ECONOMIC MODELLING OF CHP POTENTIAL IN ENERGY SUPPLY SYSTEM OF LATVIA.

KOĢENERĀCIJAS POTENCIĀLA EKONOMISKĀ MODELĒŠANA LATVIJAS ENERGOAPGĀDES SISTĒMĀ.

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Introduction

Latvian energy system has one of the highest penetration rate of district heating, and one of the lowest share of domestic electricity production among countries of EU. Therefore, use of CHP in district heating to decrease dependence on imported electricity and fuel as well as to minimise the environmental impact of heat and power supply is feasible solution that has to be promoted. The main target of the work was to continue investigation of potential heat loads of district heating available for CHP plants, selection of appropriate CHP technologies corresponding to the size of the district heating systems and available fuel, and creation of model where electricity prices from the studied CHP plants could be determined. Studies of CHP potential, based on actual fuel consumption in nearly all Latvian district heating systems with Winter maximum heat load exceeding 1 MW was done and the results are presented in this work. These results allowed to evaluate an amount of heat and electricity which could be potentially produced in Latvia by CHP plants, and corresponding saving of primary energy resources compared to separate heat and power production. Furthermore, the calculated savings of primary energy resources made it possible to estimate potential reduction of environmental impact when CHP production is compared with separate heat and power production. This reduction of environmental impact is expressed in tons of CO_2, NO_x and SO_x eliminated by CHP, and corresponding monetary value of this reduction is found by looking at CO_2 prices in emission trade market and estimates of externalities of these pollutants. With help of the model of economic calculations, investment needed to exploit the studied CHP potential is calculated, and prices of produced electricity by various CHP technologies are calculated. The calculation includes also fuel price forecast in order to compare prices of CHP electricity with forecast of general electricity price level during time period of up to 2020. The fuels that are considered to be used by analysed CHP systems are natural gas, wood and coal. Thus, the economic calculation model helps to find the optimum scenario for utilisation of CHP potential in Latvia during the considered time period with target condition that the weighted average electricity price from CHP plants is kept at minimum.

Calculation methods and results

The heat load which could be available for potential cogeneration plants is calculated on basis of data about fuel consumption in analysed district heating systems during year 2003. The calculation starts with finding of heat produced during one year based on known figure of fuel consumption:

$$Q_T = E_F \cdot \eta_{SQ} \cdot Q_L^C , \quad (1)$$

where

Q_T – amount of heat produced in the given district heating system[1];
E_F - fuel consumption in given district heating system;
η_{SQ} – efficiency of heat production;
Q_L^C - lowest heating value of the fuel.

Heat load for potential CHP plants is determined based on heat production during Winter time, therefore the average heat load of the given district heating systems is determined as follows:

$$Q_Q = (Q_h + Q_{htw}) / 4502, \tag{2}$$

where

Q_Q – average heat load of the given district heating system;
Q_h, Q_{htw} –amount of heat produced for heating and hot tap water supply respectively;
4502 – represents average heat load duration during Winter according to the chosen load duration curve for this analysis.

Total amount of heat produced Q_T was split up in Q_h and Q_{htw} by assumption that about 90% of the heat on annual basis is produced for needs of heating. There are no accurate data about the share of heat for needs of hot tap water supply in the total amount of heat available however practical observations in some district heating systems show that this may be a quite accurate assumption.

The heat load suitable for cogeneration is taken to be less than the average heat load of the given district heating system, i.e. 40% of the maximum heat load, which is twice as large as Q_Q. Depending on heat load and fuel available for cogeneration, the most suitable cogeneration technology for each district heating system is selected achievable amount of power generation, total fuel consumption by the cogeneration plants and separate heat and power production systems, corresponding fuel savings and potential reduction of CO_2, NO_x and SO_2 emissions is determined according to the same principles as in [1].

It is assumed, that small cogeneration systems with installed heat capacity up to 4 MW use gas engine technology; medium and large systems – gas turbine combined cycle systems. It is assumed that wood cogeneration plants use steam turbine technology.

Main types of fuel which can be considered for cogeneration systems in Latvia are natural gas, biomass and coal. Coal fired cogeneration system is considered for Ventspils city.

Thermal efficiency of separate electricity production for systems using natural gas is assumed to be 55%. Efficiency of separate heat production for natural gas systems is assumed to be 90%. Thermal efficiency of separate electricity production for systems using coal and wood is assumed to be 35%. Efficiency of separate heat production for coal/wood-fired systems is assumed to be 85% [2].

[1] Each town or city is considered to be as one district heating system even if heating network is not interconnected yet.

Table 1. Comparison of results for cogeneration and separate power and heat production system calculated for one year

	Natural gas	**Wood**	**Coal**
Heat production volume, GWh	5 394	428	190
Power production volume, GWh	5 003	86	86
Fuel consumption in cogeneration systems, GWh	12 998	619	345
Fuel consumption by separate heat and power production, GWh	15 092	748	367
Fuel saving, GWh	2 094	129	22
Reduction of NO_x emissions, t	1 508	-	6
Reduction of SO_2 emissions, t	-	-	313
Reduction of CO_2 emissions, t	422 978	-	7 782
Provided CO_2 savings expressed in monetary terms of CO_2 market, MUSD	2.1	-	0.039

Estimates of CHP potential and analysis of the acquired results guide to a conclusion that approximately 80% of total district heat demand of Latvia could be covered by CHP, meaning about 40% increase of the heat share which is produced in CHP plants relative to the current situation. Results of the work also show that development of CHP plants could greatly reduce necessity for imported electricity since almost all country's yearly power consumption can be covered by cogeneration. The results show that cogeneration could save as much as 2245 GWh of fuel per year relative to a separate power and heat production (Tab.1), providing corresponding reduction of pollutant emissions into atmosphere.

It is assumed in this work, that market price of CO_2 is 5 EURO/t under conditions of emission trade, and the result (Tab.1) shows that CO_2 savings provided by CHP could be up to 2.1 MEUR.

Procured amounts of emission reduction are marked in monetary terms and thus reduction of "externalities" created by emissions are determined by analysis of costs to society generated by respective environmental impact of main pollutants considered in this work (NO_x, CO_2 and SO_2). The following values were used to express the possible impact of hazardous pollutants as externality in monetary terms [3]:

- CO_2 – 0,95 LVL/t;
- NO_x – 56 LVL/t;
- SO_2 – 36 LVL/t;

By using the above values of specific externality caused by each pollutant, corresponding reduction of total externalities by cogeneration relative to separate power and heat production were calculated and the values are shown in Table 2. Amounts of reduction of each pollutant were taken from Table 1.

Table 2. Amount of externalities avoided by the cogeneration systems relative to separate power and heat production, in LVL per year

	Natural gas	Coal
Avoided CO_2 externality	400 518	7 368
Avoided NO_x externality	83 976	312
Avoided SO_2 externality	-	11 349

Results in Table 2 show that the total reduction of externalities created by environmental impact of main pollutants is nearly 500 000 LVL. If market value of CO_2 reduction is added to this amount, then figure of nearly 2,6 MLVL is achieved. If this economic benefit is allocated to the total amount of power produced by considered cogeneration systems, an almost 0,5 LVL of bonus that could be allocated to each MWh of power produced is obtained.

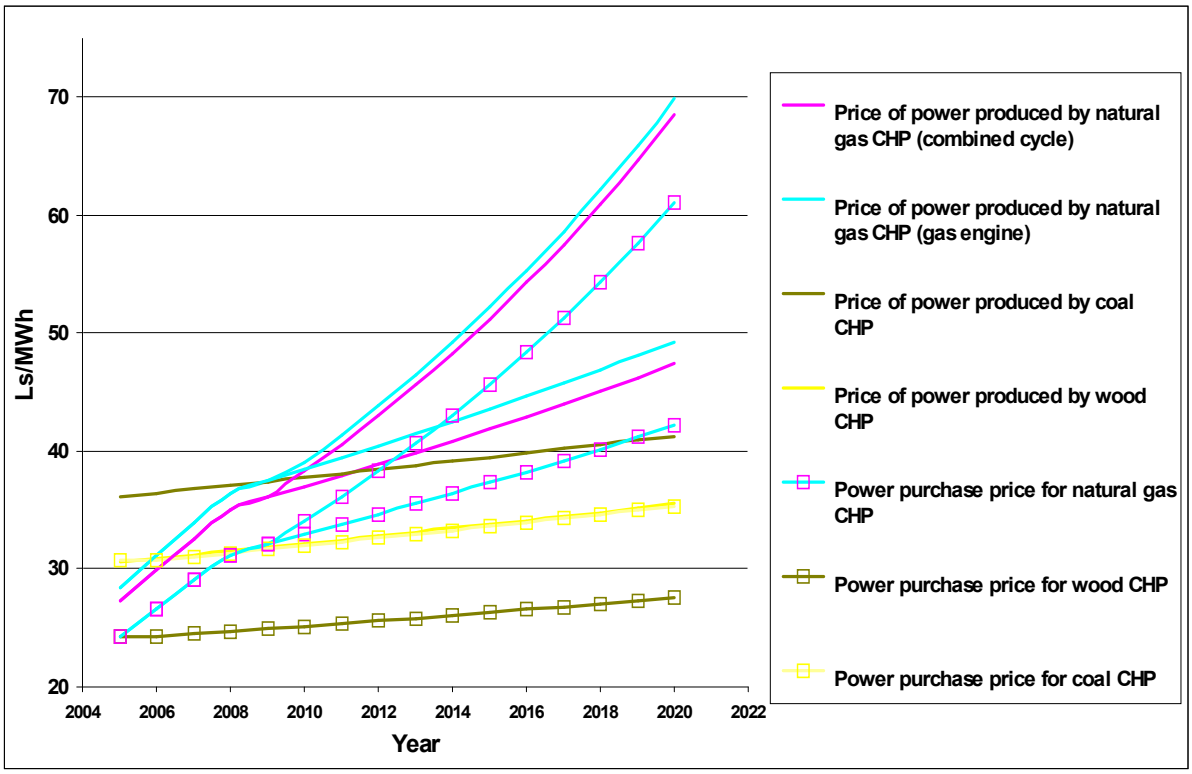

Figure 1. Electricity price forecasts

The second part of the work was to estimate the prices of power produced by potential cogeneration plants and compare these prices to the power purchase price set by legislation for CHP plants with electrical capacity up to 4 MW. The results are shown in the Figure 1.

As can be seen from the Figure 1, only electricity production costs of wood-based cogeneration plants are equal to current obligatory CHP electricity purchase tariff from those plants. After the year 2006, the power price from wood-fired CHP's will be cheaper than power prices of natural gas CHP plants if the assumed fuel price increase scenario will hold. The power price from coal-fired CHP plants will be cheaper then power price from natural gas CHP plants after the year 2012.

The power price calculation was done based on fuel price forecasts which are shown in Figure 2 [4]. Forecasts of natural gas prices are made for two scenarios: 1st scenario assumes growth of prices of natural gas by 6% per annum; the 2nd scenario - annual growth equal to Latvian inflation forecasts. Forecast for wood prices assumes growth or prices by 1% per annum, for coal - by 0,9% per annum [4].

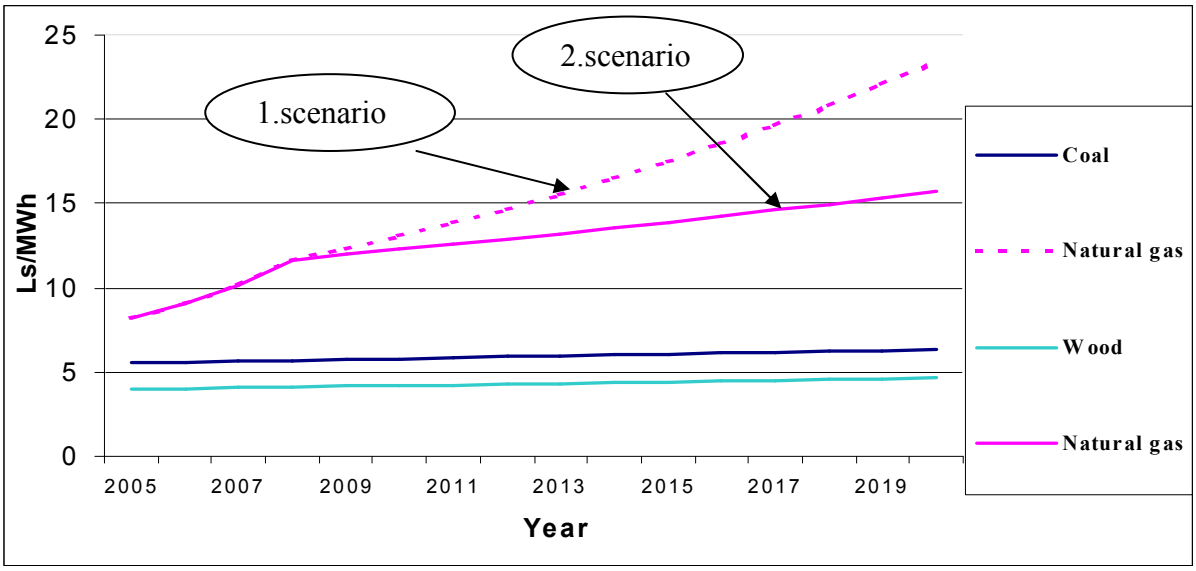

Figure 2. Fuel price forecasts

Conclusions

The obtained results show that Latvia could increase installed heat capacity of CHP units up to around 1330 MW, and produce cogeneration heat amount equal to nearly 80% of total Latvian heat demand. With help of all CHP potential Latvia could produce nearly 5200 GWh of power, that is close to 79% of total power consumption in Latvia, and reduce fuel consumption for about 2 250 GWh/year relative to separate heat and power production.
If the cost-benefit analysis is done on pure environmental basis, then results of the work show that the total benefit in monetary terms provided by potential sales of CO_2 emissions and avoided externalities is 2,6 MEUR but required total investment in cogeneration plants is nearly 720 MEUR.
The results show that the existing electricity purchase prices set by regulation authority to CHP plants with electrical capacity up to 4 MW are less than the costs of power production by coal and natural gas fired CHP plants. The work also shows that if the price of natural gas will increase as fast as forecasted that gas-fired CHP plants will loose competitiveness comparing to wood and coal fired CHP plants already by year 2006 and 2012 respectively.

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Markova D., Bažbauers G., Kundziņa A. Koģenerācijas potenciāla ekonomiskā modelēšana Latvijas energoapgādes sistēmā.
Darbā izvērtēts iespējamais koģenerācijas potenciāls Latvijā, balstoties uz Latvijas pilsētu centralizētas siltumapgādes sistēmu kurināmā patēriņiem. Salīdzināts kurināmā patēriņš koģenerācijas iekārtās un dalītas siltuma un elektrības ražošanas iekārtās, nosakot iespējamo kurināmā ietaupījumu. Balstoties uz kurināmā ietaupījumu, tika iegūts iespējamais kaitīgo izmešu samazinājums, un tika novērtēts šī samazinājuma ekonomiskais ieguvums. Darbā tiek veikta potenciālo koģenerācijas staciju tehniski - ekonomiskā modelēšana, un ar šīs modelēšanas palīdzību tiek aprēķināta koģenerācijas tehnoloģiju ražotās elektroenerģijas cenu prognoze, kas tika salīdzināta ar esošo obligāto elektroenerģijas iepirkuma tarifu no koģenerācijas stacijām.

Markova D., Bažbauer G., Kundziņa A. Economic modelling of CHP potential in energy supply system of Latvia.
Cogeneration potential in Latvia based on fuel consumption of district heating systems of Latvian towns is evaluated in the present work. Fuel consumption of cogeneration equipment and separate power and heat production equipment is compared and potential of fuel savings is determined. Potential reduction of pollutants is determined by using estimate of fuel savings, and economic benefit of this reduction is calculated. Technical and economical modelling of cogeneration potential is performed in the work and forecasts of electricity prices produced by each cogeneration technology are calculated with help of modelling. The obtained electricity price forecasts are compared with current obligatory electricity purchase tariff from cogeneration plants.

Маркова Д., Бажбауэр Г., Кундзиня А. Экономическое моделирование когенерационного потенциала для латвийской системы энергоснабжения.
В работе произведена оценка возможного когенерационного потенциала Латвии, основываясь на объемах потребления топлива центральных систем теплоснабжения городов Латвии. Произведено сравнение потребления топлива в когенерационных устройствах и при раздельном производстве тепла и электричества, определив возможную экономию топлива. Основываясь на экономии топлива, вычислено возможное уменьшение выбросов в атмосферу и оценена их экономическая прибыль. В работе произведено технически - экономическое моделирование потенциальных когенерационных станций, и с помощью этого моделирования, расчитан прогноз на цену электроэнергии когенерационных технологий, который был сопоставлен настоящему обязательному закупочному тарифу электроэнергии от когенерационных станций.