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Environmental and economic assessment of a biomass-based cogeneration plant: Polish case study

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ABSTRACT

The goal of the paper is to presents the results of the energy, economic and environmental assessment of biomass-fired combined heat and power (BCHP) units cooperating with the district heating system. The mathematical models of both considered BCHP units (with back-pressure and extraction-condensing turbines) have been elaborated and validated with the data from commercially available CHP units.

The results of this study prove that BCHP units can be a good option for the Polish energy sector, both from an environmental and energy point of view. The economic analysis showed that the analysed BCHP units could be profitable, but the are several factors, like prices of guarantees of origin for electricity producted from renewable energy sources, that strongly affect the results.

Introduction

Poland belongs to the group of countries in which energy consumption keeps rising. The country's rapid development which affects strongly the demand for electricity, along with some neglect in previous years, puts Poland in the position of a strong need for energy sector transformation. The main challenges for the Polish energy system are as follows:

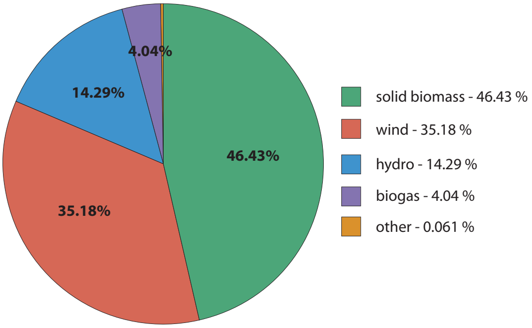
- diminishing national resources of fossil fuel in the medium-term perspective (e.g. up to 40 years for hard coal) [Okulski, 2014],
- outdated power plants (over half of the installed capacity in CHP units and conventional power plants is older than 30 years) [Szczerbowski, 2013],
- low efficiency of energy transmission and distribution (overall electricity loss in transmission and distribution was around 7.3% in 2011) [BBN, 2012],
- European Union energy and climate policy & industrial emissions directives - Poland is on the right pathway to meet the requirements for 2020, but a more ambitious goal for 2030 and beyond might in the future be hard to meet.

The above mentioned issues are of course not all the problems and challenges that the Polish energy sector has to face in the following years, but they clearly prove that energy sector transformation in Poland is inevitable. There are several pathways discussed on the government level, but depending on the political climate, the decisions change quite often. Options like nuclear energy, clean coal technologies and renewables are considered. But no matter which strategy or policy we consider, cogeneration is always pointed out as a very promising and effective option for the Polish energy sector, along with distributed energy units. The biomass potential of Poland is also pointed out in almost all of the official documents and analyses. The situation is no different in the central region of Poland where potential agricultural and industrial wood products are recognized. The Mazovian Voivodship as one of the most developed regions in the UE must contend with many challenges in the energy sector and environmental protection. According to the regional development strategy, the main objective is to increase the share of renewable energy sources (RES) in energy production (the share of RES in electricity generation in 2013 was around 1%) [*Strategia rozwoju…* 2013]. Investment in biomass cogeneration technologies may be an effective way to meet this expectation.

Thus the goal of this paper is to assess the energy, economic and environmental performance of biomass CHP unit construction and operation in Polish conditions. Additionally, within the economic assessment, the sensitivity analysis aims to provide information about the impact of the main economic factors on the profitability. Within the paper, the analysed BCHP covers the whole demand for heat within the investigated district heating system, which is not that common in Polish conditions. Thus the results of optimizing the division between the cogenerated and peak heat production are presented, by means of the coefficient of the share of cogeneration.

There are several different biomass conversion paths [IEA 2007]. This paper focuses on solid biomass combustion and then combined heat and electricity production via steam cycle. Both back-pressure and extraction-condensing turbines are considered. The CHP plant is connected to the local district heating system (around 20 MWth peak thermal energy demand). The typical size of dedicated biomass-fired steam cycles ranges from 5 to 25 MW_{el} which is around ten times smaller than coal-fired ones because of the scarce availability of local feedstock and the high transportation cost [IEA 2007]. The electrical efficiency of dedicated biomass CHP plants is around 30-35% (LHV) and the overall CHP efficiency: 85- 90% (if the CHP mode is well balanced between heat production and demand) [IEA 2007]. The net carbon emissions (based on life cycle assessment) per unit of electricity are below 10% of the emissions from fossil-based electricity generation [IEA 2007]. Due to the higher investment costs associated with biomass-fired CHP units and the higher cost of biomass (per GJ of energy), the electricity prices are higher (usually by around 50% to 100%). Thus usually each country introduces different forms of incentives to support the development of this renewable energy source (in Poland in the form of so-called "green certificates" or, recently, "green auctions").

Fig. 1. Share of RES in the total RES electricity production in Poland (in 2013)



Source: GUS 2014

Table 1. CHP units with dedicated biomass boilers in Poland

CHP unit	Electric power	Year	Type of biomass
Elektrownia Połaniec	230 (MW_{el})	2012	Forest and agricultural biomass
Elektrownia Ostrołęka	100.5 (MW_{el})	2010	Wood chips
Elektrociepłownia Czechnica	100 (MW_{el})	2010	Forest and agricultural biomass
Elektrociepłownia Białystok	78.5 (MW_{el})	2008	Wood chips and agricultural residues
Elektrownia Szczecin	68.5 (MW_{el})	2010	Forest and agricultural biomass
Elektrociepłownia Poznań	63 (MW_{el})	2012	Wood chips
Elektrociepłownia Konin	55 (MW_{el})	2012	Forest and agricultural biomass
Elektrownia Jaworzno	50 (MW_{el})	2012	Forest and agricultural biomass
Elektrociepłownia Łódź	48 (MW_{el})	2012	Wood chips and pellets
Elektrociepłownia Tychy	40 (MW_{el})	2014	Wood chips
Elektrownia Stalowa Wola	30 (MW_{el})	2008	Wood chips, sawdust and shavings
Elektrociepłownia Elbląg	25 (MW_{el})	2013	Straw pellets
Elektrociepłownia Częstochowa	10 (MW_{el})	2010	Forest and agricultural biomass
Elektrociepłownia Wałcz	7.23 (MW_{el})	2010	Wood chips
Elektrociepłownia Kielce	6.71 (MW_{el})	2008	Wood chips
Elektrociepłownia BRW Biłgoraj	2.7 (MW_{el})	2010	Industrial waste
Elektrociepłownia Płońsk	2.08 (MW_{el})	2008	Wood chips
Elektrociepłownia Krasocin	1.9 (MW_{el})	2009	Wood chips

Source: PAIZ 2013

Solid biomass combustion is a well-established and mature technology with a lot of commercial operating units around the world. The share of solid biomass in renewable electricity production in Poland is almost 50% (Fig. 1) [GUS 2014] which proves that biomass utilization is widespread among the companies operating in the electricity generation sector. In Poland biomass co-firing in coal-fired boilers is very popular, but there are also around 20 biomass-fired CHP units (Table 1) [PAIZ 2013]. In the case of Mazovia, there are two biomass systems: the Elektrownia Ostrołęka power plant with an installed dedicated biomass boiler and a small CHP plant – Elektrociepłownia Płońsk. Looking at the trends in more developed countries (e.g. Sweden) the gradual transition from co-firing (or using biomass in existing fossil fuel boilers) to using biomass in new boilers or CHP plants for biomass only, should be expected [Ericsson 2016].

The introduction of biomass boilers can also help to meet the European Union Industrial Emissions Directives. For example in the CHP unit in Białystok, the conversion of coal-fired boilers to dedicated biomass-fired boilers helps to meet the standards defined in Directive 2010/75/EU concerning the SO_2, NOx and PM limits (Table 2) [Sadowski 2012].

Table 2. . Daily average emissions in the CHP unit in Białystok

Type of boiler	Emission					
	SO_2 (mg/m^3_n)		NO_x (mg/m^3_n)		PM (mg/m^3_n)	
	Actual emission	Directive standard	Actual emission	Directive standard	Actual emission	Directive standard
pulverized Coal-fired boiler (old unit)	740	250	550	200	30	25
Biomass fluidized bed boilers (new unit)	15	100	240	250	11	15

Source: Sadowski 2012

When considering biomass CHP unit construction and operation, two main points have to be considered:

- biomass feedstock availability,
- heat demand (municipal or industrial heating system).

Several analyses have been made to optimize the location of bioenergy plants. Different potentials of biomass utilization in CHP units result from biomass availability and heat demand, depending on the region or economic profitability. According to Schmidt [2010], in Austria about 83% of the total available biomass-fired CHP production can be used, which will contribute to 3.0% of total energy consumption. It was also proved that the current support scheme (feed-in tariffs) guaranteed the economic profitability of the biomass CHP plants' operation. Nevertheless, as the authors stressed [Schmidt 2010], biomass-based CHP production potentials in Austria are still not fully used. Also Norway, which is one of the world's largest oil producers, at the current moment does not have the economic incentive to invest in biomass CHP plants, but as stated by Novakovic [2014], the government has recognised the potential of this technology. The Norwegian government's investing in developing countries with biomass and cogeneration potential has been suggested as an option [Novakovic 2014]. It should be stated that biomass-fired CHP plants give the opportunity for energy (electricity and heat) supply with negative CO_2 emission when CO_2 capture and storage technologies are introduced. The so-called BECS (biomass energy with CO_2 capture and storage) technology can give leverage to the carbon-reduction potential of the world's biomass resources [Möllersten 2003].

To sum up, using biomass instead of coal in CHP units could bring several benefits, including reduction of air pollution (including greenhouse gases), local economic development, waste reduction and the security of domestic fuel supply [U.S. EPA, 2007]. This paper is divided into four parts, including the introduction (Section 1), mathematical modelling of the CHP unit and district heating system (Section 2), results of 3xE (Energy, Economic and Ecological) analysis (Section 3) and conclusions (Section 4).

Mathematical modelling of the district heating system (DHS) and biomass combined heat and power (BCHP) unit

The demand of heat for heating, ventilation and air conditioning depends on the ambient temperature and is presented in the form of duration curves set up for the respective climatic zones of the country. This flux of heat is calculated from the equation:

$$\dot{Q}_h = \dot{Q}_{h\,max} \frac{t_{in} - t_a}{t_{in} - t_{a\,min}} \tag{1}$$

where:

$\dot{Q}_h$ - current value of the heat flux,

$\dot{Q}_{h\,max}$ - maximum demand for heat for heating, ventilation and air conditioning $t_a = t_{a\,min}$

t_{in} - internal temperature,

t_a - current ambient temperature,

$t_{a\,min}$ - lowest calculated ambient temperature characteristic for any given climatic zone.

The average flux of heat required to preheat tap water is calculated by means of the relation:

$$\dot{Q}_{htw} = \dot{G}_{htw} c_w \left(t_{htw} - t_{tw}\right) \tag{2}$$

where:

$\dot{Q}_{htw}$ - heat flux required to preheat tap water,

$\dot{G}_{htw}$ - flux of hot tap water,

t_{htw} - temperature of hot tap water,

t_{tw} - temperature of tap water.

Applying the Raiss equation [Szargut, 2000] describing the universal duration curve of ambient temperature, we may write:

$$\dot{Q}_h = \dot{Q}_{h\,max} \frac{t_{in} - t_{a\,os} + \left(t_{a\,os} - t_{a\,min}\right)\left[1 - \sqrt[3]{\frac{\tau}{\tau_o}} + \left(\frac{\tau}{\tau_o}\right)^2 \left(1 - \frac{\tau}{\tau_o}\right)\right]}{t_{in} - t_{a\,min}} \tag{3}$$

where:

$t_{a\,os}$ - ambient temperature at which the heating season starts,

τ_o - duration of the heating season,

τ - time.

The heating duration curve is characterized by two main indices [Ziębik, 2012]:

- the ratio of the heat flux for the production of hot tap water in the heating season to the maximum heat flux for heating and ventilation purposes:

$$m = \frac{\dot{Q}_{htw}}{\dot{Q}_{h\,max}} \tag{4}$$

where $\dot{Q}_{htw}$ denotes the heat flux required for the production of hot tap water and

- the degree of fluctuations in the heat demand for heating and ventilation:

$$m_o = \frac{\dot{Q}_{h\,min}}{\dot{Q}_{h\,max}} \tag{5}$$

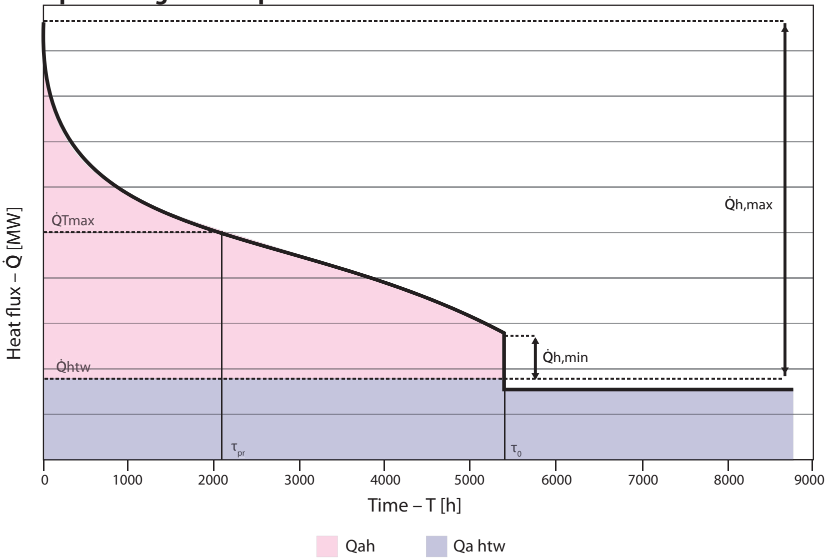
For the presented analysis, certain assumption concerning the DHS have been made (and summarized in Table 3). All the assumptions are consistent with the assumption of BCHP plant construction and operation in Poland for the purpose of local DHS.

Table 3. Assumptions concerning analysed DHS

Parameter	Abbreviation	Value
Maximum demand for heat (sum of the maximum demand for heat for heating, ventilation and air conditioning and heat flux required for the production of hot tap water)	$\dot{Q}_{max}$	19.236 (MW_{th})
Heat flux required for the production of hot tap water	$\dot{Q}_{htw}$	3.1 (MW_{th})
Lowest calculated ambient temperature characteristic for any given climatic zone	$t_{a\,min}$	-20 (°C)
Internal temperature	t_{in}	20 (°C)
Ambient temperature at which the heating season starts	$t_{a\,os}$	12 (°C)
Duration of the heating season	τ_o	5400 (h)
The ratio of the heat flux for the production of hot tap water in the heating season to the maximum heat flux for heating and ventilation purposes	m	0.2
Degree of fluctuations in the heat demand for heating and ventilation	m_o	0.15

Source: Świerzewski 2016

Fig. 2. Exemplary duration curve of the demand for heat in the district heating system; Qah - annual demand for heat for space heating and ventilation; Qa htw - annual demand for heat required to get hot tap water



Source: Ziębik 2014

Based on the equations (3) - (5) and the assumptions presented in Table 3, the duration curve of the demand for heat needed for heating, ventilation and the production of hot tap water has been modelled and presented as an example in Figure 2. The analysed heating network operates according to the qualitative-quantitative regulation described by Świerzewski [2016]. The peak demand for heat was supplied by means of a pressure-reducing valve station. The coefficient of the share of cogeneration, which is defined as follows [Ziębik 2012]:

$$\alpha_{CHP} = \frac{\dot{Q}_{T\,max}}{\dot{Q}_{max}} \tag{6}$$

where $\dot{Q}_{T\,max}$ defines the maximum heat flux transmitted by the cogeneration unit (back-pressure turbine or extraction-condensing turbine) and $\dot{Q}_{max}$defines the maximum flux of heat, was assumed based on previous studies [Ziębik, 2012, 2013] on a level of around 0.7.

The mathematical model of the analysed BCHP unit was developed by means of EBSILON Professional software which is based on the energy and mass balances of the BCHP unit components. For proper model calculations it is necessary to determine the parameters at the characteristic points of the analysed BCHP plants, including steam pressure in the turbine bleeders, temperature limitations in the heat exchangers, nominal efficiencies, etc. Such data was taken into account based partially on the information obtained for the EKOL company and partially on the technological data from the EC Sviadnov CHP plant (Table 4). Both back-pressure and extraction-condensing turbines were considered, thus two mathematical models were developed.

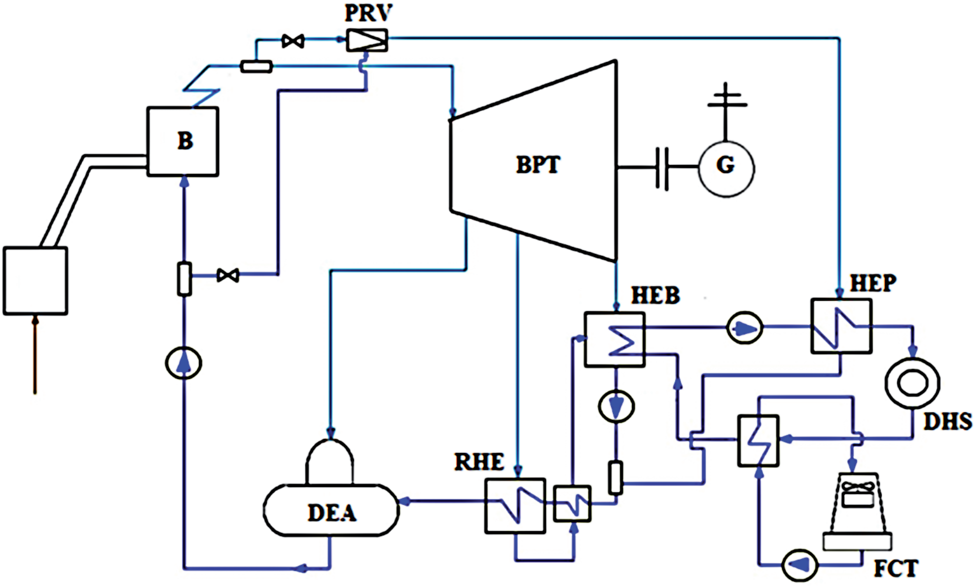
Table 4. Technical data concerning two types of biomass CHP in nominal load

Parameter	BCHP with back-pressure turbine	BCHP with extraction-condensing turbine
Live steam temperature	485 (°C)	482 (°C)
Live steam pressure	64 (bar)	53 (bar)
Live steam mass flow	28.32 (t/h)	32 (t/h)
Cogenerated thermal power output	16.2 (MW_{th})	11.95 (MW_{th})
Gross electric power output	5480 (kW)	6300 (kW)
Own electricity demand	354 (kW)	750 (kW)
Net energy efficiency	85.6 (%)	59.44 (%)
Fuel consumption	9.39 (t/h)	11.12 (t/h)

Source: Świerzewski 2016

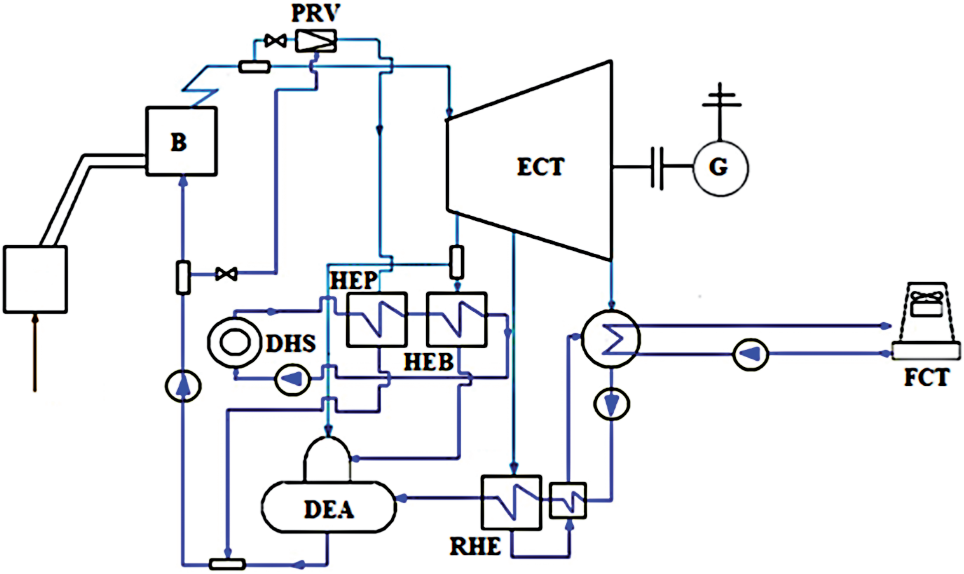
The simplified diagrams of BCHPs with back-pressure (BPT) and extraction-condensing (ECT) turbines have been presented in Fig. 3 and Fig. 4. Both variants use a stoker-fired boiler (B) which burns wood chips with a high moisture content. Live steam is generated in the boiler and then enters the steam turbine. In the steam turbine, the kinetic energy of the moving steam is converted to mechanical work and then, in the generator (G), conversion of mechanical work to electrical energy takes place. One of the outlets extracts the steam with intermediate pressure and supplies the regeneration system which consists of regenerative heat exchangers (RHE) preheating the condensate prior to feeding it to the deaerator (DEA). After oxygen and other dissolved gasses have been removed, feedwater is pumped into the boiler to repeat the cycle. Depending on the type of turbine, the outlet steam goes to the heat exchanger (Fig. 3) or condenser (Fig. 4). One heat exchanger (HEB) covers the basic heat demand resulting from the characteristics of the district heating network. The peak heat demand (heat exchanger HEP) is covered by the pressure-reducing valve station (PRV). Both of the BCHP are equipped with forced draft cooling towers (FCT). Within the BCHP plant with a back-pressure turbine, an additional heat exchanger on the return stream of the district heating water system has been added in order to maintain the technological minimum of the boiler and turbine in the off-heating season.

Fig. 3. Simplified model of a BCHP unit with a back-pressure turbine



Source: Świerzewski 2016

Fig. 4. Simplified model of a BCHP unit with an extraction-condensing turbine



Source: Świerzewski 2016

Based on the acquired data, the on-design mathematical models of both BCHP units were developed. Further on the load characteristics of turbines, boilers and heat exchangers were introduced to the model [Świerzewski, 2016], so that the thermodynamic calculations could take into account the partial load performance (so called off-design) of the components. The parameters of the assumed biomass (wood chips) have been presented in Table 5, for which the LHV (as received) was around 9534 kJ/kg.

Table 5. Biomass composition (wood chips

Ultimate analysis	Dried Ash Free - DAF, wt. (%)	Dry Basis - DB, wt. (%)	As Received - AR, wt. (%)
Carbon	50.02	48.74	28.15
Hydrogen	6.38	6.22	3.59
Oxygen	43.39	42.29	24.42
Nitrogen	0.18	0.17	0.10
Sulphur	0.04	0.03	0.02
Ash	-	2.55	1.47
Moisture	-	-	42.25

Source: Świerzewski 2016

Flue gases from the pulverized biomass boiler are fed into the flue gas conditioning system with selective non-catalytic reduction (for nitrogen oxides removal) and an electrostatic precipitator. Due to the low sulphur content in the fuel the desulphurization system has been neglected. The efficiencies of the selective non-catalytic reduction (SNCR) and electrostatic precipitator (ESP), were based on the data obtained from the EC Sviadnov CHP plant [Świerzewski, 2016].

Results of energy, economic and ecological analysis

Table 6 presents the results of the thermodynamic analysis concerning both analysed BCHP units. In Figure 4 the utilization of the chemical energy of biomass was also presented.

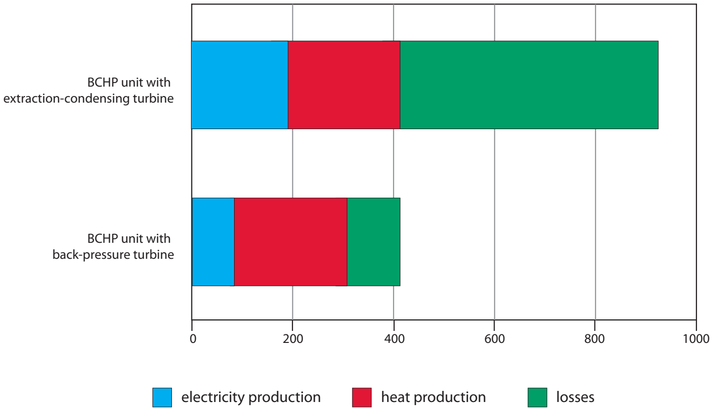
Table 6. Results of the thermodynamic analysis

Parameter	BCHP unit with back-pressure turbine	BCHP unit with extraction-condensing turbine
Annual net electricity production	23 194 (MWh)	52 566 (MWh)
Annual heat production	223 653 (GJ)	
Annual biomass consumption	43 663 (Mg)	97 389 (Mg)
Average net energy efficiency	73.78 (%)	44.47 (%)

Source: Świerzewski 2016

The criterion of qualification concerning high-efficiency cogeneration depends on the value of the PES (Primary Energy Savings) index [Directive 2004/8]. Based on the obtained results, only the BCHP unit with a back-pressure turbine had a PES index higher than 10% (around 17.8%), thus the guarantees of origin for the electricity produced in high-efficiency cogeneration cannot be assigned to the BCHP unit with an extraction-condensing turbine. More detailed thermodynamic analysis results can be found in a more detailed paper [Świerzewski 2016].

Fig. 5. Utilization of the chemical energy of biomass



Source: Świerzewski 2016

The losses that occur within the BCHP unit with a back-pressure turbine (Fig. 5) result from the heat being removed to the environment through a cooling tower that cools down the return water from the DHS during the off-heating season. As expected, the electricity production in the BCHP unit with the extraction-condensing turbine is more than two times higher than in the other analysed case, but the average net energy efficiency is almost 30 percentage points lower. The annual heat production for both BCHP units is the same, due to the assumed same DHS heat demand and characteristic.

The main goal of the environmental analysis was to check if the analysed biomass boilers can meet the requirements of the European Union Industrial Emissions Directives. In both cases the levels of air pollutions defined in the Directive are met (Table 7).

Table 7. Air pollution emissions (converted into 6% O2 concentration in flue gases)

Emission	Actual emission	IED Directive
NO_x	168.2 (mg/m^3_n)	250 (mg/m^3_n)
SO_2	85.5 (mg/m^3_n)	100 (mg/m^3_n)
CO	113.2 (mg/m^3_n)	250 (mg/m^3_n)
PM	10.7 (mg/m^3_n)	15 (mg/m^3_n)

Source: Świerzewski 2016

The annual CO_2 emission, resulting directly from the biomass consumption, for the analysed cases are as follows:

- BCHP unit with back-pressure turbine - 42 563.2 Mg $CO_{2,}$
- BCHP unit with extraction-condensing turbine - 94 935.9 Mg CO_2.

For the economic assessment the following indices have been calculated for both analysed BCHP units:

- Net Present Value (NPV),
- Net Present Value Ratio (NPVR),
- Modified Net Present Value (MNPV),
- Internal Rate of Return (IRR),
- Modified Internal Rate of Return (MIRR),
- Discount Payback Time (DPB).

The cash flows have been defined as Free Cash Flow for the Firm (FCFF) which are a measure of financial performance that expresses the net amount of cash that is generated for a firm after expenses, taxes and changes in net working capital and investments are deducted. The most important data for the economic assessment has been presented in Table 8.

Table 8. Data for the economic assessment

Parameter	Value
CAPEX2015 (BCHP with back-pressure turbine)	62.5 (million PLN)
CAPEX2015 (BCHP unit with extraction-condensing turbine)	74.1 (million PLN)
Unit cost of electricity	180 (PLN/MWh)
Unit cost of the guarantees of origin for electricity produced in high-efficiency cogeneration	11 (PLN/MWh)
Unit cost of the guarantees of origin for electricity produced from renewable energy sources	160 (PLN/MWh)
Unit cost of the heat	25.8 (PLN/GJ)
Unit cost of the chemical energy of biomass	17 (PLN/GJ)
Annual rate of costs of repairs and maintenance	1.5% of CAPEX
Discount rate	4.3 (%)
Reinvestment rate	6.5 (%)
Inflation	2.0 (%)
Operation time	30 (years)
Construction time	1 (year)

Source: Świerzewski 2016

The currency used was the Polish Zloty (PLN), which is worth around 4.2 PLN per 1 EUR. For the economic analysis, 25% of the CAPEX expenditures were assumed as subsidy, based on the information gathered for other similar BCHP units in Poland. Other costs like waste management, raw water consumption, payrolls and emissions were also taken into account [Świerzewski 2016].

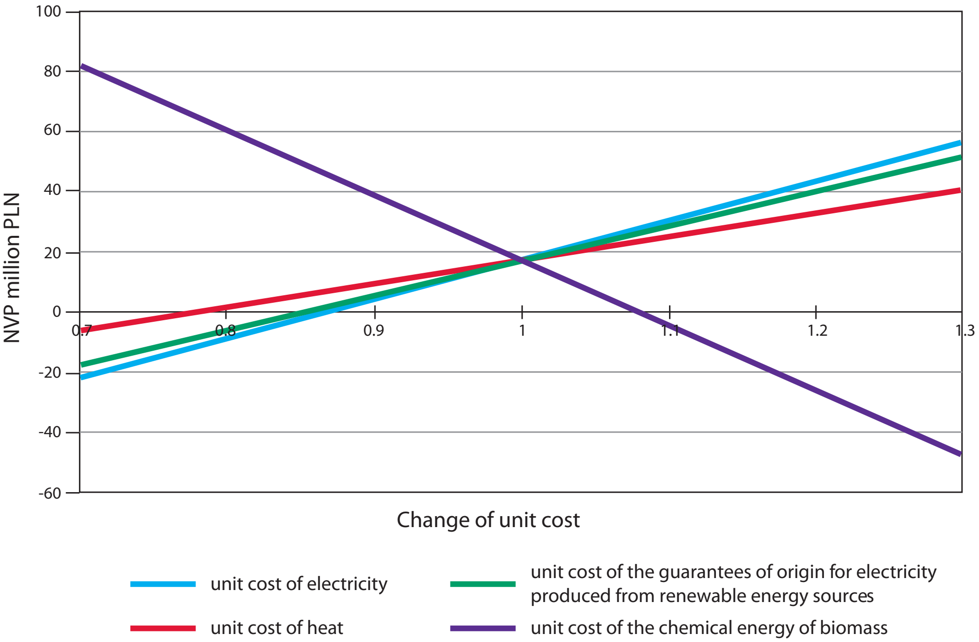
Table 9. Results of the economic analysis

	BCHP with back-pressure turbine		BCHP unit with extraction-condensing turbine	
	with subsidy	without subsidy	with subsidy	without subsidy
NPV	18 455 230 (PLN)	1 866 606 (PLN)	19 839 894 (PLN)	166 621 (PLN)
NPVR	0.394	0.03	0.357	0.002
MNPV	49 328 363 (PLN)	32 062 210 (PLN)	55 518 762 (PLN)	35 041 973 (PLN)
IRR	7.32 (%)	4.51 (%)	7.05 (%)	4.28 (%)
MIRR	6.79 (%)	5.71 (%)	6.70 (%)	5.62 (%)
DPB	17 (year)	28.5 (year)	18 (year)	29.5 (year)

Source: Świerzewski 2016

In Table 9 the results of the economic assessment have been presented. The subsidy plays a crucial role in the economic effectiveness of the BCHP units. The values of NPV and IRR for the BCHP units with the subsidy prove that the investment is profitable, and the payback time of 17-18 years could be acceptable for potential investors. Also, a slightly higher economic profitability in terms of NPV can be observed for the BCHP unit with an extraction-condensing turbine, but other indices like NPVR and DPB are more in favour of the other BCHP unit configuration. When the results of the economic analysis without the subsidy are investigated, the DPB times are close to the assumed operational time (30 years) which indicates that it might not be an interesting option of the investors. Other economic factors, like NPV and IRR, in the no-subsidy variant show that the investment in BCHP plants might be unprofitable or high-risk.

Fig. 6. Results of the sensitivity analysis



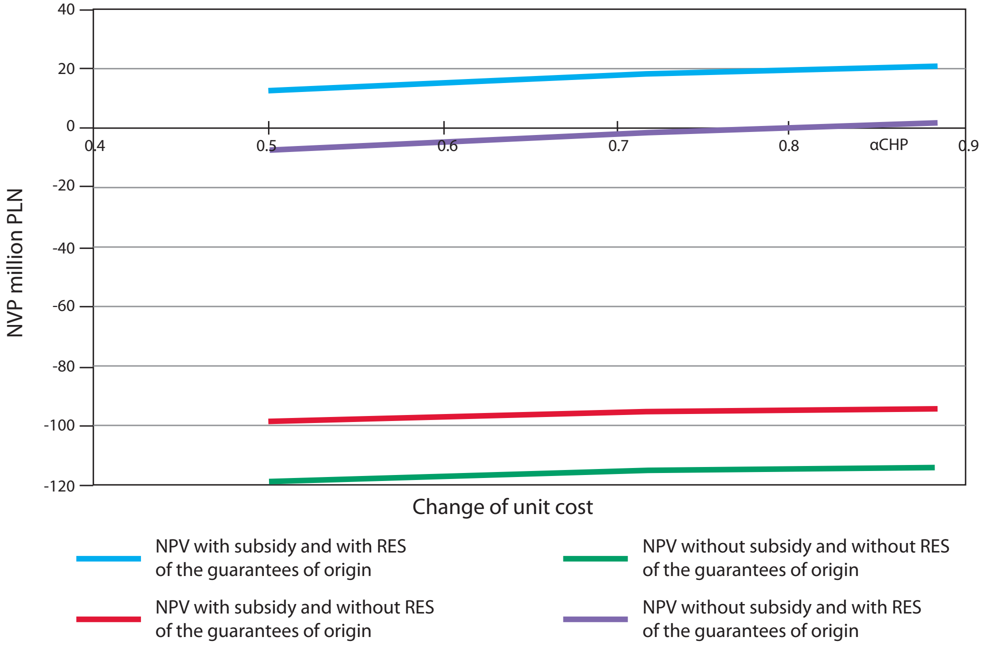
Source: Świerzewski 2016

Figure 6 presents the results of the sensitivity analysis for the BCHP unit with an extraction-condensing turbine. The influence of the change of unit costs of several main elements on the NPV has been shown. The greatest impact can be proved concerning the change of the unit cost of the chemical energy of biomass. The second most influential parameters are the unit cost of electricity and the guarantees of origin for electricity production from RES.

Through the economic analysis, the authors attempted to optimize the NPV as a function of the share of cogeneration for the BCHP unit with an extraction-condensing turbine. The assumed range of the coefficient was between 0.5 and 0.9. Also taken into account were the impact of the subsidy and the guarantees of origin for electricity produced from renewable energy sources. The results of this analysis have been presented in Figure 7.

First of all, a significant impact on the economic profitability of the guarantees of origin for electricity produced from renewable energy sources can be observed. Secondly, the optimisation shows that the NPV rises with the increase of the share of cogeneration, thus the optimum could not be determined. These results are partially correlated with the findings of the CHP_Strateg project [Ziębik 2009] where similar results were obtained for large coal-fired CHP plants with extraction-condensing turbines.

Fig. 7. Results of the optimization analysis



Source: Świerzewski 2016

Conclusions

The paper presents the results of the energy, environmental and economic assessment of biomass combined heat and power units. The mathematical models of both considered BCHP units have been elaborated and validated with data from commercially available CHP units. The assumed district heating system was also modelled, assuming a peak heat demand of around 19 MWth, by means of the duration curve of heat demand. Further on, thermodynamic, environmental and economic analyses were performed, assuming that the BCHP unit will operate in Polish conditions.

The results of this study prove that BCHP units can be a good option for the Polish energy sector, both from the point of view of the environment and energy. It should be kept in mind that the economic profitability of the BCHP strongly depends on the unit cost of biomass and the support scheme for electricity generation from RES. Currently, guarantees of origin for electricity production from RES have reached their lowest values and are 3 times cheaper than the assumed values within this analysis, which would make the investment not profitable at all. The assumed subsidy for the investment outlay is also currently being discussed.

Nevertheless, taking into account the benefits of the implementation of cogeneration and use of RES, BCHP units might be a good pathway for the modernisation of the Polish energy sector. Although it should always be kept in mind that biomass feedstock availability and heat demand are the crucial elements that always have to be considered.

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Analiza ekologiczna i ekonomiczna układu skojarzonego zasilanego biomasą: studium przypadku dla Polski

Streszczenie

W artykule zaprezentowano wyniki analizy energetycznej, ekonomicznej oraz ekologicznej elektrociepłowni pracującej w miejskim systemie ciepłowniczym. Modele matematyczne rozważanych wariantów elektrociepłowni (z turbiną przeciwprężną oraz turbiną kondensacyjną) zostały opracowane i zweryfikowane na podstawie dostępnych danych z jednostek kogeneracyjnych.

Otrzymane wyniki wskazują, że biomasowe układy kogeneracyjne mogą stanowić dobrą alternatywę dla polskiego sektora energetycznego, zarówno z ekologicznego jak i energetycznego punktu widzenia. Analiza ekonomiczna wskazała, że analizowane warianty elektrociepłowni mogą być opłacalne lecz takie czynniki jak cena za świadectwa pochodzenia produkcji energii ze źródeł odnawialnych mogą znacząco wpłynąć na uzyskane wyniki.

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