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THE POTENTIAL COGENERATION THERMAL CAPACITY CHOICE FOR HEAT SOURCE GROUP

SILTUMA AVOTU GRUPAS POTENCIĀLĀS KOĢENERĀCIJAS SILTUMA JAUDAS IZVĒLE

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Introduction

Heating in Latvia is primarily produced on a centralized basis. This means that consumers are grouped and heating is distributed from a heat source which is intended for the consumer group. The heat source power, depending on the consumer group, is from tens of kW to several hundred MW. The lower range in power corresponds to groups of buildings, individual houses or even apartment heating. Heating of residential and individual homes belongs is provided through decentralized heating. It should be noted that the degree of centralization varies - from the apartment or individual home to a municipal or city heat supply. One of the benefits of district heating is the centralization of the heat load, which makes it possible to increase the heat source power and to form basis for the development of cogeneration power. In Latvia large heat consumers, such as the heating systems in large cities like Riga, cogeneration plants are installed and energy development activities are carried out in CHP's TEC 1 and TEC 2. Left are customers who are not connected to a district heating or switched off from it. For the most part, district heating exists also elsewhere in the country which indicates a possibility for CHP development. This will be dispersed power production. It is important to determine what capacity equipment is needed and how high the total capacity is, depending on the consumer's load. Data on the source of heat loads can be obtained from different databases, for example - Gaiss 2 and, for companies using natural gas, - from the *Latvijas Gaze* database.
Data on the heat sources using gas is available in more detail, which characterizes consumption by decades, and thus makes it possible to trace the dynamics of loads during the year and to construct load duration curves. Gas customers form a large heat source group, but gas can be used only where there are gas pipes. Throughout the remainder of the country’s territory, solid or liquid fuels are used. Although these companies, using the appropriate technological equipment, can develop CHP energy. For its exploration is used Gaiss 2 database.

Selection methodology of cogeneration heat capacity

The aim of data analysis is to estimate the capacity of those heat sources where cogeneration equipment is not installed and to determine the potential for CHP based on the capacity of the heat source. The paper deals only with those companies that use natural gas.
As it is known, CHP plants cover only a part of the total heat load. The rest of the load is covered by the peak load boilers. This means that, based on the total heat capacity of the source, the potential heat capacity of cogeneration should be assessed quantitatively. The heat capacity of a cogeneration plant has to be selected such that, upon operating the equipment at the particular capacity selected, heat production reaches its maximum [1].
The paper develops a heat load duration curve for the selected capacity group and stemming from that - evaluates the appropriate group heat source capacity for potential cogeneration. The question is how justified is such a generalized approach, because the equipment is installed at each individual heat source. The conformity of characteristics of the group's heat load duration curve to the heat load duration curve of separate source timetable is analyzed on the basis of operational results in 2007 of the Lielvarde cogeneration station.
The heat capacity of the group is determined by inputting the decade or annual gas consumption in the following equation (1):

$$N_{th} = \frac{B_i Q_z^d \eta}{\tau_i}, MW, \qquad (1)$$

where
B_i - decade or annual gas consumption, m^3;
Qz^d - net calorific value, MWh/m^3;
η=0,9 - efficiency ratio of the heat source;
τ_i - decade or annual number of hours, h.

Using the equation (1), the average heat capacity over the decade is calculated as (2):

$$N_{th} = 0{,}035.10^{-3}.B_d,\ MW, \qquad (2)$$

where
B_d - decade gas consumption, m^3.

The annual average heat capacity is determined by the equation (3):

$$N_{th} = 0{,}972.10^{-6}.B_g,\ MWh, \qquad (3)$$

where
B_g - year gas consumption, m^3.
The average capacity changes in decades in 2007 for the capacity group 0.05-0.5 MW of the heat sources are seen in Figure 1.

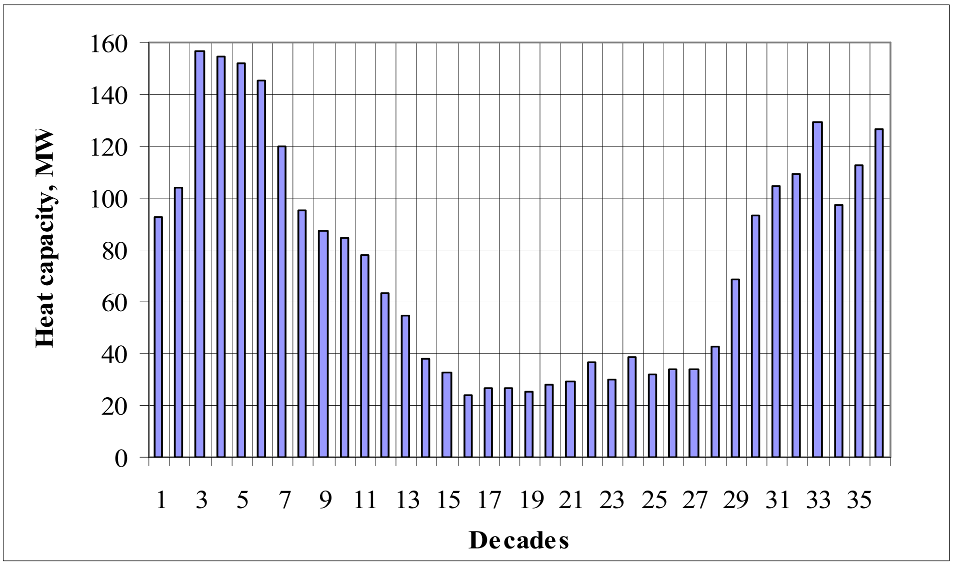

Fig. 1. Decades average power changes in year for 0,05-0,5 MW capacity group of heat sources

It appears that the heat capacity varies from 156 MW in winter's coldest decade up to 24 MW in summer.
Moreover, the heat capacity of the source will be influenced by changing climatic conditions and consequently the load duration curve will be changed. In order to assign the load changes of the source, the generalizing nature has to be recalculated according to climatic factors determined by building standard in Latvia LBN 003-01 "Buvklimatologija". Recalculation is carried out by using the degree-day values GDn and GD_{2007}, which shall be determined using regulatory conditions of building standard, and metrological station measurement data from year 2007. GDn/GD_{2007} ratio is 1.173. Climatic conditions do not significantly affect the hot domestic water load therefore the heating load part has to be recalculated. The corrected heat load duration curve of the capacity group and its approximation are shown in Figure 2.

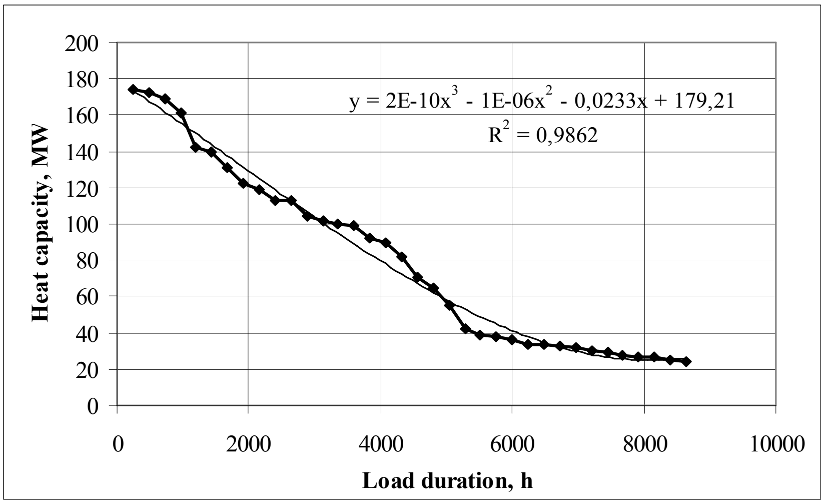

Fig. 2. Corrected load duration curve of the group

The picture shows the graph approximation curve with its equation. Approximation curve and real-time schedule have a very good correlation, R^2=0,98. Adjusted load has increased in the winter and the heat capacity is 179 MW compared to 160 MW in the uncorrected case load.

In order to generalize load duration curve and to compare it to other capacity groups or individual source load curve, the relative heat capacity changes are made depending on the relative time. The relative capacity is determined as the instantaneous capacity to the maximum capacity of N_{th}/N_{th}^{max} and relative length of load duration as the number of hours of time to the number of hours per year $\tau/8760$. The relative capacity as well as the relative length of load time varies from 0 to 1. Relative load duration curve is shown in Figure 3.

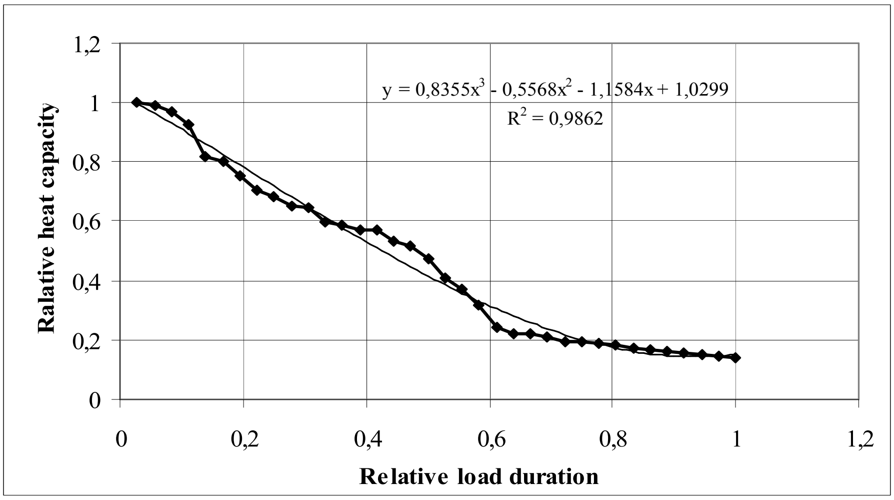

Fig. 3. Relative corrected load duration curve of the group

Installed heat capacity of the cogeneration plant should be chosen in the way that production of heat is on maximum (optimum) for the equipment operated with this capacity. The development of heat energy by cogeneration is defined from the load duration curve as (4).

$$Q_{th} = N_{th}.\tau, \ MWh, \qquad (4)$$

where

τ - possible time of use of heat capacity, h.

The transition from a real-time to relative load duration curve, indicator of optimization will no longer be the energy production Q_{th}, , but appropriate to it index - which is determined as (5).

$$\beta = \frac{N_{th}}{N_{th}^{\max}} \cdot \frac{\tau}{8760} = N_{th}^{rel} . \tau_{rel} . \qquad (5)$$

where

N_{th}^{rel} - relative heat capacity;

τ_{rel} - relative time value.

It is important to know how long the CHP can be operated in the optimum power mode providing that the maximum heat is produced. Figure 4 shows the indicator changes depending on the relative running time.

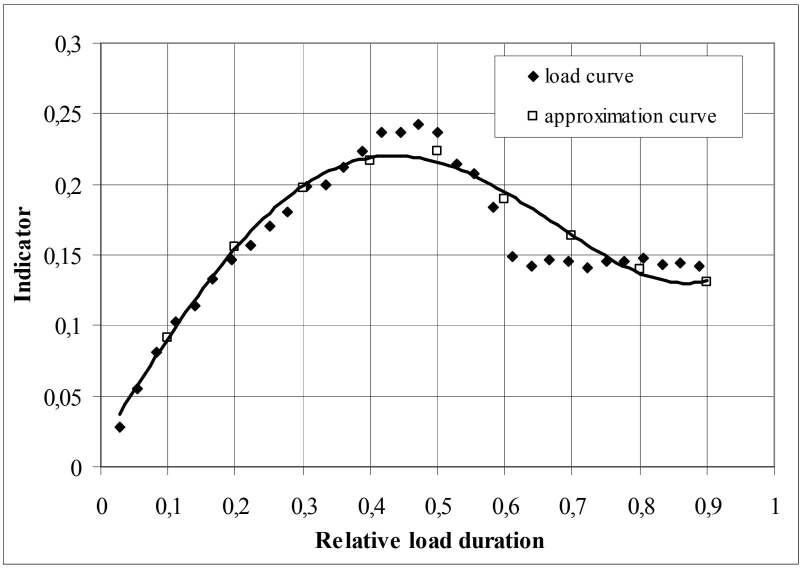

Fig. 4. CHP heat production indicator changes depending on the relative load duration curve

It appears that the maximum indicator value for the relative load duration curve is 0.46 and the corresponding to it number of hours is about 4000 h. This means that equipment with installed thermal capacity of 85 MW can be operated on a full load 4000 hours per year, thus achieving an optimum heat production, the maximum fuel savings and CO_2 emission reductions [2].

The examined optimal size assessment is conducted by the help of measure change schedule. If obtained load duration curve approximation equations, the evaluation can be carried out in analytically estimate way. Relative adjusted capacity group changes depending on the relative time are given by the equation (6).

$$N_{th}^{rel}\left(\tau_{rel}\right)=0{,}836.\tau_{rel}^{3}-0{,}557.\tau_{rel}^{2}-1{,}158.\tau_{rel}+1{,}03 \quad (6)$$

According to relationship (5) and (6) the indicator is calculated in terms (7).

$$\beta=N_{th}^{rel}\left(\tau_{rel}\right).\tau_{rel}=0{,}836.\tau_{rel}^{4}-0{,}557.\tau_{rel}^{3}-1{,}158.\tau_{rel}^{2}+1{,}03.\tau_{rel} \quad (7)$$

The indicator value of the optimal rule is (8) [3].

$$\frac{d\beta}{d\tau_{rel}}=0. \quad (8)$$

Differentiating expression (7) yields the equation for optimal indicator for the relative time calculation (9).

$$\frac{d\beta}{d\tau_{rel}}=3{,}344.\tau_{rel}^{3}-1{,}671.\tau_{rel}^{2}-2{,}316.\tau+1{,}03=0 \quad (9)$$

By inserting calculated τ_{rel} value in equation (6) is determining that relative installed capacity of CHP in which the equipment will develop the maximum of heat energy in cogeneration mode. Calculations show that τ_{rel} value is 0.43 and the corresponding relative capacity N_{th}^{rel} is 0.49 or τ=3770 h and N_{th}=88 MW. Analyses show that analytically calculated values from the load duration curve value are well-correlated. The value difference is 5.7% for time estimation and 3.5% for capacity.

In order to define a cogeneration potential it is necessary to evaluate the source average heat capacity correlation in a year with the optimal installed heat capacity of CHP. In the database Gaiss 2 there are available data about the total fuel consumption of the sources, which makes possible to determine the average capacity. The annual average relative capacity is determined by integrating expression (6) in the relative timing of the range from 0 till τ_{rel}^{g} (10).

$$N_{th}^{rel.vid}=\frac{1}{\tau_{rel}^{g}}.\int_{0}^{\tau_{rel}^{g}}N_{th}^{rel}\left(\tau_{rel}\right)d\tau_{rel}=\frac{1}{\tau_{rel}^{g}}.\int_{0}^{\tau_{rel}^{g}}\left(0{,}836.\tau_{rel}^{3}-0{,}557.\tau_{rel}^{2}-1{,}158.\tau+1{,}03\right)d\tau_{rel}=$$
$$=\frac{1}{\tau_{rel}^{g}}.\left(0{,}209.\tau_{rel}^{4}-0{,}186.\tau_{rel}^{3}-0{,}579.\tau_{rel}^{2}+1{,}03.\tau_{rel}\right) \quad (10)$$

By inserting the integration limit values 0 and 1 we obtain that the relative capacity of average in year is 0.47, or 84 MW. The annual average and the calculated optimal CHP capacity ratio is 0.95. This means that heat capacity of potential CHP in the examined capacity group of sources can be valued at the average capacity group of sources multiplied by 0.95. It should be noted that other capacity group analysis shows that relationship value can vary from 0.80 to 0.95.

Lielvarde cogeneration plant data analysis

Lielvarde cogeneration station belongs to 0.05-0.5 MW capacity group. CHP average heat capacity is 0.49 MW and the development of cogeneration energy is used 0.265 MW. The remaining part of the load is covered by the peak load boilers.

The aim of using Lielvarde cogeneration plant operating data from 2007 is to assess the data compliance with the source of the group analysis, obtained in relative values, thus justifying the use of source group analysis accuracy. Lielvardes heat source decades and the annual gas consumption data are used in the analysis. Designated thermal power is converted into the normative climatic conditions.

It is created a load duration curve based on a decade heat capacity changes during the year Relative duration curve makes it possible to compare the source and the sources group heat load changes. Relative changes in load, depending on the relative time are shown in Figure 5.

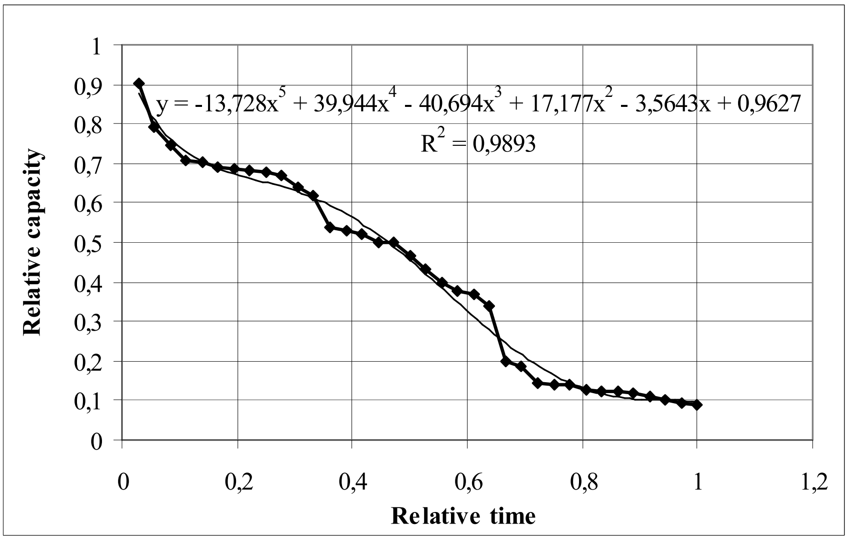

Fig. 5. Relative load duration curve of heat source in Lielvarde

Loads graphic approximation curve and its equation are also seen in the Figure 5. This is the polynomial of the 5th degree expression, which describes 99% of the load data changes. The determination coefficient is 0.989. Equation high degree is explained by the strong imbalance in relative power changes.

Result analyses

Lielvarde plant heat setting indicator changes depending on the relative load are shown in Figure 6.

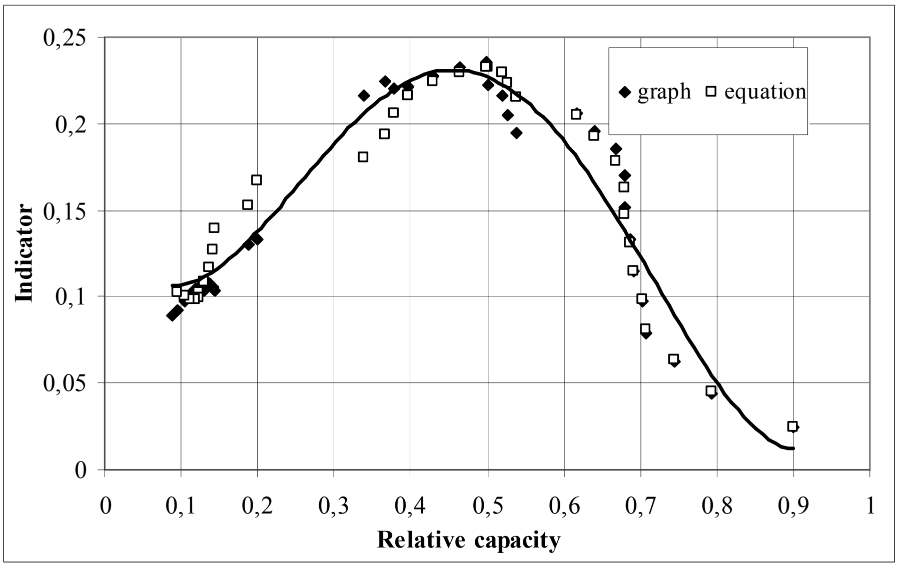

Fig. 6. Lielvarde plant heat setting indicator changes depending on the relative load

It appears that the optimal criteria value corresponds to the relative power value 0.45. This means that the majority of heat production in cogeneration mode Lielvarde heat source could provide if there would be installed cogeneration plant with a thermal capacity of 0.45 from the maximum or 0.45 MW. According to the heat load curve this kind of power plant could work around 4000 hrs a year. With the current installed capacity of cogeneration equipment, according to the heat load duration curve, unit on a full load can work around 5700 hrs a year. In case of optimal thermal power, cogeneration plant could develop additional 290 MWh of heat and according to it 180 MWh of electricity. Cogeneration heat development indicator comparison between Lielvarde heat source and the group of sources is shown in Figure 7.

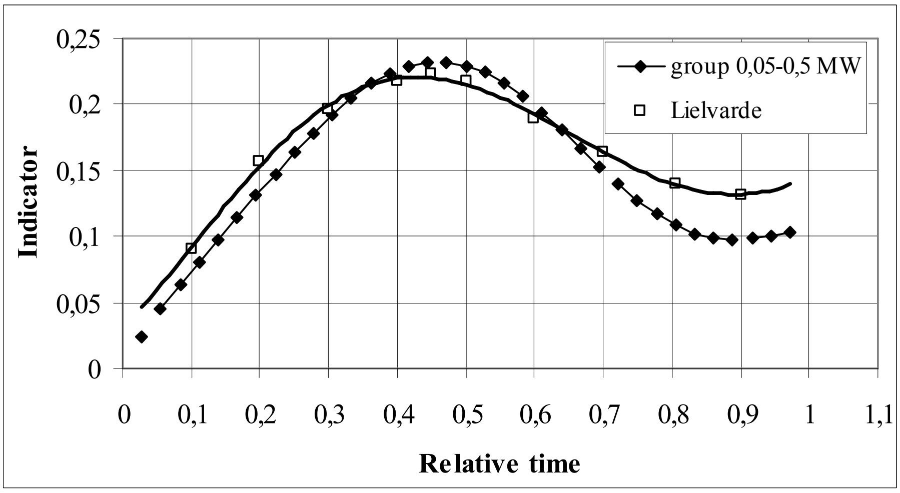

Fig. 7. Lielvarde and source group of sources indicator change comparison

According to Figure 7 there can be observed slightly different values in group and source indicators. In cases of small and large relative time Lielvarde heat source indicator values are higher compared to the capacity group indicator values. The optimal value of the indicator is higher for the capacity group. It is essential that the optimal indicator values are observed almost at the same time and the optimal indicator value margin is small.

In order to assess quantitatively differences between Lielvarde and group of sources indicators, changes are compared to relative and absolute values.

Parameter values and the comparison are shown in the Table 1 below.

Table 1.

Comparison between Lielvarde and capacity group of sources indicators

Parameter	Lielvarde	Capacity group	Difference,%
Optimum relative time	0,45	0,46	-2,2
Operating time with the optimal capacity, h	3940	4030	-2,3
Optimum relative power	0,45	0,47	-4,4
The optimal thermal power, MW	0,45	85	
The annual average heat capacity, MW	0,490	87	
Optimum heat capacity correlation to annual average heat capacity	0,92	0,98	-6,5

Parameter difference in percentage is determined as Lielvarde and group size

difference referenced to Lielvarde parameters. It appears that the difference is small and does not exceed 6.5%. This shows that the potential for cogeneration heat capacity can be reasonably evaluated by using the capacity group summary load duration curve.

Conclusions

Offered heat source cogeneration potential assessment method is based on the heat sources group gathered heat load duration curve analysis and optimization of installed thermal power of cogeneration unit. Heat loads of sources group are converted into the normative climatic conditions. Lielvarde heat source operating data from year 2007 are used for the method verification. The results show that quantitative indicator value differences are small and methods of use are correct. There is investigated cogeneration optimal heat capacity correlation with the source of the average heat capacity, which significantly facilitates the assessment of the potential of CHP in case if there are available only one year fuel consumptions.

Lielvarde heat source cogeneration thermal capacity optimization is performed in evaluation process of present methods and it is found that the installed capacity is less than optimal. There are observed possible amounts for heat and power generation in optimal capacity case.

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Edgars Vīgants, Ivars Veidenbergs, Dagnija Blumberga, Francesco Romagnoli, Siltuma avotu grupas potenciālās koģenerācijas siltuma jaudas izvēle

Darbā piedāvāta siltuma avotu koģenerācijas potenciāla novērtējuma metode, kas balstīta uz siltuma avotu grupas apkopoto siltuma slodzes ilguma grafika analīzi un koģenerācijas stacijā uzstādīto siltuma jaudu optimizāciju. Avotu grupas siltuma slodzes ir pārrēķinātas uz normatīviem klimatoloģiskiem apstākļiem. Metodes pārbaudei izmantoti Lielvārdes siltuma avota 2007.gada darbināšanas dati. Rezultāti liecina, ka. metodē izmantojamo kvantitatīvo rādītāju vērtību atšķirības ir nelielas un metodes lietojums ir korekts.

Izpētīta koģenerācijas optimālās siltuma jaudas korelācija ar avota gada vidējo siltuma jaudu, kas būtiski atvieglo koģenerācijas potenciāla novērtējumu tajā gadījumā, ja ir pieejami tikai gada kurināmā patēriņi. Metodes pārbaudes gaitā veikta Lielvārdes siltuma avota koģenerācijas siltuma jaudas optimizācija un noskaidrots, ka uzstādītā jauda ir mazāka par optimālo. Aplūkoti iespējamie siltuma un elektroenerģijas izstrādes apjomi optimālās jaudas gadījumā.

Edgars Vīgants, Ivars Veidenbergs, Dagnija Blumberga, Francesco Romagnoli, The potential cogeneration thermal capacity choice for heat source group

The proposed in the paper heat source cogeneration potential assessment method, is based on the heat sources group gathered heat load duration curve analysis and optimization of installed thermal power of cogeneration unit. Heat loads of sources group are converted into the normative climatic conditions. For the method verification are used Lielvarde heat source operating data in year 2007. The results show that quantitative indicator value differences are small and methods of use are correct. There is investigated cogeneration optimal heat capacity correlation with the source of the average heat capacity, which significantly facilitates the assessment of the potential of CHP in the event if there are available only year fuel consumptions.

During the methods inspection process is performed Lielvarde heat source cogeneration thermal capacity optimization and found that the installed capacity is less than optimal. There are observed possible amounts for heat and power generation in optimal capacity case.

Эдгарс Вигантс, Иварс Вэйденбергс, Дагния Блумберга, Подбор тепловой мощности потенциальной когенерации для группы теплового источника

В работе представлен метод оценки потенциала когенерации источников тепла, который основывается на обобщённом анализе графика продолжительности тепловой нагрузки группы тепловых источников и оптимизации установленной тепловой мощности когенерационной станции. Тепловые нагрузки группы источников пересчитаны на нормативные климатологические условия. Для проверки метода использованы данные 2007 года источника тепла в Лиелварде. Результаты показывают, что различия значений квантитативных показателей использованных в методе не большие и применение метода корректно. Изучена колерация оптимальной тепловой мощности когенерации со средней годовой тепловой нагрузкой источника, что существенно упрощает оценку потенциала когенерации в том случае, если доступны только данные годового расхода топлива. В процессе проверки метода произведена оптимизация тепловой мощности когенерации теплового источника Лиелварде и выяснено, что установленная мощность меньше оптимальной. Рассмотрены возможные объёмы выработки тепла и электроэнергии при оптимальной мощности.