ECOLOGICAL AND ECONOMIC ASPECTS OF MODERNIZING DISTRICT HEATING SYSTEMS IN NORTH-EASTERN POLAND

EKOLOGICZNO-EKONOMICZNE ASPEKTY MODERNIZACJI SYSTEMÓW CIEPŁOWNICZYCH W PÓŁNOCNO-WSCHODNIM REJONIE POLSKI

Abstract: On the basis of audit surveys concerning modernization of heating systems in middle-sized towns (of 16 to 65 thousand inhabitants), a technical-economic analysis as well as an ecological analysis of feasible investment projects were performed. The audit surveys concentrated mainly on 152 local low-temperature boiler houses with low emission sources in selected towns of the north-eastern Poland. The audit surveys mentioned above involved also measurements of the amounts of SO$_2$ and particulate matter polluting the air. The fundamental purpose of the suggested modernization of the researched heating systems was to improve the very low operating efficiency of the boiler houses (mainly with low emission sources) under concern, as well as - or perhaps above all - to reduce levels of SO$_2$ and particulate matter polluting the air. One of the criteria applied in the economic assessment of the suggested projects (investments) was the Net Present Value (NPV), whereas in the case of the ecological assessment - reducing air pollution.

Keywords: heat management, pollution reduction, economic effectiveness

Introduction

Air pollution with sulphur dioxide, particulate matter, and other substances, eg CO and NO$_2$, is regarded as the so-called primary pollution which is generated mainly during combustion of fuels in the process of energy production. The major sources of primary pollution emission are, above all, emission sources of utility and industrial power plants (the so-called high emission), and also the municipal and residential sector: local boiler houses, service companies, and individual households (the so-called low emission) [1, 2].

In order to prevent emission of global pollutants, an international agreement, called the Kyoto Protocol, was signed in 1997. The countries which ratified the agreement committed themselves to a reduction of their emissions by at least 5% from the 1990 level by 2012.

Also reducing the negative influence of humans on the natural environment (including the air pollution) is one of the European Union's priorities, and therefore, for the last several years requirements pertaining to, among others, the acceptable level of polluting the air with...
substances produced during combustion of fuels in the process of energy production, have been made more stringent.

In Poland (similarly to other EU countries), starting from 2010, the admissible level for carbon monoxide is 10 000 µg/8 h, for sulphur dioxide (SO₂) - 350 µg/m³/h, and the concentration of the biggest particles of PM10 particulate matter (PM10 - particles whose diameter is 10 µm) amounts to 40 µg/m³ (as the averaged value in a calendar year). In areas where pollution is very strong (e.g., the Silesian urban agglomeration), the term for meeting these requirements was prolonged by 3 years [3].

Sulphur dioxide comes mainly from sulphur compounds contained in combusted fuels. The concentration of sulphur dioxide in the air in Poland has been considerably reduced when compared with that in 1994, but unfortunately, since 2001 no significant reduction of the indicator of air pollution with SO₂ has been observed, similarly to the cases of reducing the levels of suspended particulate matter (PM10) and carbon monoxide (CO) (Fig. 4) [1, 4, 5].

Housing estates supplied with heat power by furnace heating are most exposed to high PM10 concentrations from primary emission resulting from fuel combustion.

Data from 2004, contained in a European Environment Agency report, indicate that the highest concentration levels of PM10 suspended particulate matter in urban areas can be found in Poland, Romania, Bulgaria, Italy, and in the Benelux countries [1, 6].

In Poland, emission of pollutants to the atmosphere is regulated by the legal provisions in force which require:
- obtaining the needed emission licences,
- obtaining allowances for emission of an adequate amount of CO₂,
- observing the so-called emission standards (for SO₂, NOₓ, and particulate matter).

In order to effectively reduce the amount of particulate matter and gases in the air, produced as a result of burning fossil fuels (mainly coal), the amount of combusted coal has to be reduced, and systems for desulphurisation of combustion gases as well as dust removal devices have to be used in the first place. A basic condition of reducing fossil fuels combustion is decreasing (restricting) energy production for the purposes of central heating and hot utility water through: thorough modernization of heating systems, which would mainly improve their efficiency, thermomodernization of buildings, and increasing the share of renewable energy sources, such as: biomass, solar energy, wind energy, and hydropower, in energy production [2, 6, 7].

In the 1990s, the author of the present article took part in carrying out several surveys concerning energy-saving modernisation of heating systems in several middle-sized towns located in the north-east of Poland [8, 9]. These surveys aimed at reducing heat demand for the purposes connected with buildings, and thus at reducing the amount of air pollutants generated during fuel combustion. The surveys included detailed characteristics and assessment of the technical condition of the elements of the existing heating systems, i.e.: heat sources, heat networks and distribution centres, buildings, and their internal systems. On the basis of analysing the observed technical condition of the studied heating systems, guidelines concerning investments rationalising heat consumption by recipients were made, and economic and ‘ecological’ analyses of these investments were developed. The economic analysis pertained to modernising the existing heating systems. The NPV (Net Present Value) indicator as well as the Internal Rate of Return (IRR) were adopted as the criteria of the effectiveness of investments connected with modernising the heating systems.
The basic criterion in the 'ecological' analysis was the reduction in the levels of PM10 particulate matter and gases polluting the air (among others, SO\(_2\) sulphur dioxide and CO carbon monoxide), obtained as a result of modernising the heating systems [6].

**Characteristics of elements of the existing heating systems in selected towns**

In the second half of the 1990s, heat management in all the towns under analysis, similarly to the situation all over Poland, was characterised by a low thermal efficiency and it was highly damaging for the environment [1, 6, 8, 9, 13-15]. Operating efficiencies of most boiler houses, mainly these with low emission sources, were low, and they often amounted to, in the case of central heating (c.h.), less than 70%, and, in the case of hot utility water (h.u.w.) < 65%. Figure 1 presents changes of the efficiency of heating systems within the last 90 years in Poland.

![Efficiency of heating systems for c.h. and h.u.w. depending on the year of system construction](image)

In the towns under analysis, 80% of the heat distribution centres under research were energy-consuming hydrophobic centres without any automatic regulation devices. The analysed low-temperature boiler houses were equipped with boilers of the Eca IV, Rumia, etc. types which required high quality coal. The vast majority of these boilers had been used for > 15 years at that time, and therefore their technical condition was rated as unsatisfactory.

Because of their simple construction and because of being easy to operate, stoker-fired boilers were widely used for burning coal, as sources of heat and process steam both in heat
engineering and in industrial plants. The main disadvantages of devices of this type were their low efficiency (the \( \eta \) annual average efficiency was often < 65%) and their relatively high emission of toxic gases (SO\(_2\), CO, CO\(_2\), NO\(_2\)). The efficiency of a properly constructed stoker-fired boiler can reach values which are a little lower than these of a pulverised-fuel boiler. The major reason for a low efficiency of a boiler (especially in heat engineering) is inappropriate selection of working parameters of the boiler, depending on the required productivity, where changes in the weather conditions force frequent changes in the boiler productivity in the wide range of the rated power [16, 17]. In the 1990s, an ‘optimal’ performance of stoker-fired boilers was ‘set’ on the basis of indirect indications such as eg combustion gas analysis. The present advancement of control engineering makes it possible to directly optimise efficiency of such stoker-fired boilers, which significantly improves efficiency of heating systems. The payback period on investments into boiler automation and metering is often much shorter than 1 year. Efficiency of heating systems after modernization (as a result of introducing automation) was increased by 12÷15% (from 62 to 75÷77%) [16-19].

Table 1

Data concerning boiler houses and heat distribution centres in the different towns

<table>
<thead>
<tr>
<th>No.</th>
<th>Town</th>
<th>Average performance of boilers</th>
<th>Heat demand [MW]</th>
<th>Boiler houses</th>
<th>Buildings equipped with thermo valves h.u.w. water meters</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Suwalki</td>
<td>75÷81%</td>
<td>151.2</td>
<td>121 items</td>
<td>354, in 62% of which central heating and h.u.w. were automatically controlled</td>
<td>60 85 Monitoring of the system operation data</td>
</tr>
<tr>
<td>2.</td>
<td>Lomza</td>
<td>65÷78%</td>
<td>133</td>
<td>100 items</td>
<td>291, injection pumps in 16%</td>
<td>15 65 70 buildings were heated with furnaces, no automatic control in 60% of heat distribution centres</td>
</tr>
<tr>
<td>3.</td>
<td>Hajnowka</td>
<td>50÷65%</td>
<td>35</td>
<td>17 items</td>
<td>26, injection pumps in 96%</td>
<td>8 8 9 buildings were heated with furnaces, only 14% buildings with central heating systems had h.u.w.</td>
</tr>
<tr>
<td>4.</td>
<td>Gizycko</td>
<td>55÷70%</td>
<td>39.2</td>
<td>29 items</td>
<td>98, injection pumps in 22%</td>
<td>55 35 21 buildings were heated with furnaces</td>
</tr>
<tr>
<td>5.</td>
<td>Pisz</td>
<td>50÷62%</td>
<td>27.7</td>
<td>15 items</td>
<td>73, injection pumps in 74.7%</td>
<td>20.3 100 51 were heated with furnaces</td>
</tr>
<tr>
<td>6.</td>
<td>Siemiatyce</td>
<td>56÷58%</td>
<td>18.5</td>
<td>10 items</td>
<td>---</td>
<td>88 100 75.8% of all boiler houses are gas ones; they cover 48.7% of heat demand</td>
</tr>
<tr>
<td>7.</td>
<td>Kolno</td>
<td>40÷50%</td>
<td>14.54</td>
<td>19 items</td>
<td>58 injection pumps in 26%</td>
<td>84 91 Boilers in bad technical condition - 40÷50% of efficiency (100% for coal-fuelled)</td>
</tr>
<tr>
<td>8.</td>
<td>Czarna Bialostocka</td>
<td>45÷50%</td>
<td>15.34</td>
<td>26 items</td>
<td>23 (injection pumps or pumps in 82%)</td>
<td>7 97 45.6% residential buildings without h.u.w.</td>
</tr>
</tbody>
</table>
Boilers of the WR-5 type, burning fine coal, were installed in the researched high-parameter boiler houses; the technical condition of the boilers was rated as satisfactory. Suwalki was an exception among the analysed towns: the technical condition was estimated as good, and the existing district heating system was classified as one of the most modern systems in Poland. The above picture of the heating systems under research is indicative of their low (considering their technical potential) energy and economic efficiency and of the fact that they are relatively highly damaging for the natural environment [1, 8, 9, 15].

The data concerning the types and number of boiler houses for producing power for the purposes of central heating and hot utility water in the different towns are presented in Table 1.

**Suggestions for modernising heating systems**

Considering the technical condition of the heating systems analysed in the surveys, investments modernising heating systems were suggested for particular towns [8, 9, 20, 21]. The investments aimed at achieving the following two basic objectives:

I) reducing the heat power demand through applying energy-saving technical solutions,
II) lowering the present emission of air pollutants through liquidation or modernization of the existing emission sources in the form of low-parameter coal-fuelled boiler houses and furnace heating.

**Objective I is accomplished by:**

- performing comprehensive thermomodernization of buildings, reducing the indicator per cubic capacity to the value of 12÷15 W/m$^3$, which can result in reducing the heat demand (depending on the town) by 10.78 to 24.05% at present (in 2010) 60÷80% of this aim has been achieved (depending on the town),
- energy-saving heating of hot utility water with the use of the water from central heating systems (diminishing the maximum design heat power demand for h.u.w. purposes can reach up to 80%); the present data (from MPEC and PEC district heating companies) indicate that 40÷50% of this aim has been reached,
- using thermo valves which guarantee savings of ~20% during the whole heating period (95% of this objective has been accomplished at present),
- using h.u.w. water meters whose installation ‘forces’ users to use h.u.w., reducing consumption by ~30% (this aim has at present been reached in 100%),
- converting heat distribution centres equipped with injection pumps into automatically controlled heat exchangers, owing to which heat power consumption during a heating period can be reduced by up to 30% (this aim has at present been reached in 100%).

**Effects of modernizing heat distribution centres and buildings with their internal systems (Objective I)**

In order to determine the effects of modernizing heating systems (in the form of reducing heat demand), simulation calculations were performed of heat demand before and after modernizing internal systems of buildings, their thermorenovation, and modernizing
heat distribution centres. The forecasted reduction in the values of heat demand for the purposes of residential buildings is presented in Table 2 and in Figure 2.

<table>
<thead>
<tr>
<th>No.</th>
<th>Town</th>
<th>Number of residents</th>
<th>Heat demand before modernization [MW]</th>
<th>Heat demand reduction [MW]</th>
<th>Heat demand reduction [%]</th>
<th>Reduction of heat demand for heating buildings $\Delta E_{oo}$</th>
</tr>
</thead>
</table>
|     |               |                     | [MW] [MW] [MW] [MW] [MW] [MW] [MW] |                           |                           | $\Delta E_{oo}$ $\Delta E_{oo}$ $\Delta E_{oo}$ $\Delta E_{oo}$ $\Delta E_{oo}$ $\Delta E_{oo}$ $\Delta E_{oo}$ | $

Fig. 2. Reduction of heat demand in particular towns, caused by the performed thermorenovation of buildings, modernization of heat distribution centres, installing thermo valves and h.u.w. water meters, compared with the situation before modernization (before 1996)
Having analysed the above results, it was concluded that such significant reductions of the heat power demand (20÷55%) compensate for the increased demand resulting from the prospective development of the studied towns. This produces an additional economic effect connected with eliminating capital expenditures which are necessary for possible extension of the heat sources. However, it has to be taken into account that such reduction can be obtained only if 100% of the suggested modernization works are carried out. For example, modernizing and automation of heat distribution centres should involve converting heat distribution centres equipped with injection pumps into heat exchanger distribution centres, applying energy-saving methods of heating hot utility water (h.u.w.), regulating operation parameters for central heating, regulating the h.u.w. temperature, regulating differences in the pressures of network water flowing to and out of heat distribution centres, as well as equipping heat distribution centres with heat meters.

Accomplishing objective II involves:
- modernizing (automation) of high-temperature heating systems [18, 19],
- liquidating or modernizing the existing heat sources in the form of low-parameter coal-fuelled boiler houses and furnace heating.

Accomplishing objective II requires investing significant amounts of money because it concerns big investments such as:
- building a central heat source equipped with high-efficiency power boilers and systems of exhaust gas treatment (the source cooperates with heat distribution centres through distribution heat networks covering selected areas of towns).
- building district boiler houses equipped with high-efficiency power boilers and systems of exhaust gas treatment (the source cooperates with heat distribution centres through distribution heat networks covering selected areas of towns),
- modernizing the existing heat sources, consisting in increasing their heat power and installing systems of exhaust gas treatment (replacing the boilers used at present with high-efficiency power boilers).

Table 3

<table>
<thead>
<tr>
<th>No</th>
<th>Town</th>
<th>Reduction in air pollution with SO\textsubscript{2} to</th>
<th>Suggested modernization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Suwalki</td>
<td>SO\textsubscript{2} - 290% PM10 - 300%</td>
<td>Scenario I - extension of the main heating plant and the heating plant in the centre, II - extension of the main heating plant only, liquidation of the heating plant in the centre, III - extension of the main heating plant, and the heating plant in the centre is fuelled only with ecological fuel, ie natural gas or fuel oil. The remaining boiler houses should be fuelled with coal containing less sulphur. Individual boiler houses (12.8 MW) should be connected to the district heating system. Suggested scenario III.</td>
</tr>
<tr>
<td>2.</td>
<td>Lomza</td>
<td>SO\textsubscript{2} - 320% PM10 - 320%</td>
<td>Thorough modernization based on the extension of the existing system of heating plants.</td>
</tr>
<tr>
<td>3.</td>
<td>Gżycko</td>
<td>SO\textsubscript{2} - 230% PM10 - 250%</td>
<td>Gżycko - suggested scenario III - using the district boiler house and modernizing the remaining boiler houses.</td>
</tr>
<tr>
<td>4.</td>
<td>Hajnowka</td>
<td>SO\textsubscript{2} - 98% PM10 - 200%</td>
<td>Hajnowka - scenario I - building 1 central town heating plant, scenario II - 1 town boiler house supported by an industrial boiler house, scenario III - converting the selected coal-fuelled boiler houses into gas-fuelled or fuel oil ones, together with increasing the number of consumers using heat from these boiler houses. Scenario I is optimal as far as reducing pollution is concerned.</td>
</tr>
<tr>
<td>5.</td>
<td>Pisz</td>
<td>SO\textsubscript{2} - 318% PM10 - 300%</td>
<td>Liquidating coal-fuelled boiler houses, modernizing heat distribution centres. Considering great energy reserves obtained as a result of the suggested modernization, extension of the existing boiler houses is not necessary.</td>
</tr>
<tr>
<td>6.</td>
<td>Siemiatycze</td>
<td>SO\textsubscript{2} - 172% PM10 - 180%</td>
<td>Liquidating local coal-fuelled boiler houses, liquidating furnace heating, connecting to boiler houses powered by the gas network. At present (2010) there are 4 gas boiler houses and 3 coal-fuelled ones.</td>
</tr>
<tr>
<td>7.</td>
<td>Kolno</td>
<td>SO\textsubscript{2} - 217% PM10 - 220%</td>
<td>Scenario I includes constructing a Town Heating Plant (36 MW) and saving the ‘old’ boiler house. Both these boiler houses would have sulphur removal systems. Liquidating smaller units in the town. Scenario II - converting 16 coal-fuelled boiler houses into 16 gas ones.</td>
</tr>
<tr>
<td>8.</td>
<td>Czarna</td>
<td>SO\textsubscript{2} - 195% PM10 - 250%</td>
<td>Connecting the 2 boiler houses to the heat network, savings will allow for liquidating 1 boiler in a bad technical condition. Future prospects - an exhaust gas treatment plant for the town heating plant, expanding the heat network, replacing low-parameter central heating networks with low-parameter ones.</td>
</tr>
</tbody>
</table>

\*A highly efficient exhaust gas treatment system might lead to reducing the amounts of SO\textsubscript{2} and particulate matter up to 90%, and the amount of nitric oxides up to 30%.
Achieving the second (II) objective concerns big and very expensive investments. Taking this fact into consideration, 2-3 feasible scenarios were analysed and the optimum scenario (both from the financial and ecological point of view) was chosen [18]. The suggested scenarios of modernizing heating systems in the towns under research, and the resulting reduction in air pollution with SO$_2$ and with PM10 particulate matter are listed in Table 3 and in Figure 3.

Analysis of the economic efficiency of the investments

The required investment expenses connected with comprehensive modernization of the heating systems in the small towns under research exceeded their annual budgets, therefore a need arose for creating lines of credit with preferential treatment, making it possible to carry out the planned investments.

Assessing the economic efficiency of works connected with modernizing the heating systems under analysis was carried out with the use two types of methods:

a) methods neglecting the influence of time on the value of money; the Simple Pay Back Time (SPBT) and the Rate of Return are examples of such methods,

b) methods taking into consideration the value of money in time through techniques using the so-called discount. Some basic indicators applying the discount method are: the Net Present Value (NPV), and the Internal Rate of Return (IRR). The Net Present Value (NPV) means the difference between the values of cash flows and the investment costs discounted at a given moment in time and at the specified discount rate.

Assessment of economic efficiency of suggested investment projects

Table 4

<table>
<thead>
<tr>
<th>Town</th>
<th>Economic indicators for suggested scenarios of modernizing heating systems</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I*</td>
<td>II*</td>
</tr>
<tr>
<td></td>
<td>NPV</td>
<td>IRR</td>
</tr>
<tr>
<td>Suwalki</td>
<td>+</td>
<td>&gt; 100%</td>
</tr>
<tr>
<td>Lomza</td>
<td>+</td>
<td>&gt; 100%</td>
</tr>
<tr>
<td>Hajnowka</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gżycko</td>
<td>+</td>
<td>&gt; 100%</td>
</tr>
<tr>
<td>Pisz</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Siemiatycze</td>
<td>+</td>
<td>&gt; 100%</td>
</tr>
<tr>
<td>Kolno</td>
<td>No information</td>
<td></td>
</tr>
<tr>
<td>Czarna</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bialostocka</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Particular scenarios are described in Table 3.

If a project is to be approved, then the NPV indicator value for this investment should be greater than zero.

The Internal Rate of Return describes the maximum interest rate for using funds, which is acceptable for the project if all the investment expenses and possible operating costs (eg paying back credit with interest) incurred during the whole period of operating are to be
returned. The value of this indicator describes the discount rate for which the Net Present Value (NPV) equals zero. In other words, NPV (IRR) = 0.

If the value of the internal rate of return is higher than or equal to the adopted hurdle rate, the project can be approved [10-12]. The indicators described above were used for assessing the investment projects concerning modernization of the heating systems in the analysed towns. The results of these analyses are listed in Table 4.

After analysing the results pertaining to the economic efficiency of the suggested investments (achieving objective II), it is possible to conclude that in 5 out of the 7 studied towns all the proposed scenarios were approved for implementation (NPV > 0).

On the basis of both the performed economic and ecological analyses of the suggested scenarios, the scenarios whose implementation guaranteed better ecological effects were chosen as optimal scenarios. The suggested scenarios for different towns are listed in Table 2. Current data for particular towns under analysis show that 55÷75% of Objective II have been completed, depending on the town. It was observed that towns with a bigger number of inhabitants (Lomza, Suwałki, Giżycko) accomplished the tasks set in Objective II to a much greater extent (by 15÷25%) than the other towns (eg Czarna Bialostocka, Siemiatycze, Kolno). It results from the fact that smaller towns have smaller amounts of money at their disposal [20].

**Reduction of air pollution as a result of performed modernization (data from direct measurements)**

The requirements concerning air pollution with SO$_2$, which were in force in Poland in the period of 1997-2011, are listed in Table 5, while Tables 6 and 7, and Figures 4 and 5, show current data (as of 2010) pertaining to the air pollution with SO$_2$ and PM10 particulate matter for the 2 biggest towns (Suwałki and Lomza) out of the 8 towns under concern. The data for the town of Lomza concern the air pollution generated by operating the town heating plant which covers 44.5% of the heat demand.

### Table 5

<table>
<thead>
<tr>
<th>Acceptable levels of sulphur dioxide in the air [3]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emission of SO$_2$ in Poland</strong></td>
</tr>
<tr>
<td>[thou. Mg/year]</td>
</tr>
<tr>
<td>2 368</td>
</tr>
</tbody>
</table>

### Table 6

<table>
<thead>
<tr>
<th>No.</th>
<th>Town</th>
<th>Air pollution in [Mg/year]</th>
<th>Reduction of air pollution in comparison with 1996 [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1996</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO$_2$ Particulate matter</td>
<td>SO$_2$ Particulate matter</td>
</tr>
<tr>
<td>1.</td>
<td>Lomza</td>
<td>919</td>
<td>1180</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*forecasted values (after implementing all suggested modernization procedures) - data only for the town heating plant, **continuous measurement - data from Provincial Environmental Inspection (www.wios.bialystok.pl), and MPEC Lomza
Table 7

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SO\textsubscript{2}</td>
<td>1052</td>
<td>960</td>
<td>456</td>
<td>464</td>
<td>476</td>
<td>454</td>
<td>399</td>
<td>285</td>
<td>454</td>
<td>374</td>
<td>286</td>
<td>352</td>
<td>347</td>
</tr>
<tr>
<td>CO</td>
<td>176</td>
<td>140</td>
<td>34</td>
<td>44</td>
<td>38</td>
<td>42</td>
<td>39</td>
<td>68</td>
<td>40</td>
<td>39</td>
<td>34</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>440</td>
<td>288</td>
<td>106</td>
<td>126</td>
<td>114</td>
<td>116</td>
<td>108</td>
<td>64</td>
<td>66</td>
<td>56</td>
<td>54</td>
<td>68</td>
<td>71</td>
</tr>
</tbody>
</table>

*Particulate matter

Fig. 4. Emission of air pollutants (chimney 150 m): SO\textsubscript{2}, particulate matter, and CO in the period of 1996-2010 [www.wios.bialystok]

Fig. 5. Emission of pollutants with PM10 suspended particulate matter - 24-hour concentration of December 2010 - data from direct measurements in the towns of Lomza and Suwalki [www.wios.bialystok.pl]
Having analysed the emission of SO$_2$ on the example of the town boiler house in Lomza, it can be concluded that the performed modernization investments met the assumptions concerning the reduction in emitting SO$_2$, and despite subsequent rising of the relevant requirements (Table 5), the values obtained from the performed measurements do not exceed the limit values in force since 2011 (Treaty of Accession).

In the case of concentration of PM10 suspended particulate matter, the situation is worse. On the basis of the results from direct measurements (presented in Fig. 5), exceeding of limits was observed in Lomza on 13 days during only 1 month (December) out of 35 days permissible within the whole calendar year.

The situation is much better in Suwalki where the acceptable PM 10 concentration was only slightly exceeded (Fig. 5) and it took place exclusively on 1 day within this whole-winter-month.

In the remaining towns under analysis, the current situation concerning the air pollution with SO$_2$, CO, and PM10 is on average by 10÷20% worse than the situation in the town of Suwalki (as the biggest town out of the towns under research).

**Discussion and conclusions**

1. According to the Polish regulations currently in force, strategic environmental assessment is a forecast which consists in thorough evaluation of possible effects (positive or negative) resulting from implementation of projects, plans, etc. Scenario solutions are also evaluated, and the conclusions which are arrived at are used in the decision process [4, 11]. The above rules were applied to develop different scenarios of modernizing the heating systems in the analysed towns.

2. The presented results of analyses performed for 8 middle-sized towns indicate that thorough thermorenovation of buildings, modernization of internal systems (thermo valves, h.u.w. meters, etc), as well as modernization and automation of heat distribution centres can lead to saving of anything from 20 to 50% of power per one heat source (depending on the technical condition of buildings and of internal and external heating systems).

3. In the 1990s, some multi-family buildings (from 8 up to 45% - in Pisz) in all the towns under research were heated with furnaces. Moreover, a significant percentage of the analysed buildings (from 20 to 58% - in Gizycko) equipped with central heating systems did not have hot utility water (h.u.w.) systems. Considering the above, it was necessary to modernize the existing heating systems by liquidating individual heating plants in the form of low-parameter coal-fuelled boiler houses (with low emission sources), liquidating furnace heating, and by connecting some of the buildings under concern to h.u.w. systems. It often involved extending the central heating plants powered by (preferably - if there was such a possibility) gas networks, or building new heating plants.

4. Regarding the fact that investments of this kind are very expensive, the suggested solutions were analysed from the economic point of view (Table 6). On the basis of the performed economic analysis it was concluded that in 5 out of the 8 towns under concern, the NPV indicators were positive, which meant that these projects could be financially approved for implementation.
5. As a result of the performed comprehensive modernization (accomplishing objectives I and II) it was estimated that the amounts of SO$_2$ polluting the air can be reduced more than twofold in comparison with the amounts emitted in 2000 (depending on the town).

6. On the basis of the data obtained in direct measurements (in 2010) considering the maximum concentrations of SO$_2$ and particulate matter in the air for the town heating plant in Lomza, and the amounts of particulate matter for the town heating plant in Suwalki, it was observed that the performed comprehensive modernization works of the respective heating systems had produced the expected effects. In Lomza, the maximum hourly concentrations of SO$_2$ in the air (both the 1-hour and 24-hour concentrations) amounted to up to 50% of the acceptable values (in force since 1.01.2004), whereas in the case of PM10 suspended particulate matter, the 24-hour concentrations in Lomza were exceeded on 13 days within 1 month (out of 35 permissible days in a whole calendar year), while in Suwalki the 24-hour concentrations were in the range of 50÷100% of the acceptable values, with only one case of exceeding the limits slightly during the 31 days of the analysed winter month.

7. The values of emissions of air pollutants in the analysed 8 towns, compared with the values for other Polish towns, are not high, and they approach the permissible maximum values. The research within the last 5 years, carried out mainly by Provincial Inspectorates of Environmental Protection, shows that the registered concentration values of the basic air pollutants: SO$_2$ sulphur dioxide, NO$_2$ nitric dioxide, and suspended particulate matter in most regions of Poland, are also at satisfactory levels [1, 15]. Unfortunately, implementation of the requirements of the so-called ‘Energy and Climate Package’, including the so-called EU-ETS Directive regulating trading allowances to emit greenhouse gases (published in the EU Official Journal L 140 of 05.06.2009), to the Polish law, changes the principles of allocation of allowances for emission - ultimately, allocation of free allowances will be liquidated, and particular systems will have to receive allowances by auctioning. For heating systems (producing district heating), the Directive sets a transitional period. During this period, systems can obtain free allowances: maximum 80% of free allowances in 2013, maximum 30% of free allowances in 2020; 0% of free allowances in 2027 (the end of the transitional period). During the whole period mentioned above, the number of free allowances is to decrease constantly. Furthermore, the Directive on Industrial Emissions (IED) will drastically reduce the so-called emission standards. The new standards enter into force in 2016. For systems whose power does not exceed 200 MW (thermal power in fuel), this term can be extended until the end of 2023.

8. Implementation of the requirements of the EU-ETS and IED Directives will force changes in the structures of fuels to be used, and thus in the structures of sources, and it will also force construction of new sources as well as construction of combustion gas cleaning systems for boilers. Such operations require substantial investment costs which are impossible to pay without financial help from the outside or without effective logistics which would ensure fuel delivery safety [2, 7, 13, 21]. The moment the stringent standards on pollutant emissions enter into force, cases of exceeding maximum permissible emission standards for pollutants in many parts of some urban agglomerations (mainly of much industrialised ones) are going to be observed [22].

9. In order to meet further limitations and to reduce costs of buying allowances to emit greenhouse gases, one should aim at a maximum reduction of emitting basic air
pollutants generated during fuel combustion in the process of energy production - by optimising production and transmission efficiency, as well as monitoring of emissions of eg CO$_2$, and by using low- or zero-emission fuels [22, 23].

References

[3] Regulation of the Minister of Environment on admissible levels of some substances in the air, on alarm levels of some substances in the air, and on tolerance margins for admissible levels of some substances, Journal of Laws of 2002, No. 87, item 796 (in Polish).
EKOLOGICZNO-EKONOMICZNE ASPEKTY MODERNIZACJI SYSTEMÓW CIEPŁOWNICZYCH W PÓŁNOCNO-WSCHODNIM REJONIE POLSKI

Wydział Budownictwa i Inżynierii Środowiska, Politechnika Białostocka, Białystok

Abstrakt: Na podstawie opracowań dotyczących modernizacji gospodarki cieplnej w miastach średniej wielkości (od 16 do 65 tysięcy mieszkańców) przeprowadzono analizę techniczno-ekonomiczną oraz ekologiczną możliwych do zrealizowania przedsięwzięć modernizacyjnych. Opracowania audytorskie dotyczyły głównie lokalnych kotłowni niskotemperaturowych (152 kotłownie) z niskimi emitorami w wybranych miastach w północno-wschodnim rejonie Polski. W ramach ww. opracowań wykonano również pomiary zanieczyszczeń powietrza SO$_2$ oraz pyłami. Zasadniczym celem zaproponowanych modernizacji systemów ciepłowniczych było poprawienie bardzo niskich sprawności eksploatacyjnych kotłowni, głównie z niskimi emitorami, a także (a może przede wszystkim) obniżenie zanieczyszczeń powietrza SO$_2$ oraz pyłami. Jednym z kryteriów oceny ekonomicznej zaproponowanych przedsięwzięć (inwestycji) była Aktualna Wartość Netto (NPV), natomiast oceny ekologicznej - redukcja zanieczyszczeń powietrza.

Słowa kluczowe: gospodarka cieplna, redukcja zanieczyszczeń, efektywność ekonomiczna