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Modernisation of a Coal-Fired Heating Plant to Switch to Woodchips, in Accordance with Logistics Principles

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Summary. The article analyses selected aspects of the technology and logistics used to modernise a coal-fired heating plant to switch to woodchips, which is illustrated with a specific investment. The study presents characteristics of the investment's heat economy before the modernisation, as well as the assumptions and program of the project. Finally, selected effects of the modernisation have been described.

Key words: heating plant, modernisation, woodchips, power engineering.

INTRODUCTION

The development of the renewable energy sector in Poland is being hindered by legal and financial barriers and only constitutes insignificant part of the country's fuel and energy balance [4, 35, 39]. Although the participation of renewable energy sources (RES) in the overall primary energy produced in Poland started to grow later than in Europe, an upward trend has been reported (11.9% in 2013) [1, 6, 36]. In 2013, more than 80% of energy from RES obtained in Poland was generated from solid biofuels, meaning fuel wood, forestry waste and by-products of forest and paper-making industry. The share of liquid biofuels slightly exceeded 8%, while wind energy constituted 6%. The participation of water energy and biogas energy equalled 2.5 and 2%, respectively, with other energy carriers constituting less than 1% of the overall RES energy generated. Modern societies are eager to use pro-ecological RES [5, 13, 19, 32]. The growing importance of renewable energy sources in Europe is connected with introduction of the "Climate and Energy Package" of the European Commission of January 10th 2007, which sets forth energy targets for individual Member States [11, 12, 28]. The energy target set to Poland provided for the increase in the use of RES in the power sector by 15% until 2020. In the first half of 2015, the installed capacity in RES grew by 304.3 MW, i.e. nearly to 6.333 GW (according to data provided by the Energy Regulatory Office), which was by 5% more than at the end of 2014. Like in the previous period, the RES energy gain is mainly attributable to wind power engineering. Almost 284 MW of the overall 303.4 MW of new capacities in the area of RES was generated by wind farms [18].

Cities and towns located near forests are increasingly eager to use waste wood [22, 23, 27, 29, 30], chips or sawdust as heating fuel [7, 9, 10, 34, 42]. This is mainly for ecological reasons, and because 4 million tons of fuel wood is obtainable in Poland each year, the majority of which is burnt at felling sites [2, 8, 17, 25, 31]. Wishing to satisfy the expectations of the society and ecologists, District Author-

Table 1. Installed capacity in RES in the first half of 2015

Type of RES	31.12.2014 [MW]	30.06.2015 [MW]	Change MW	Change %
Biogas power plants	188.549	191.381	2.832	1.5%
Biomass power plants	1,008.245	1 008.245	0.000	0.0%
Photovoltaic power plants	21.004	35.586	14.582	69.4%
Wind power plants	3 833.832	4 117.421	283.589	7.4%
Water power plants	977.007	980.323	3.316	0.3%
In total	6028.637	6332.956	304.319	5.0%

[Own elaboration based on 21]

ities are more and more willing to modernise the existent heating plants in their subordinate areas and to switch to ecological fuels [16, 26, 38, 40, 41]. The assumptions behind such modernisation are prepared based on the principles and methods used in logistics [3, 14, 33, 43], which is considered one of the most important tools to rationalise operations of the company, reduce costs and increase competitiveness in the market [15, 20, 24, 37].

ASSESSMENT OF HEAT ECONOMY OF THE INVESTMENT ANALYSED BEFORE MODERNISATION

The heat economy system concerning the investment analysed was mainly based on coal-fired heating plants. The system's running costs were high, and mainly encompassed coal purchase, cost of day-to-day repairs of worn out devices and other expenses needed to run the plant (stokers' pay). Moreover, coal-fired heating plants also caused high environmental pollution. The plan provided for modernisation of the heating system mainly through switching to ecological energy sources, including gas, oil or biomass. Straw-fuelled plants were eliminated, as the investment was located in the city centre and it was impossible to supply and store the straw.

Buildings: The public utility buildings analysed were in as much as in 45% qualified as very cold buildings were characterised by high energy consumption. Most of them were built in the first half of the 20th century, in technology where the heat-transfer coefficient $q \geq 1$. The construction technology, which satisfied the then heating standards with the heat-transfer coefficient $k = 1$, does not satisfy the currently applicable standards for newly-constructed buildings, where $k < 0.25$. Therefore, the Power Auditor (Audytor Energetyczny) software was used to calculate indicative power demand of all buildings after thermal improvement. The overall floorage of the rooms heated equalled 36772 m2.

Identification of energy resources of fuels: The possibilities to obtain fuel for a biomass-fired heating plant were examined as part of the investment. As there was no forestry commission in the location analysed, research on the potential to obtain wood was extended to encompass the neighbouring districts (poviats). The reconnaissance was performed within a c.a. 35-km radius, which proved enough to obtain fuel for the biomass-fired heating plant.

ASSUMPTIONS BEHIND THE PROGRAMME OF HEATING PLANT CONSTRUCTION

The assumptions underlying the programme of the heating plant construction in the selected location were adopted based on the condition of the heat economy, heat demand and demand for investments that would rationalise the heat consumption by recipients. It was concluded that liquidation of the existent low-parameter coal-fired heating plants located within the city, which were responsible for low and onerous air pollution, would be the right thing to do. This was planned to be done through connecting the recipients to the existent heating system and heating plants or through replacement of such plants with modern individual heating rooms fired by ecological fuels.

To reduce the costs of power production in the heating plants in Starosty, detailed technical-economic analyses of the modernisation and rationalisation of exploitation of the heating plants were commissioned. Additionally, to reduce heat demand of the existing recipients, plans were prepared to carry out complex thermal improvement of public utility buildings as well as to modernise the existent heating installation and install thermostatic valves.

The analysis of the investment was based on the fact that the price of energy was highly determined by the volume of the fuel used which, in turn, depended on the duration of the heating season. As it was necessary to have certain amounts of fuel in stock before the start of the heating season, the demand for current capital was also taken into account.

Table 2 presents estimated costs of obtaining power from various types of fuel (prices from 2013). Average price of woodchips (small-sized wood) from the State Forests in 2013 was 51.11 PLN/m³.

Table 2. Costs of obtaining power (prices in 2013)

Name	Price for commercial unit	Cost of obtaining 1kWh of effective heat power
Natural gas	2.0 PLN/m³	PLN 0.21-0.25
Liquid gas – propane	3.0 PLN/litre	PLN 0.48-0.50
Fuel oil	4.2 PLN/litre	PLN 0.45-0.50
Coal	800 PLN/ton	PLN 0.15-0.18
Fuel wood	200 PLN/stere	PLN 0.12-0.15
Electrical current, tariff I	0.6 PLN/kWh	PLN 0.56-0.62
Heat pump (costs of electrical energy)		PLN 0.14-0.17

[Own elaboration based on 8]

HEATING PLANT MODERNISATION PROGRAMME

The analysed investment project included modernisation of the existent coal-fired heating plants for facilities managed by Starosty to switch to gas, fuel oil and biomass, and resignation from coal. The assumptions included construction of one biomass plant, four fuel oil-fired plants and nine natural gas-fired plants. The estimated cost of operation of a modernised plant in the heating season should be by c.a. 25% lower than before the modernisation.

The key element of the investment project was the modernisation of the coal-fired heating plant in the Juvenile Reform School to switch to biomass/wood. The heating plant was localised in the existing facility. Local coal-fired heating rooms were liquidated, namely, the heating room in the Vocational School Complex, the Special School and Care Centre, the boarding house of the Special School and Care Centre and in the Inter-school Dormitory.

The programme assumed the construction of a heating system with a biomass heating room for the facilities where the existent heating rooms were to be liquidated. The power capacity of the modernised heating room would increase from 600kW to 1.5 MW, thus satisfying the heating needs of the facilities connected thereto. Moreover, it was decided that as a result of modernisation five local heating rooms which generated high air pollution would be liquidated and replaced with a big ecological (biomass/wood-fired) heating plant.

The thermal balance was prepared based on the stocktaking in the facilities and a utility programme, which was necessary in order to calculate current heat demand. The calculations were prepared with the use of the AUDYTOR OZC software.

Technical designs of the heating systems were prepared assuming that heat would be delivered to the facilities from one woodchip-fired heating plant, that a dual-circuit network of pre-insulated pipes would be constructed and that a heat centre would be ensured in each facility, divided into central heating and hot service water. Total heat power demand for the facilities for which the heat system was built from the biomass-heated plant equals 1810kW (Fig. 1).

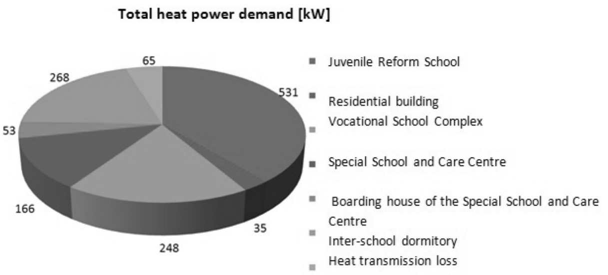

Fig. 1. Total heat power demand for facilities fed from biomass-heated plants [Own elaboration]

MODERNISATION OF A COAL-FIRED HEATING PLANT TO SWITCH TO WOODCHIPS

According to the project, heat is produced in the heating room of the Juvenile Reform School, which is a low-parameter water heating room fired with woodchips (humidity up to 60%), with an oil-firing option. The heating room produces heat for central heating and hot service water, in line with the heat balance prepared.

Before the modernisation, the heating room was fitted with three steel coil boilers: two UKS-type water boilers (universal steel boilers) and one UKS P. steam boiler.

The modernisation involved a replacement of the existent boilers with two NT LEGNABLOCK boilers by FERROLI, fired with woodchips (humidity up to 60%), and complete replacement of the majority of devices in the heating room's technology. At the designing stage, attention was paid to issues related to fire safety. When there are long breaks in the boiler's operations, during which the grate is inactive, or when low-density fuel is used and the natural draught is high, or when the perpetual screw is unfilled due to problems with fuel transport to the intermediate tank, the flame might slowly retract through the fuel to the feeding screw.

Fuel installations: It was assumed that biomass would be stored in a concrete tank sized 10.4 x 5 x 2.1m. The remaining fuel (biomass) required for uninterrupted operation of the boilers is stored under a roofed shelter sized 12 x 8 x 5m. Fuel transport from the concrete tank to intermediate tanks located by the boilers is performed with the use of hydraulic installation, namely, movable floor, feeding screw (horizontal), feeding screw (skew) and redler feeder with a driving station, end reversal station and a system of rotary valves coupled with an automatic fuel-to-boiler feeding system (Fig. 2).

The designed discharge system is adjusted to feeding woodchips (humidity up to 60%) from concrete tanks with rectangular base.

On the bottom of the tank are discharge frames used to pull the biomass out of the concrete tank. The back and forth motion is imparted by three dual-action hydraulic actuators. The actuators, together with the rest of the hydraulic system, are located in a separate hydraulics room. The system control depends on the maximum pressure, which means that the piston changes direction when in extreme position, i.e. when pressure reaches the maximum level. The biomass is pulled to the transverse feeding screw. A set of PECs is installed above the feeding screw, which decides when the discharge system is to be activated or stopped.

Fig. 2. Elements of the fuel (biomass) feeding system [Own elaboration]

At the next stage woodchips are transported through the skew feeding screw to the redler feeder, from which they are batched through a system of installed rotary valves to the intermediate tanks installed immediately by the LEGNABLOCK NT boilers.

Intermediate steel fuel-feeding tanks of the capacity V = 1.2 m^3, fitted with max and min level sensors are an integral element of delivery of the LEGNABLOCK NT units. The sensors ensure smooth fuel supply to the boiler's furnace feeding screw. The boiler control is automatic and depends on the volumes of the fed fuel and air.

The use of alternative fuel (light EKOTERM oil) shall also be possible in case of momentary shortages of the primary fuel (biomass) in stock. The LEGNABLOCK NT used in the installation comes with the option to install a burner on the slide. A dual-stage oil burner was used (RIELLO, type RL100). The burner is controlled from the boiler's switchboard. The fuel oil is warehoused in two PE tanks, each of the capacity of 1660l. The tanks are located in a tight tub, 0.6m-high, which in the case of leakage retains 100% of the oil. A list of fittings for the modernised heating plant is presented in Table 3.

Table 3. List of fittings of the modernised heating plant

No.	Device type	Type	Quantity (pcs.)
1	Low-temperature biomass-fired water boiler	LEGNABLOCK NT 08	2
2	Oil burner	RL 100	2
3	Insulated multi-cell cyclone	800	2
4	Exhaust fan	800	2
5	Boiler circuit pumps	UPS 80-120F	4
6	Intermediate fuel pump		2
7	System pump	NB 50-250/263	2
8	Expansion vessel, capacity 820dm^3	A-1	1
9	Expansion vessel, capacity 800dm^3		1
10	Heating and ventilation devices	SWO-5	1
11	Water purification plant 1.6m^3/h	A16CH	1
12	Oil tanks, cap. 1665l	Cubic Tank	2
13	Movable floor, capacity 1t fuel/h		1
14	Mechanical fuel transport /redler/	SP10	1

[Own elaboration]

Ecological impact of modernisation of the heating plant: As a result of the modernisation projects, emission of pollutants to the environment dropped. Table 4 presents annual emission of pollutants before modernisation of the facilities, which were later connected to the biomass-fired heating plant as part of the investment.

Figure 3 presents annual emission of pollutants after modernisation of the facilities fed from the biomass-fired heating plant.

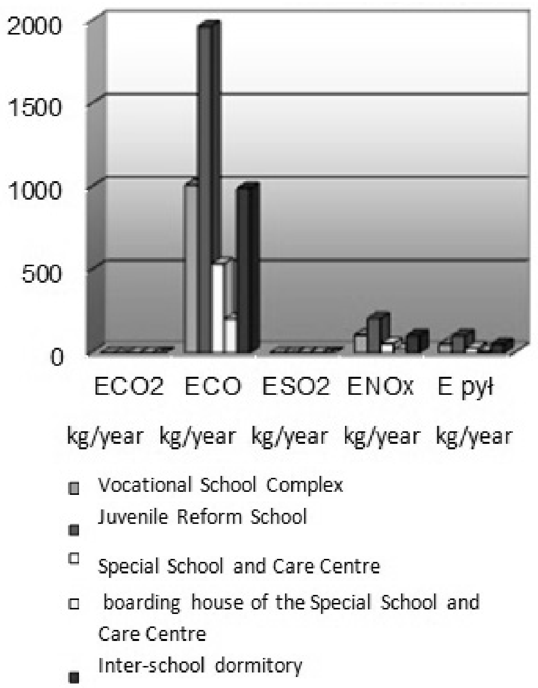

Fig. 3. Emissions of pollutants after modernisation [Own elaboration]

CONCLUSIONS

The modernisation of a coal-fired heating plant and switching to woodchips provided savings of app. 25% when compared to the costs incurred during heating seasons before the investment. Additionally, the investment significantly reduced the emission of pollutants to the atmosphere, which was also necessary in order to obtain European Union subsidies for the project, and improved reliability of the heating installation. The complexity of the works carried out should also be highlighted, as the investment encompassed not only the modernisation, but also thermal improvement of the facilities where the heat is supplied.

Table 4. Annual emission of pollutants before modernisation

Item	Name of facility	Annual coal consumption	ECO$_2$	ECO	ESO$_2$	ENO$_X$	E dust
		t/season	t/year	t/year	t/year	t/year	t/year
1	Vocational School Complex	13	26.03	0.62	0.12	0.03	0.39
2	Juvenile Reform School	240	480.48	11.52	2.16	0.48	7.20
3	Special School and Care Centre	38	76.08	1.82	0.34	0.08	1.14
4	Boarding house of the Special School and Care Centre	29	58.06	1.39	0.26	0.06	0.87
5	Inter-school Dormitory	130	260.26	6.24	1.17	0.26	3.90

[Own elaboration]

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MODERNIZACJA KOTŁOWNI WĘGLOWEJ NA ZRĘBKI DREWNIANE Z UWZGLĘDNIENIEM ZASAD LOGISTYKI

Streszczenie: W artykule omówiono wybrane aspekty z zakresu analizy technicznej i logistycznej modernizacji kotłowni węglowej na zrębki drewniane na przykładzie wybranej inwestycji. Opracowanie zawiera charakterystykę gospodarki cieplnej analizowanej inwestycji przed modernizacją, założenia i program modernizacji kotłowni. Ponadto, w artykule przedstawiono wybrane efekty realizacji modernizacji kotłowni.

Słowa kluczowe: kotłownia, modernizacja, zrębki drewniane, energetyka.