Environmental and Climate Technologies

2019, vol. 23, no. 2, pp. 64–73
doi: 10.2478/rtuect-2019-0055
https://content.sciendo.com

Estimation of Carbon Emission Reduction from Upgrading the DH Network to the 4th Generation. Multivariate Linear Regression Model

Ieva PAKERE[1]*, Dace LAUKA[2], Dagnija BLUMBERGA[3]

[1–3]*Institute of Energy Systems and Environment, Riga Technical University, Azenes iela 12/1, Riga, LV-1048, Latvia*

Abstract **– The district heating (DH) system consists of three basic elements – a heat source, heating network and heat consumers. All of these elements have a definite role in the overall development of the DH system. The transition to 4th generation DH (4GDH) involves changes in each of those elements that interact with each other. Therefore, various related processes form the potential energy savings and reduction of CO_2 emissions when introducing 4GDH as whole system in all elements. To estimate the potential outcome from such projects it requires complex engineering calculations, which is not always possible without relevant expertise. The article describes a novel simplified methodology for evaluating the potential GHG emission reduction when implementing 4GDH. Thus, it is proposed to use a simplified calculation formula from linear regression model for the calculation of CO_2 reduction.**

Keywords **– 4th generation district heating; greenhouse gas emissions; linear regression model; lowering district heating temperature**

Nomenclature	
4GDH	4th generation district heating
CHP	Combined heating plant
DH	District heating
EU	European Union
GHG	Greenhouse gases
RES	Renewable energy sources
R_{CO2}	CO_2 emission factor, tonnes/kWh
$\eta_{buildings}$	Specific heat consumption in buildings, kWh/m^2
$\eta_{network}$	Energy efficiency in heating network
η_{source}	Energy efficiency at the heat source

1. INTRODUCTION

Increasing energy efficiency and optimizing power systems has become a key task to promote energy security and reduce overall environmental impact [1]. Political decisions and regulations at both European and national level contribute to reach those targets [2], [3]. The

* Corresponding author.
E-mail address: ieva.pakere@rtu.lv

European Union (EU) and its Member States, including Latvia, has implemented targeted policies towards low carbon development since 2013. In 2014, the European Climate and Energy Framework for 2030 was adopted, which sets an aim of greenhouse gas (GHG) reduction by 40 % compared to year 1990 [4]. It aims to reach at least 32 % share of renewable energy in gross final consumption and at least 32.5 % energy efficiency gains [5]. Therefore, EU Member States must move towards a low-carbon economy by 2050.

Several researchers [6]–[8] have developed the idea of 100 % renewable energy systems. Such conceptual systems are mainly based on the combination of variable renewable energy sources (RES) (wind, geothermal, solar) with more controllable energy resources such as waste and biomass. However, in order to reduce the need for biomass that primarily should be used for the production of higher quality products, the concept of sustainable energy system development should also include energy efficiency and energy savings.

In many countries, including Latvia, providing heat to buildings and preparing hot water is one of the basic needs. Currently, there is an intensive discussion on how to optimize heat supply to reduce the share of fossil energy resources and to ensure an optimal level of costs [9]. The infrastructure of district heating (DH) system plays an important role in improving energy efficiency and adapting available RES to energy consumption [10]. The DH network connects buildings in different areas of cities and other settlements, so the heat can be supplied from different centralized boiler houses, combined heating plants (CHP) or several heat production facilities of a lower capacity. This approach allows integrating and combining different heat sources more easily [11].

Competitiveness of DH system derives from a combination of heat generation and supply efficiency conditions. An important requirement for optimal heat supply is that the demand for heat should be concentrated in order to reduce distribution costs and heat losses. 4^{th} generation DH (4GDH) concept has been introduced which emphases that existing heating systems require essential changes by reducing the heat carrier's temperature in networks, adapting to the energy consumption of energy-efficient buildings and becoming part of a common "smart" energy system [12], [13].

The introduction of 4GDH is a set of complex solutions that can combine different technological solutions for the consumers, heating networks and heat source [14]. The conditions for the implementation of such complex system should ensure achieving maximum economically viable efficiency in the overall heat supply system, taking into account the interaction between the implemented measures. The introduction of various innovative solutions (such as opening up networks to integrate surplus heat, load management, build-up of accumulation systems, etc.) requires careful alignment and optimization of system components [15], [16].

Implementation of 4GDH requires long-term strategic planning and higher investments for innovative solutions. Therefore, in 2017 Germany launched a subsidies program for 4GDH pilot projects "Modellvorhaben Wärmenetzsysteme 4.0", which supports both feasibility study and implementation of measures in heating network and heat source [17]. The main aim of the program is to increase the share of renewable energy sources and increase the DH system cost efficiency. However, the environmental benefits are not straightly evaluated in this support program.

There are several methods for evaluation of climate change mitigation measures such as multi-criteria analyses [18], equilibrium [19], input – output framework [20] etc. Cilinskis et al. [21] have analysed different policy instruments supporting GHG emissions reduction through system dynamics approach. Authors conclude that the best results can be achieved by subsidies for solar energy technologies and increased CO_2 tax.

To determine the potential energy savings and GHG emission reduction from 4GDH implementation in all system elements it requires complex simulation of DH system operation. Consequently, only experts in field can conduct such analyses. This aspect can cause difficulties when it is necessary to evaluate and compare several pilot projects as there is lack of such specialists in governmental institutions, enterprises and other organizations. Therefore, the main aim of this article is to introduce simple methodology for estimating the total climate gain when introducing 4GDH.

2. METHODOLOGY

In Latvia the amount of fuel consumed in the transformation sector for the production of heat and electricity was 51.2 PJ in 2017, therefore 46.9 PJ of fuel was used in CHP and boiler houses [22]. The main energy source in heating sector is natural gas (62 %) while rest of heat in generated from wood biomass (firewood, wood chips, pellets etc.). The share of wood consumption is higher in heat-only boilers (excluding the heat produced in CHP) and it has increased from 31 % in 2012 to 42 % in 2017. However, the direct replacement of natural gas with the use of biomass, which also reduces GHG emissions, is not a sustainable solution due to land limitations and necessity to produce high value products and not use it for energy production [23].

GHG emissions originate mainly from the combustion of natural gas for energy production. Therefore, the main objective to achieve GHG emission reductions in this sector is to reduce natural gas consumption. This can be achieved by replacing natural gas with renewable energy sources and by reducing total energy consumption.

The introduction of 4GDH would contribute to the reduction of emissions in the energy sector by reducing heat losses in heating network and increasing heat production efficiency [24] and increasing of renewable energy source potential. Fig. 1 shows a simplified flow diagram for the energy sector, where the main flows are generated and consumed heat and power. A coloured energy system flows and elements would be affected by the transition to 4GDH.

The main reduction of GHG emissions when introducing 4GDH would be by the following energy efficiency improvements:

- Replacement of natural gas and other fuels (1) with renewable energy sources (biomass, solar thermal, thermal energy from technological processes, etc.);
- Increasing the efficiency of condensing economizer operation in biomass boiler houses (2);
- Increased amount of electricity generated in CHP (3);
- Reduction of heat loss in heat networks (4);
- Reduction of heat consumption in buildings due to increased energy efficiency (5).

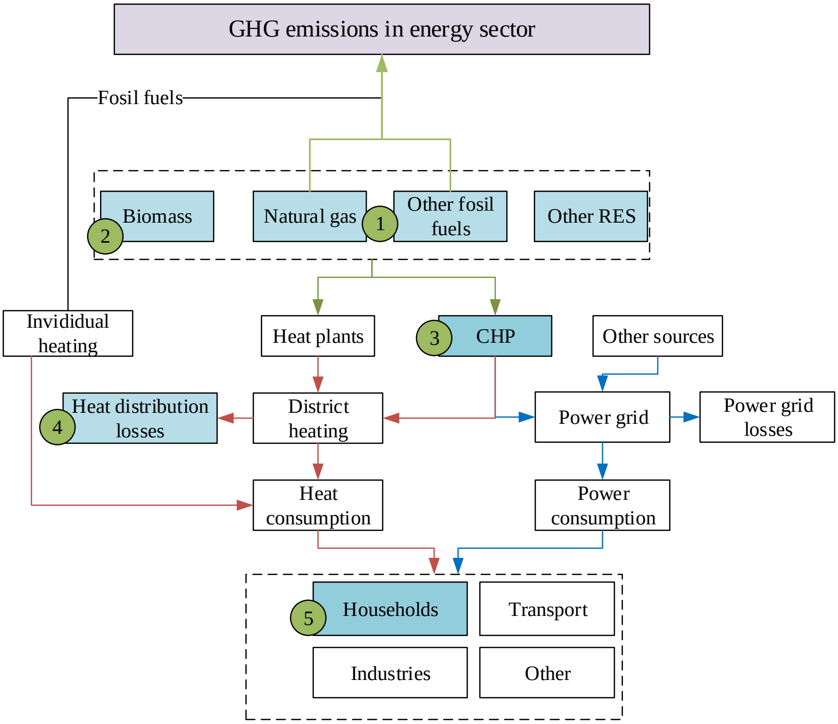

Fig. 1. Energy sector scheme in Latvia and processes affected by 4GDH introduction.

The linear regression equation describes the relationship between CO_2 emissions and 3 independent variables. This is achieved by analysing various DH element development scenarios and their maximum and minimum achievable CO_2 emission savings, which, as an example for one of the analysed cases, is summarized in a matrix table below.

TABLE 1. EXAMPLE OF SCENARIO MATRIX FOR BUILDINGS WITH HEAT DEMAND 70–140 KWH/M^2 PER YEAR (SOURCE: NATURAL GAS)

Energy efficiency at heat source	**Energy efficiency in heating network**	**Energy efficiency in buildings**	**CO_2 emissions tonnes per year**
0.95	0.92	70.00	28.35
0.75	0.80	140.00	82.60
0.75	0.80	70.00	41.30
0.75	0.92	140.00	71.83
0.75	0.92	70.00	35.91
0.95	0.92	140.00	56.70
0.95	0.80	70.00	32.61
0.95	0.80	140.00	65.21
0.85	0.86	105	50.85

The matrix example in Table 1 has been developed by assuming different maximal and minimal efficiency values for heat source, heating network and heat consumptions in buildings. To calculate the amount of CO_2 emissions (tonnes per year), Eq. (1) is applied for all the developed scenarios. The CO_2 emission factors that are used in calculations are summarized in Table 2.

$$CO_2 = \frac{\eta_{\text{building}}}{\eta_{\text{network}} \cdot \eta_{\text{source}}} \cdot R_{CO_2}, \tag{1}$$

where

η_{source}	Energy efficiency at the heat source;
η_{network}	Energy efficiency in heating network;
$\eta_{\text{buildings}}$	Specific heat consumption in buildings, kWh/m^2;
R_{CO_2}	CO_2 emission factor, tonnes/kWh.

TABLE 2. CO_2 EMISSION FACTORS USED IN RESEARCH

Fuel type	**Specific CO_2 emission factor, tonnes/kWh**
Natural gas	0.202
Diesel fuel	0.267
Fuel oil	0.279
Liquid natural gas	0.227
Coal	0.354
District heating	0.123

After scenario selection multiple regression analysis is used to create mathematical equation, what describe how variables affect response. Algorithm for scenario analysis and calculation for CO_2 emission savings are given in Fig. 2.

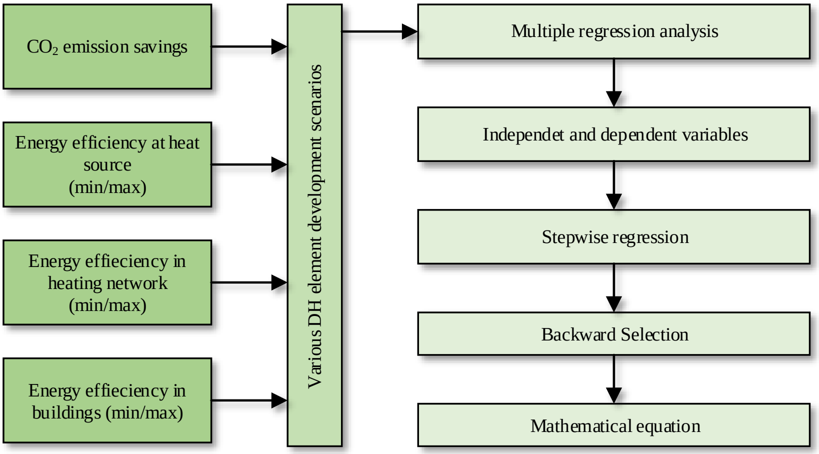

Fig. 2. Algorithm for CO_2 savings.

The first step is definition of independent variables and dependent variable. There are three independent variables: (1) energy efficiency in heat source, (2) energy efficiency in heating network, (3) energy efficiency in buildings and dependent variable (1) CO_2 emission savings. Second step is to create stepwise regression. Stepwise regression is a method for simplification of the model. In stepwise regression, variables are added or removed from the regression model one by one to obtain a model that contains only significant predicators, but does not exclude any useful variables. This method includes forward and backward selections. For this mathematical equation, a backward selection is performed, starting with a model containing all variables and removing them one by one until all the remaining variables are statistically significant. By using the backward method, the removed variables can be re-entered at a later stage if they later appear to be useful predictors or the previously entered variables can be removed later if they are no longer relevant [25].

A regression model validation is performed on a significance test. A data set is generally considered statistically significant if the probability of a random occurrence is less than 1/20, resulting in a p value of 5 %. Therefore, if p is less than 5 %, it shows a statistically significant result between the variables [24].

3. RESULTS

The 4GDH introduction activities (such as energy efficiency measures in building, temperature reduction in heating network, integration of RES etc.) interact with each other, for example, insulation of buildings can allow to DH Company lowering the temperature in the networks, which in turn increases the efficiency of the networks and heat generation plant. In such cases, the potential energy savings and reduction of CO_2 emissions are formed by various related processes that require complex engineering calculations. Thus, for the calculation of CO_2 reduction in tonnes, it is proposed to use a simplified calculation formula obtained by preparing the mathematical model and including the assessment of the energy efficiency component in a particular heat supply element with a certain technological solution.

$$\mathrm{CO}_2 = (a - b \cdot \eta_{\mathrm{source}} - c \cdot \eta_{\mathrm{network}} + d \cdot \eta_{\mathrm{buildings}}) \cdot A, \quad (2)$$

$$\mathrm{CO}_2' = (a - b \cdot \eta_{\mathrm{source}}' - c \cdot \eta_{\mathrm{network}}' + d \cdot \eta_{\mathrm{buildings}}') \cdot A, \quad (3)$$

where

η_{source}`	Energy efficiency at the heat source after the measures;
$\eta_{network}$`	Energy efficiency in heating network;
$\eta_{buildings}$`	Specific heat consumption in buildings after the measures, kWh/m^2;
A	Building heating area, m^2;
a, b, c, d	Values according Table 2.

The linear regression model allows to obtain simplified coefficients for CO_2 determination in case of different fuels used and for different energy efficiency levels of buildings. Since the observed significance level (P) for the obtained equation is less than 0.05, the statistically significant relationship between the variables is at the 95 % confidence level. The determination coefficient (r^2) for the equation is 98.39 %, which explains the variability of the CO_2 emission factor. To compare the value (CO_2 emissions) of the various variables, the corrected r^2 value is 97.14 %. The average absolute error of the generated equation is 1.325.

The variance analysis shows that the variables selected in the model are significant and there is no need to change the selected values.

Energy efficiency at heat plant before and after the energy efficiency measures (η_{source} and η_{source}`) is determined by an independent expert on energy performance of buildings with an appropriate certificate on inspection of heating and air conditioning systems. The efficiency of heat production must be between 0.75 and 0.95. Energy efficiency after temperature lowering in heating network will be higher for following cases:

- Flue gas condenser is installed as it is possible to recover a larger share of heat;
- Heat is produced in a CHP unit as more electricity can be generated;
- The use of alternative energy sources increases (for example, solar collectors, heat pump) as they energy production efficiency increases;
- Surplus heat or the return flow of another housing district is used as it is possible to extract low potential heat.

TABLE 3. LINEAR REGRESSION EQUATION COEFFICIENT VALUES FOR DIFFERENT TYPES OF FUELS AND BUILDINGS

Fuel type	**Specific heat consumption of buildings for space heating**							
	Consumption range 70–140 kWh/m^2 per year				Consumption range 141–250 kWh/m^2 per year			
	a	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Natural gas	59.1	34.8	34.4	0.28	109.8	64.6	63.8	0.28
Diesel fuel	78.2	46.0	45.4	0.37	135.6	75.4	78.8	0.35
Fuel oil	81.7	48.0	47.5	0.39	141.7	78.7	82.4	0.36
Liquid natural gas	66.5	39.1	38.6	0.32	115.3	64.1	67.1	0.30
Coal	103.7	61.0	60.3	0.49	179.8	99.9	104.5	0.46
District heating	35.9	21.2	20.9	0.17	62.4	34.7	36.3	0.16

An independent expert determines the energy efficiency of heat networks before and after the introduction of measures ($\eta_{networks}$ and $\eta_{networks}$`). The energy efficiency values of the heating networks must be between 0.8 and 0.92. The values vary according to the type of heat network, pipe parameters, location and heat carrier temperature. Energy efficiency increases in case of lower heat network temperature.

The energy efficiency of the consumer before and after the implementation of the measures ($\eta_{buildings}$ and $\eta_{buildings}$`) is determined according to building energy audit as specific heat consumption. The maximum value of the specific heat consumption to be achieved for heating is 70 kWh/m^{2}a, which is in accordance with Latvian construction legislation. The maximum specific consumption of the building for heating before the implementation of the measures is determined as 250 kWh/m^2 per year.

The set of limits of minimal energy efficiency levels allows to exclude the priority for extreme project cases when good engineering and maintenance practices are not been done properly. If the set values are outside these limits, then they are equalized.

The example of methodology application is proposed below.

The building with total heating area of 2000 m^2 needs to be insulated in order to reduce the specific heat consumption for space heating from 150 kWh/m^2 to 80 kWh/m^2. In addition, the reconstruction of the heating units for the improvement of the heating system is planned in order to reduce the temperature of the heating networks. Existing inefficient heat networks will be replaced by new, well insulated pipelines, and the heat carrier temperature will be reduced from 90 ºC (supply) and 70 ºC (return) to 70 ºC (supply) and 40 ºC (return). Therefore, network efficiency due to heat loss reduction will increase from 0.82 to 0.91. For the production of thermal energy, it is planned to replace the existing natural gas boiler with the wood pellet boiler and the production efficiency would increase from 0.85 to 0.9. In the example, the natural gas values are used for the calculation of overall CO_2 savings to emphases the efficiency increase from 4GDH implementation. Alternative calculation method would assume that after the reconstruction when biomass is used for heat generation there is no CO_2 emissions at all. However, it would not show the overall gains from energy efficiency increase.

Therefore, by using the linear regression values from Table 3 and the determined energy efficiency values, the potential CO_2 emission reduction can be determined:

$$\Delta CO_2 = (109.8 - 64.6 \cdot 0.85 - 63.8 \cdot 0.82 + 0.28 \cdot 150) \cdot 2000/1000 - (59.1 - 34.8 \cdot 0.9 - 34.4 \cdot 0.91 + 0.28 \cdot 80) \cdot 2000/1000 = 89.15 - 37.75 = 51.39 \text{ t.}$$

The calculated potential CO_2 reduction in this example would be around 51.39 tonnes per year. This value can be used to determine other evaluation criteria for example the specific CO_2 reduction costs.

4. Conclusions

All of DH system elements have a defined role in the overall development of the DH system. The transition to 4GDH involves changes in each of those elements that interact with each other. For example, energy efficiency measures in buildings allows to lower heat carrier temperature in the heating network. In addition, lower heating network temperature increases the heat generation efficiency and allows integrating low potential heat sources. Therefore, various related processes form the potential energy savings and reduction of CO_2 emissions when introducing 4GDH system as whole in all elements.

The article describes a novel methodology for evaluating the potential GHG emission reduction when implementing 4GDH. Thus, for the calculation of CO_2 reduction, it is proposed to use a simplified calculation formula from a linear regression model. Methodology includes the assessment of the energy efficiency component in a particular heat supply element with a certain technological solution.

The main steps in the proposed methodology are the definition of independent variables (energy efficiency in heat source, energy efficiency in heat network, energy efficiency in buildings), calculation of dependent variable CO_2 emission savings, creation of stepwise regression, backward selection and validation of the obtained linear regression equation.

Authors have obtained values of linear regression equation coefficients for different types of fuels and buildings in order to estimate the overall environmental benefit from 4GDH implementation. The total CO_2 savings results from reduced energy consumption of buildings, decreased heat losses in heating network and more efficient heat generation. The offered methodology allows simplifying the evaluation process of complex DH system pilot projects in order to support the most beneficial ones.

The significance test was carried out in order to validate the proposed linear regression model. The variance analysis shows that the variables selected in the model are significant and there is no need to change the selected values.

Different local or national authorities can use the proposed linear regression methodology as it allows evaluating the environmental benefit when transforming existing DH systems to low temperature 4GDH system without complex engineering calculations. The methodology can be applied for different case studies if only specific heat consumption of buildings and energy efficiency of heating networks and heat plant meet the certain boundaries.

Nevertheless, one can customize the obtained linear regression equation with particular conditions when following the methodology described in the article. There are numerous different heat generation options including use of various heat sources or mixes of them and heat generation technologies (heat only boilers, combined heat and power plants, renewable technologies etc.). The proposed linear regression methodology mainly investigates the benefit from energy efficiency increase in overall DH system. To determine the gains from other energy efficiency measures (such as switching from heat only boiler to CHP, use of fuel mixes and RES) additional criterions should be added to the evaluation methodology (example, generated heat from RES, specific heat consumption in buildings etc.). In addition to the calculation of several criterions, the 4GDH project developer should carry out detailed analyses of the heat supply system development alternatives assessing different levels of heat consumption, heat carrier temperature levels and thermal energy production technologies. Such analyses allow to identify most economically, socially and technologically feasible solutions.

ACKNOWLEDGEMENT

This research is funded by the Ministry of Economics of the Republic of Latvia, project "Development of heat supply and cooling systems in Latvia", project No. VPP-EM-EE-2018/1-0002.

REFERENCES

[1] Latosov E., Volkova A., Siirde A., Kurnitski J., Thalfeldt M. Methodological approach to determining the effect of parallel energy consumption on district heating system. *Environmental and Climate Technologies* 2017:19(1):5–14. doi:10.1515/rtuect-2017-0001

[2] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/ECE. *Official Journal of the European Union* 2012:L315/1.

[3] Energy efficiency law. *Latvijas Vestnesis* 2016:2(5624).

[4] 2030 climate & energy framework [Online]. [Accessed 02.02.2019]. Available: https://ec.europa.eu/clima/policies/strategies/2030_en

[5] Proposal for a Directive of the European Parliament and of the Council amending Directive 2009/28 / EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources [Online]. [Accessed 02.02.2019]. Available: https://eur-lex.europa.eu/resource.html?uri=cellar:1907bfec-b7e9-11e6-9e3c-01aa75ed71a1.0007.02/DOC_1&format=PDF

[6] Østergaard A. P., Mathiesen B. V., Möller B., Lund H. A renewable energy scenario for Aalborg municipality based on low-temperature geothermal heat, wind power and biomass. *Energy* 2010:35(2):4892–4901. doi:10.1016/j.energy.2010.08.041

[7] Østergaard P. A., Lund H. A renewable energy system in Frederikshavn using low-temperature geothermal energy for district heating. *Applied Energy* 2011:88(2):479–487. doi:10.1016/j.apenergy.2010.03.018

[8] Lund H. Renewable energy strategies for sustainable development. *Energy* 2007:32(6):912–919. doi:10.1016/j.energy.2006.10.017

[9] Paiho S., Saastamoinen H. How to develop district heating in Finland? *Energy Policy* 2018:122:668–676. doi:10.1016/j.enpol.2018.08.025

[10] Latõšov E., Volkova A., Siirde A., Kurnitski J., Thalfeldt M. Primary energy factor for district heating networks in European Union member states. *Energy Procedia* 2017:116:69–77. doi:10.1016/j.egypro.2017.05.056
[11] Hast A., Syri S., Lekavicius V., Galinis A. District heating in cities as a part of low-carbon energy system. *Energy* 2018:152:627–639. doi:10.1016/j.energy.2018.03.156
[12] Lund H., et al. 4th Generation District Heating (4GDH). Integrating smart thermal grids into future sustainable energy systems. *Energy* 2014:68:1–11. doi:10.1016/j.energy.2014.02.089
[13] Latosov E., Volkova A., Siirde A., Thalfeldt M., Kurnitski J. The Impact of Parallel Energy Consumption on the District Heating Networks. *Environmental and Climate Technologies* 2019:23(1):1–13. doi:10.2478/rtuect-2019-0001
[14] Rama M., Sipila K. Transition to low temperature distribution in existing systems. *Energy Procedia* 2017:116:58–68. doi:10.1016/j.egypro.2017.05.055
[15] Fenton P., Gustafsson S., Ivner J., Palm J. Sustainable Energy and Climate Strategies: lessons from planning processes in five municipalities. *Journal of Cleaner Production* 2015:98:213–221. doi:10.1016/j.jclepro.2014.08.001
[16] Schuchardt G. K. Integration of decentralized thermal storages within district heating (DH) networks. *Environmental and Climate Technologies* 2016:18(1):5–16. doi:10.1515/rtuect-2016-0009
[17] DH development programm "Modellvorhaben Wärmenetzsysteme 4.0" [Online]. [Accessed 02.02.2019]. Available: http://www.bafa.de/DE/Energie/Energieeffizienz/Waermenetze/ waermenetzenode.html
[18] Konidari P., Mavrakis D. A multi-criteria evaluation method for climate change mitigation policy instruments. *Energy Policy* 2007:35(12):6235–6257. doi:10.1016/j.enpol.2007.07.007
[19] Babatundea K. A., Begumc R. A., Saida F. F. Application of computable general equilibrium (CGE) to climate change mitigation policy. *Renewable and Sustainable Energy Reviews* 2017:78(C):61–71. doi:10.1016/j.rser.2017.04.064
[20] Choi J. K., Bakshi B. R., Hubacek K., Nader J. A sequential input–output framework to analyze the economic and environmental implications of energy policies: Gas taxes and fuel subsidies. *Applied Energy* 2016:184:830–39. doi:10.1016/j.apenergy.2016.05.033
[21] Cilinskis E., Ziemele J., Blumberga A., Blumberga D. Analysis of support measures for promoting energy efficiency and renewables for GHG emissions reduction in non-ETS sector. *Energy Procedia* 2017:142:2838–2843. doi:10.1016/j.egypro.2017.12.430
[22] Central Statistical Bureau of Latvia. ENG020. Energy balance, TJ, thsd toe (NACE Rev. 2) [Online]. [Accessed 02.02.2019] Available: https://data1.csb.gov.lv/pxweb/en/vide/vide__energetika__ikgad/ENG020.px/
[23] Muizniece I., Gravelsins A., Brauners I., Blumberga A., Blumberga D. Innovative bioproducts from forest biomass. Method of analysis. *Energy Procedia* 2017:113:434–441. doi:10.1016/j.egypro.2017.04.035
[24] Castro Flores J. F., Lacarrière B., Chiu J. N. W., Martin V. Assessing the techno-economic impact of low-temperature subnets in conventional district heating networks. *Energy Procedia* 2017:116:260–272. doi:10.1016/j.egypro.2017.05.073
[25] James G., Witten D., Hastie T., Tibshirani R. An Introduction to Statistical Learning with Applications in R. New York: Springer, 2013. doi:10.1007/978-1-4614-7138-7