated water heating boilers with investments already paid back or not. Depending on the situation, their heat production costs would be between 80 and 120 LTL/MWh. So, the weighted threshold heat production costs at which biofuel-based cogeneration plants would be competitive on the market are between about 94 and 110 LTL/MWh. Where the installed capacity of biofuel-based water heating boilers is insufficient for fully meeting summer heat demand or where there is no return on investment yet, the weighted threshold heat production costs of biofuel-based CHPs would be about LTL 120/MWh. Where the installed capacity of biofuel-based water heating boilers is insufficient for fully meeting summer heat demand or where there is no return on investment yet, the weighted threshold heat production costs of biofuel-based CHPs would be about LTL 120/MWh. Where because of specific heat consumption patterns and/or current situation biofuel-based cogeneration plants within the structure of generating capacities have a real opportunity to operate only during the heating season, the weighted threshold heat production costs of biofuel-operated cogeneration plants would be about LTL 105 to 136/MWh and would depend on whether they need to compete with biofuel boilers already gaining return on investment or those having no return just yet.

93. Competitive conditions of heat production technologies may be predicted by heat production costs of biofuel-based water heating boilers which are about LTL 94 to 120/MWh given biofuel price forecasts and the 8% discount rate. Where a heat production unit also produces electricity, its competitive conditions on the electricity market would be defined by the whole electricity price, which is about LTL 170/MWh.

94. An analysis of technical and economic data of certain types of cogeneration plants and possible variations thereof has resulted in a number of sets of technical and economic data (see Tables 26 to 29) defining conditions for estimating changes in production costs incurred by such facilities.

95. Assuming that electricity generated by cogeneration plants is bought in at LTL 170/MWh, heat production costs depending on the type of the facility and the duration of operation at maximum capacity vary between LTL 55.6 and 571/MWh (see Fig. 39).

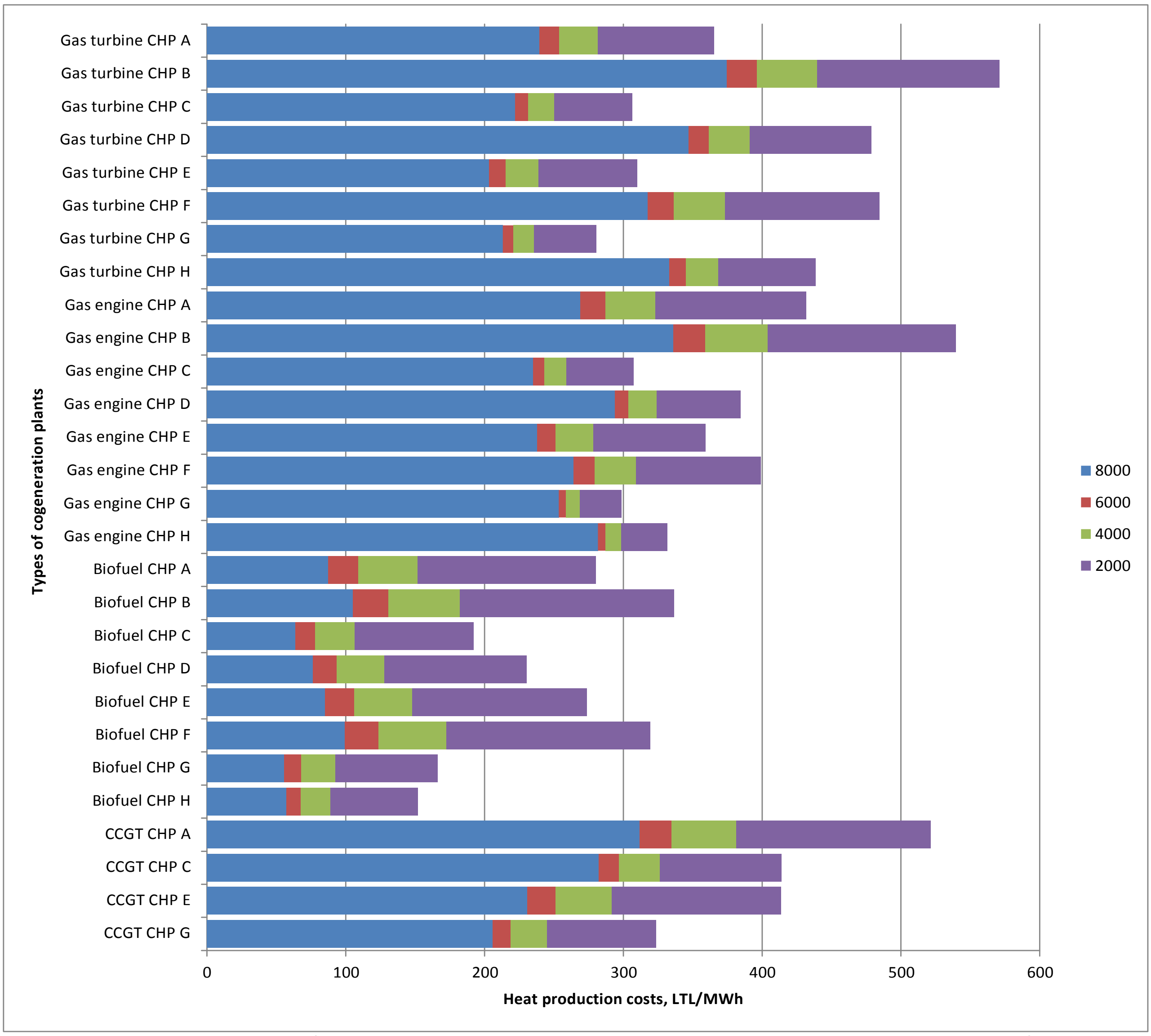


Fig. 39. Heat production costs of cogeneration plants where electricity buy-in price is LTL 170/MWh and fuel prices match the data of Table 6

Table 26. Ranges of changes in technical and economic indicators of biofuel-operated cogeneration plants

Option		***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***
Reference electric power of the unit	MW	5		5		10		10	
Comparative investment	LTL/kW$_e$	17264.0		11394.2		15882.9		9322.6	
	EUR/kW$_e$	5000		3300		4600		2700	
Operational costs	LTL/MWh$_e$	138.11		79.41		65.60		65.60	
	EUR/MWh$_e$	40.00		23.00		19.00		19.00	
Standing operational costs	LTL/kW$_e$	138.11		100.13		138.11		79.41	
	EUR/kW$_e$	40.00		29		40.00		23	
Variable operational costs	LTL/MWh$_e$	22.10		13.47		22.10		11.05	
	EUR/MWh$_e$	6.40		3.9		6.40		3.2	
Electric and heat capacity ratio, *Cb*	Rel. unit	0.25	0.30	0.25	0.30	0.25	0.30	0.25	0.30
Electricity performance factor	Rel. unit	0.25		0.25		0.29		0.29	

Table 27. Parameters used for economic calculations for gas turbine cogeneration plants

Option		***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***
Reference electric power of the unit	MW	10		10		20		20	
Comparative investment	LTL/kW$_e$	5179.2		3452.8		4316.0		2762.2	
	EUR/kW$_e$	1500		1000		1250		800	
Operational costs	LTL/MWh$_e$	26.24		15.54		22.44		13.81	
	EUR/MWh$_e$	7.60		4.50		6.50		4.00	
Standing operational costs	LTL/kW$_e$	25.68		15.20		25.08		15.43	
	EUR/kW$_e$	7.44		4.40		7.26		4.47	
Variable operational costs	LTL/MWh$_e$	22.85		13.53		18.75		11.54	
	EUR/MWh$_e$	6.62		3.92		5.43		3.34	
Electric and heat capacity ratio, *Cb*	Rel. unit	0.64	1.00	0.64	1.00	0.64	1.00	0.64	1.00
Electricity performance factor	Rel. unit	0.36		0.36		0.4		0.4	

Table 28. Parameters used for economic calculations for cogeneration plants with gas-based internal combustion engines

Option		***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***
Reference electric power of the unit	MW	1		1		5		5	
Comparative investment	LTL/kW$_e$	5179.2		2244.3		3798.1		1381.1	
	EUR/kW$_e$	1500		650		1100		400	
Operational costs	LTL/MWh$_e$	37.98		32.80		24.17		24.17	
	EUR/MWh$_e$	11.00		9.50		7.00		7.00	
Standing operational costs	LTL/kW$_e$	14.59		12.60		3.76		3.76	
	EUR/kW$_e$	4.23		3.65		1.09		1.09	
Variable operational costs	LTL/MWh$_e$	35.58		30.73		23.13		23.13	
	EUR/MWh$_e$	10.31		8.9		6.70		6.7	
Electric and heat capacity ratio, *Cb*	Rel. unit	0.80	1.00	0.80	1.00	0.90	1.10	0.90	1.10
Electricity performance factor	Rel. unit	0.4		0.4		0.45		0.45	

Table 29. Parameters used for economic calculations for combined cycle gas turbine cogeneration plants

Option		***A***	***C***	***E***	***G***
Reference electric power of the unit	MW	10	10	20	20
Comparative investment	LTL/kW$_e$	5524.5	3452.8	4833.9	3107.5
	EUR/kW$_e$	1600	1000	1400	900
Operational costs	LTL/MWh$_e$	12.78	8.63	12.78	8.63
	EUR/MWh$_e$	3.70	2.50	3.70	2.50
Standing operational costs	LTL/kW$_e$	25.55	17.26	20.44	13.81
	EUR/kW$_e$	7.40	5	5.92	4
Variable operational costs	LTL/MWh$_e$	9.58	6.47	10.22	6.91
	EUR/MWh$_e$	2.78	1.875	2.96	2
Electric and heat capacity ratio, *Cb*	Rel. unit	1.00	1.00	1.00	1.00
Electricity performance factor	Rel. unit	0.41	0.41	0.5	0.5

96. In evaluating possible development areas for the heating sector and support to the implementation of technologies, it is important to take into account external economic effects relating to the implementation and functioning of various energy technologies. For instance, the above calculations (Drawing up an integrated investment programme for 2011-2020 for the district heating sector and developing implementing measures. Vilnius, 2011) have shown that in boiler facilities 1 TWh of increased heat production levels where biofuel is used creates 700 new jobs (taking into account direct and indirect effects by applying the cost and production analysis method). In general, positive external effects are intrinsic to those district heating technologies which use local resources (e.g. biofuel) but it is important to note that the said effects should not be ignored: where the use of local fuel causes energy products to become more expensive, damage done by the decreasing competitiveness of enterprises using energy resources may exceed the benefits of using local resources.

97. With a view to preventing the ongoing ageing of heat transmission and distribution pipelines of district heating systems, about 80 km of mains should be renovated each year. This would require about LTL 180 million annually. If 50% of funds come from the support funds, the annual support level would be estimated at LTL 90 million. During 2014-2020 that would amount to LTL 630 million. Given that the support fund for the implementation of energy supply and efficiency measure in the public sector and in households is a mere LTL 240 million, it is impossible to meet the financial needs of heating mains renovation works. However it is necessary to seek that the maximum possible support amount is allocated to the renovation of the mains of district heating systems.

98. In Lithuania district heating undertakings own about 2440 km of heating pipelines. The technical life cycle of the pipelines is 30 years of operation. However the average age of the pipelines of the majority of heat supply undertakings is over 34 years. For a long time investments in the renovation of pipelines have been inadequate, which is why there is a need to focus on and ensure financial resources at least for the renovation of pipelines that is absolutely necessary. To ensure at least that the average age of pipelines does not increase, about 80 km of the mains need to be renovated annually. This requires about LTL 180 million annually. During 2014-2020 that would amount to LTL 1260 million. To collect this entire amount of money from heat tariffs, the network renovation component would be about LTL ct 2/kWh.

99. So far the annual renovation rate has been about 50 to 60 km of the piping of district heating systems in the country. Renovation works have been performed partially with own funds of undertakings and partially financed from the support funds. Specific amounts of own or support funds used for the network renovation are unknown but assuming that the network renovation at the scale ensured so far will continue in the future, annual investment levels as well as the recent support allocated to the network renovation would have to be increased by 35 to 60%, or LTL 45 to 65 million. If no additional support is allocated to network renovation but the required renovation works are carried out, the funds needed would have to be collected from higher consumer heat tariffs making them increase by another LTL ct 0.5-0.8/kWh.

REFERENCES

1. Renovation of multi-apartment buildings (2013) Wikipedia: http://lt.wikipedia.org/wiki/Daugiabu%C4%8Di%C5%B3_renovacija
2. EU support website (2013). http://esparama.lt/
3. Galinis, A., Miškinis, V., Kveselis, V., Konstantinavičiūtė, I., Kuprys, A., Norvaiša, E., Tarvydas, D., Lisauskas, A., Lekavičius, V., Masaitis, S., Tutlytė, O., Dzenajavičienė, E. F., Alėbaitė, I., Jurkšienė, G., Rasburskis, N. (2009). Šalies savivaldybėse esamų atsinaujinančių energijos išteklių (biokuro, hidroenergijos, saulės energijos, geoterminės energijos) ir komunalinių atliekų panaudojimas energijai gaminti (Use of renewable energy resources (biofuel, hydropower, solar power and geothermal power) available in the municipalities and municipal waste for energy production).
4. Galinis, A., Miškinis, V., Lekavičius, V., Norvaiša, E., Konstantinavičiūtė, I., Buinevičius, K., Lukoševičius, V., Jasas, D. (2011). 2011–2020 metų kompleksinės investicinės programos centralizuoto šilumos tiekimo sektoriuje parengimas ir įgyvendinimo priemonių sukūrimas (Drawing up an integrated investment programme for 2011-2020 for the district heating sector and developing implementing measures) http://www.lsta.lt/files/studijos/2011%20metu/A-63_110527_KIP%20galutine_20110527%20.pdf
5. Sipila, K., Ikaheimo, J. et al. (2005). Technical Features for Heat Trade in Distributed Energy Generation. VTT research notes 2305. Julkaisija-Utgivare.
6. Technology Data for Energy Plants: Generation of Electricity and District Heating, Energy Storage and Energy Carrier Generation and Conversion (2012). ISBN 978-87-7844-931-3.

Indicative heating capacity of new or modernised heat sources, MW (electric capacity, MW)

	Heat generation technology	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Scenario E*	*Scenario F*	*Scenario G*	*Scenario H*	*Scenario I*
Vilnius City Municipality	Water heating boilers running on fossil fuels	636.6	633.2	639.4	604.4	654.8	645.7	652.3	627.2	630.1
	Biofuel/diesel WHB			3.9						
	Biofuel-based water heating boilers	36.7	31.2	31.2	31.2	31.2	31.2	37.4	31.2	31.2
	Biogas-based cogeneration plants									
	Biofuel and waste CHP	175.5 (125)	175.4 (125)	177.4 (125.6)	240.2 (144.9)	175.4 (125)	194.5 (130.8)	175.5 (125)	175.4 (125)	176.3 (125.2)
	Fossil fuel cogeneration plants		32.8 (43.9)	15.5 (20.7)		32.4 (43.3)	14.9 (20)		33.5 (44.9)	19.1 (25.6)
Kaunas City Municipality	Water heating boilers running on fossil fuels	203.4	205.6	202.2	186.7	186.2	186.5	208.2	208.2	200.6
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	114.3	99.8	99.5	85.6	83.2	83.2	114.9	118	118
	Biogas-based cogeneration plants									
	Biofuel and waste CHP	92.6 (35.4)	112.8 (42.6)	113.4 (42.8)	138.6 (52.6)	138 (52.1)	137.8 (52.3)	90.9 (34.5)	97 (36.6)	97 (36.6)
	Fossil fuel cogeneration plants		2.6 (3.4)						3.9 (5.2)	
Klaipėda City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3
	Biogas-based cogeneration plants									
	Biofuel and waste CHP									
	Fossil fuel cogeneration plants		0.1 (0.1)						0.1 (0.1)	
Šiauliai City Municipality	Water heating boilers running on fossil fuels	47	47.8	47.8	48.8	48.2	48.8	43	43	43
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	25	25	25	25	25	25	25	25	25
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	4.8 (1.5)	6.9 (2.2)	7.3 (2.3)	13 (4.1)	13.2 (4.1)	13 (4.1)	0.1 (0.03)	1 (0.3)	1.8 (0.6)
	Fossil fuel cogeneration plants									
Panevėžys City Municipality	Water heating boilers running on fossil fuels	49.4	49.9	49.9	49.8	52.2	51.3	49.4	49.5	49.5
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	35.6	19.6	19.6	35.4	19.7	18.6	34.2	19.7	19.7
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	0.5 (0.2)	1.6 (0.7)	1.6 (0.7)	6.8 (2.7)	8.8 (3.5)	8.8 (3.5)		1.5 (0.6)	1.5 (0.6)

	Heat generation technology Fossil fuel cogeneration plants	***Scenario A***	***Scenario B***	***Scenario C***	***Scenario D***	***Scenario E***	***Scenario F***	***Scenario G***	***Scenario H***	***Scenario I***
Alytus City Municipality	Water heating boilers running on fossil fuels	28.5	29.3	29.6	21.4	20.8	20.8	29.9	32.1	32.1
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	38	38	38	38	38	38	38	38	38
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	4.9 (2)	3 (1.2)	2.6 (1.1)	11.4 (4.6)	12 (4.9)	12 (4.9)	2.3 (0.9)		
	Fossil fuel cogeneration plants									
Utena District Municipality	Water heating boilers running on fossil fuels	4.6	1.3	1.3		0.1	0.1	4.6	1.3	1.3
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	10.1	10	10	14.7	10	10	10.1	10	10
	Biogas-based cogeneration plants	0.3 (0.3)			1.2 (1.3)			0.3 (0.3)		
	Biofuel-based cogeneration plants		1 (0.4)	1 (0.4)		6.1 (2.5)	6.1 (2.5)		1 (0.4)	1 (0.4)
Marijampolė Municipality	Water heating boilers running on fossil fuels	1	0.1	0.3	1.1	0.2	0.1	1.2	0.1	0.2
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
	Biogas-based cogeneration plants	0.2 (0.2)			0.2 (0.1)					
	Biofuel-based cogeneration plants		1 (0.2)	0.9 (0.1)		1 (0.2)	1 (0.2)		1.1 (0.2)	1 (0.2)
	Fossil fuel cogeneration plants									
Kėdainiai District Municipality	Water heating boilers running on fossil fuels	3.2	3.6	3.6	2.4	3.6	3.4	3.2	3.6	3.6
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	0.3			2.1	0.1	0.3	0.3		
	Biogas-based cogeneration plants	0.1 (0.1)			0.1 (0.1)			0.1 (0.1)		
	Biofuel-based cogeneration plants									
Elektrėnai City Municipality	Water heating boilers running on fossil fuels	50	50	50	50	50	50	50	50	50
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	40	40	40	40	40	40	40	40	40
	Biogas-based cogeneration plants	0.1 (0.1)			0.1 (0.1)			0.9 (1)		
	Biofuel-based cogeneration plants									
Mažeikiai municipalit	Water heating boilers running on fossil fuels	42.2	42.5	44.2	34.9	39.1	38.6	42.9	45.7	46.5
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	4.9	2.1	0.8	8.8	4.9	5.4	3.7	0.7	
	Biogas-based cogeneration plants	0.1 (0.1)			0.1 (0.1)			0.1 (0.1)		

	Heat generation technology	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Scenario E*	*Scenario F*	*Scenario G*	*Scenario H*	*Scenario I*
	Biofuel-based cogeneration plants		2 (0.6)	1.6 (0.5)	4 (1.3)	3.9 (1.2)	3.9 (1.2)			
Other municipalities	Water heating boilers running on fossil fuels	75.3	46.9	52.3	34.1	23.6	25	79.4	40.5	51.2
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	146.1	111.8	121.7	213.1	148.7	163.6	134	111.8	111.8
	Biogas-based cogeneration plants	39.3 (38)	37.1 (40.4)	37.2 (40.4)	37.4 (40.6)	39.1 (42.4)	39.1 (42.5)	34.4 (31.7)	33.9 (36.8)	37.9 (40.4)
	Biofuel-based cogeneration plants	46 (13.8)	73.9 (22.2)	70.4 (21.1)	40.4 (12.1)	72.5 (21.7)	70.3 (21.1)	54.3 (16.3)	83.6 (25.1)	72.9 (21.8)
	Fossil fuel cogeneration plants		29.9 (33.2)	20.9 (23.2)		36.9 (40.9)	24.2 (26.9)		14 (15.5)	13.5 (15)
Total:		**2036.2 (216.6)**	**2047.4 (316.2)**	**2039.7 (279)**	**2100.3 (264.6)**	**2098.5 (341.9)**	**2090.8 (309.8)**	**2040.3 (209.9)**	**2021.2 (290.8)**	**2003.4 (266.4)**

Note: Because of discrete equipment sizes, the capacity of installations may slightly differ from that indicated in the table.

Indicative investments to develop and modernise heat and electricity production sources, LTL million

	Heat generation technology	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Scenario E*	*Scenario F*	*Scenario G*	*Scenario H*	*Scenario I*
Vilnius City Municipality	Water heating boilers running on fossil fuels	133.7	133.0	134.3	126.9	137.6	137.8	137.0	131.7	132.3
	Biofuel/diesel WHB			1.0						
	Biofuel-based water heating boilers	48.1	42.6	42.6	42.6	42.6	42.6	48.8	42.6	42.6
	Biogas-based cogeneration plants									
	Biofuel and waste CHP	141.7	166.8	167.3	567.3	335.0	408.4	670.0	670.0	675.7
	Fossil fuel cogeneration plants		129.2	61.0		127.4	58.8		132.0	75.3
Kaunas City Municipality	Water heating boilers running on fossil fuels	26.5	26.7	26.4	24.8	24.7	24.8	27.0	27.0	26.2
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	144.7	130.1	129.9	116.0	113.5	113.5	145.3	148.3	148.3
	Biogas-based cogeneration plants									
	Biofuel and waste CHP	71.4	72.9	74.7	238.5	198.6	221.2	310.4	238.1	238.2
	Fossil fuel cogeneration plants		10.1						15.3	
Klaipeda City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4
	Biogas-based cogeneration plants									
	Biofuel and waste CHP									
	Fossil fuel cogeneration plants									
Šiauliai City Municipality	Water heating boilers running on fossil fuels	9.9	10.0	10.0	10.2	10.1	10.2	9.0	9.0	9.0
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1	34.1
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	4.1	7.2	7.2	28.0	28.0	28.0	0.6	4.3	7.7
	Fossil fuel cogeneration plants									
Panevėžys City Municipality	Water heating boilers running on fossil fuels	10.4	10.5	10.5	10.5	11.0	10.8	10.4	10.4	10.4
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	35.6	19.6	19.6	25.3	18.4	18.3	34.2	19.7	19.7
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	0.6	8.1	8.2	18.7	24.5	24.5		8.1	8.1

	Heat generation technology Fossil fuel cogeneration plants	***Scenario A***	***Scenario B***	***Scenario C***	***Scenario D***	***Scenario E***	***Scenario F***	***Scenario G***	***Scenario H***	***Scenario I***
Alytus City Municipality	Water heating boilers running on fossil fuels	6.0	6.2	6.2	4.5	4.4	4.4	6.3	6.7	6.7
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9	51.9
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	5.5	3.3	2.9	31.9	33.5	33.5	13.0		
	Fossil fuel cogeneration plants									
Utena District Municipality	Water heating boilers running on fossil fuels	5.1	1.4	1.4				5.1	1.4	1.4
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	13.8	13.6	13.6	16.0	13.6	13.6	13.8	13.6	13.6
	Biogas-based cogeneration plants	1.0			10.4			5.2		
	Biofuel-based cogeneration plants		7.3	7.3		22.3	22.3		7.3	7.3
Marijampolė Municipality	Water heating boilers running on fossil fuels	0.2			0.2			0.2		
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9
	Biogas-based cogeneration plants	2.9			0.9					
	Biofuel-based cogeneration plants		3.9	2.0		2.5	2.3		4.0	2.6
	Fossil fuel cogeneration plants									
Kėdainiai District Municipality	Water heating boilers running on fossil fuels	1.5	2.0	2.0	0.6	1.9	1.8	1.5	2.0	2.0
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	0.3			1.0		0.1	0.3		
	Biogas-based cogeneration plants	1.1			0.6			1.1		
	Biofuel-based cogeneration plants									
Elektrėnai City Municipality	Water heating boilers running on fossil fuels	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6
	Biogas-based cogeneration plants	1.3			1.3			15.1		
	Biofuel-based cogeneration plants									
Mažeikiai Municipality	Water heating boilers running on fossil fuels	15.0	15.4	17.2	7.3	11.6	11.0	15.8	18.8	19.7
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	1.1	0.4	0.2	4.4	2.4	2.7	3.7	0.7	

	Heat generation technology	***Scenario A***	***Scenario B***	***Scenario C***	***Scenario D***	***Scenario E***	***Scenario F***	***Scenario G***	***Scenario H***	***Scenario I***
	Biogas-based cogeneration plants	1.1			0.6			1.1		
	Biofuel-based cogeneration plants		3.4	2.9	13.1	12.9	12.9			
Other municipalities	Water heating boilers running on fossil fuels	55.6	26.7	30.4	10.4	5.0	5.3	60.2	20.3	29.2
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	172.4	152.6	154.6	203.3	171.0	178.5	174.8	152.6	152.6
	Biogas-based cogeneration plants	177.9	176.0	175.9	320.7	338.2	338.4	496.6	576.5	632.4
	Biofuel-based cogeneration plants	193.0	310.3	295.6	169.7	304.2	295.1	227.9	350.8	305.8
	Fossil fuel cogeneration plants		70.1	48.6		94.8	64.7		67.0	64.7
All municipalities	Heat transmission and distribution networks	1000	1000	1000	1000	1000	1000	1240	1240	1240
Total		2535.2	2813.3	2707.0	3259.4	3343.5	3339.0	3928.2	4173.1	4125.9

Indicative support to install heat source, LTL million

	Heat generation technology	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Scenario E*	*Scenario F*	*Scenario G*	*Scenario H*	*Scenario I*
Vilnius City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers									
	Biogas-based cogeneration plants									
	Biofuel and waste CHP	528.3	503.2	516.1	567.3	335.0	396.3			
	Fossil fuel cogeneration plants									
Kaunas City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers									
	Biogas-based cogeneration plants									
	Biofuel and waste CHP	285.5	211.1	215.4	238.5	187.7	210.3			
	Fossil fuel cogeneration plants									
Klaipeda City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers									
	Biogas-based cogeneration plants									
	Biofuel and waste CHP									
	Fossil fuel cogeneration plants									
Šiauliai City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers									
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	21.1	23.0	24.1	28.0	28.0	28.0			
	Fossil fuel cogeneration plants									
Panevėžys City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers				8.7	1.1	0.3			
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	11.3	1.0	1.0	18.7	24.5	24.5			

	Heat generation technology Fossil fuel cogeneration plants	***Scenario A***	***Scenario B***	***Scenario C***	***Scenario D***	***Scenario E***	***Scenario F***	***Scenario G***	***Scenario H***	***Scenario I***
Alytus City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers									
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants	42.9	13.3	11.8	31.9	33.5	33.5			
	Fossil fuel cogeneration plants									
Utena District Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers				2.2					
	Biogas-based cogeneration plants	2.0			4.9					
	Biofuel-based cogeneration plants					21.6	21.6			
Marijampolė Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers									
	Biogas-based cogeneration plants				2.1					
	Biofuel-based cogeneration plants									
	Fossil fuel cogeneration plants									
Kėdainiai District Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers				1.1		0.1			
	Biogas-based cogeneration plants				0.5					
	Biofuel-based cogeneration plants									
Elektrėnai City Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers									
	Biogas-based cogeneration plants									
	Biofuel-based cogeneration plants									
Mažeikiai Municipality	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	3.3	1.5	0.6	3.8	2.1	2.3			

	Heat generation technology	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Scenario F	Scenario G	Scenario H	Scenario I
	Biogas-based cogeneration plants				0.5					
	Biofuel-based cogeneration plants		9.9	7.8	13.1	12.3	12.3			
Other municipalities	Water heating boilers running on fossil fuels									
	Biofuel/diesel WHB									
	Biofuel-based water heating boilers	12.5		6.8	65.3	15.9	22.3			
	Biogas-based cogeneration plants	417.1	457.9	457.9	318.0	326.6	326.8			
	Biofuel-based cogeneration plants									
	Fossil fuel cogeneration plants		107.6	86.0		116.1	84.3			
All municipalities	Heat transmission and distribution networks	240	240	240	240	240	240			
Total		**1563.8**	**1568.3**	**1567.4**	**1545.6**	**1344.5**	**1402.7**			