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DISTRIBUTION OF COMMUNE BUDGET RESOURCES FOR PRO-ENVIRONMENTAL ACTIVITIES IN RURAL HOUSEHOLDS

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Summary. The present study provides a solution to the decision-making task, which involves the distribution of limited budget resources of communes, aimed at supporting the replacement of currently used coal-fired boilers, which ensures desired reduction of pollution of the atmosphere, while minimising the average cost of heating the converted structures. The decision-making task has been solved with the integer linear programming method for a typical agricultural, agricultural and tourist and sub-urban communes in Małopolska Region. It has been found, that the choice of an optimal combination of boilers, in the purchase of which the commune might participate, depends on the funds which can be spent on the donation programme. The communes having considerably limited funds should mainly support the purchase of gas-fired boilers, which might constitute around 50 % of the replaced boilers. The replacement of coal-fired boilers with the biomass-fired ones should be supported to an increasingly higher degree, along with the investment resources increase.

Key words: optimal distribution of funds, optimization of energy consumption, pro-environmental activities

INTRODUCTION

One of the key objectives to be met by the communal self-governments, while planning the supplies of heat, electric energy and gas fuel, is the optimisation of energy consumption, aimed in particular at achieving possibly the slightest adverse environmental impact. Although the owners are free to decide on the type and method of the activities related to optimisation of energy consumption, the communes – through an information campaign and various means of promotion – might have a substantial impact on the activities in this subject area.

As the territorial self-governments are mainly interested in liquidation of obsolete and inefficient coal-fired boilers, the information campaign should present the benefits resulting from the exchange of heat sources, as well as indicate the opportunities of financial support for modernisation activities from the regional environment-protection

funds, or from other units offering donations or preferential credits for replacement of coal-fired boilers with the environment-friendly, natural gas or biomass-fired ones.

The territorial self-government units can also support the building owners with the funds coming from the communal environment-protection funds [Dz. U. Nr 49, 1994, Nr 133, 1997] in the liquidation of obsolete and inefficient coal-fired furnaces, by granting non-returnable donations to replace them. However, the funds available for that sort of activities in the communes are limited, and while distributing them the interest of both, the commune willing to meet its environmental objective, and the individual energy users (whose main concern while selecting the boiler type is the cost of heating), should be taken into account.

The study is aimed at the distribution of budget resources of communes, for the replacement of currently used coal-fired boilers with more environment-friendly ones, so to ensure the desired reduction of pollution of the atmosphere, while minimising the average cost of heating in the converted structures. The task has been solved by means of the integer linear programming method.

CALCULATION METHODS

In order to solve the decision-making task, the following functional has been created:

$$f(x_1, x_2, x_3, x_4) = c_1 \cdot x_1 + c_2 \cdot x_2 + c_3 \cdot x_3 + c_4 \cdot x_4 \rightarrow \min \tag{1}$$

where:

x_1 – the number of old coal-fired boilers converted to modern coal boilers, pcs.,
x_2 – the number of old coal-fired boilers converted to gas-fired boilers, pcs.,
x_3 – the number of old coal-fired boilers converted to wood-fired boilers, pcs.,
x_4 – the number of old coal-fired boilers converted to straw-fired boilers, pcs.,
$c_j = \mathrm{SRKU_j}$ – the change of summarised annual user's cost (fuel cost, maintenance and repairs and investment expenditure in a given year), resulting from the conversion, %,
$j = 1, 2, 3, 4$.

The change of summarised annual user's cost has been obtained from the dependency:

$$SRKU_j = -\left(1 - \frac{\frac{1}{p} NIK_j + RKUK_j}{RKU_j}\right) 100 \tag{2}$$

$$NIK_j = k_j - d_j \tag{3}$$

$$\frac{1}{p} = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{4}$$

where:

NIK_j – investment expenditure on boiler conversion of the j-type, PLN,
k_j – total cost of purchasing the j-type boiler, PLN,
d_j – donation granted by the commune to purchase the boiler of the j-type, PLN,
$RKUK_j$ – annual user's cost after the conversion, PLN,
RKU_j – annual user's cost before the conversion, PLN,
$\frac{1}{p}$ – the write-off factor,
i – discount rate,
n – duration of investment activity (project duration in years).

The amount of investment expenditure on conversion and prices of the energy carriers have been assumed based on the technical and economic catalogue [Danish-Polish project 2002]. 5% discount rate and 20-year period has been assumed [Laudyn 1999].

Limiting conditions

– Limitation related to the reduction of the release of air pollutants assumed by the commune, as a result of the replacement of boilers carried out:

$$ZOE_D \le \varepsilon_1 x_1 + \varepsilon_2 x_2 + \varepsilon_3 x_3 + \varepsilon_4 x_4 \le ZOE_G \tag{5}$$

where:

$ZOE_{D,G}$ – assumed degree of emission reduction within the commune, %,
ε_j – reduction of total release of pollutants on the communal scale, resulting from the conversion of a single coal-fired boiler with a different one, expressed as equivalent release, as compared to the original state, %,
j = 1, 2, 3, 4.

– Limitation related to the amount of funds the commune intends to use for donation:

$$d_1 x_1 + d_2 x_2 + d_3 x_3 + d_4 x_4 = SF \tag{6}$$

where:

d_1 – donation for the purchase of coal-fired boiler, PLN,
d_2 – donation for the purchase of gas-fired boiler, PLN,
d_3 – donation for the purchase of wood-fired boiler, PLN,
d_4 – donation for the purchase of straw-fired boiler, PLN,
SF – total funds the commune is willing to use for donations for the replacement of boilers, PLN.

– Limitation related to the target group the commune intends to cover in the donation programme:

$$x_1 + x_2 + x_3 + x_4 \le GD \tag{7}$$

where:

GD – target group (number of coal-fired boilers' owners declaring the willingness to replace them with modern sources of heat).

– Limitation related to the minimum range of support programme offered by the commune to the target group:

$$x_1 + x_2 + x_3 + x_4 \geq MZ \tag{8}$$

where:

MZ – minimum number of boiler owners covered in the donation programme.

– limitation related to the owners' declarations on the preferences regarding the choice of the heat sources:

$$\begin{aligned} x_1 &\leq DKW \\ x_2 &\leq DKG \\ x_3 &\leq DKD \\ x_4 &\leq DKS \end{aligned} \tag{9}$$

where:

DKW – target group which has expressed the willingness to replace the old coal fired boiler with a new and more efficient one,

DKG – target group which has expressed the willingness to replace the old coal-fired boiler with a modern gas-fired boiler,

DKD – target group which has expressed the willingness to replace the old coal-fired boiler with a wood-fired boiler,

DKS – target group which has expressed the willingness to replace the old coal-fired boiler with a straw-fired boiler.

While determining the target group interested in the conversion of coal-fired boilers into biomass-fired boilers (*SKD* and *DKS*), it has been assumed that the number of such boilers is limited by the amount of energetic biomass resources possible to be acquired in the territory of the commune, in the analysed time interval.

Boundary conditions

$$x_j \geq 0, \qquad x_j = \text{total} \qquad j = 1, 2, 3, 4.$$

CALCULATION RESULTS

The task involving optimum distribution of limited funds of the commune, to support the activities related to the optimisation of energy consumption, so to ensure reduction of the release of air pollutants, has been solved in the case of typical Małopolska rural communes, i.e. the agricultural (Koniusza), agriculture and tourist (Lanckorona) and sub-urban (Kocmyrzów-Luborzyca) communes.

The authorities of the communes are planning to assign the funds of approx. PLN 300 thousand, in the budget for 2006–2010, to be spent on the conversion of coal-fired

boilers. Depending on the local conditions, those funds might be increased by around 25% in Koniusza commune and up to 50% in Lanckorona, respectively. The funds will be used for donations granted to the commune residents willing to replace the old coal-fired boilers with more efficient, gas, wood or straw-fired ones.

The communes are planning the unit donation for conversion of various types of boilers amount to be approx. 40% of the replacement cost. The calculations also assume that, as a result of the undertaken actions, the level of pollutants released should decrease by 5–6% as compared to that of 2005.

The authorities of Lanckorona are planning to cover at least half of the target group in the boiler replacement programme, and in the case of Koniusza and Kocmyrzów-Luborzyca, at least one third would be covered, where the first group to be offered will be the owners of obsolete and worn heating equipment.

In order to determine the target groups in the investigated communes, the preferences of owners while choosing sources of heat have been identified (Tab. 1), and the energetic potential of biomass – especially wood and straw – has been assessed in individual communes (Table 2).

Table 1. The size of target groups in analysed communes

Commune	Koniusza	Lanckorona	Kocmyrzów-Luborzyca
Number of boiler owners	360	290	430

Source: own study

Table 2. Biomass potential in analysed communes

Description	Koniusza	Lanckorona	Kocmyrzów-Luborzyca
Wood, tpu	200	1410	620
Straw*) tpu	1310	190	1330
Total resources, tpu	1510	1600	1950

*) It has been assumed that 25% of straw available in given area can be used for energy-generation purpose [Stelmachowski 2001].

Source: own study

The emissions of individual pollutants in communes have been calculated with the indicative method [Ministerstwo…2003]. The figures of emission indices have been assumed according to the Protection and Shaping of the Environment Act [Dz. U. Nr 49, 1980], and according to the recommendations of the „Ministry of the Environment" [Ministerstwo…2003], pertaining to the assessment of environmental impact.

In order to compare various pollutants in terms of their harshness, another index, so called equivalent emission, has been applied [Butcher and Pierce 1995, Górka and Kowalski 2000].

With the above assumptions and having obtained the unit emission change indices for each commune, as a result of conversion of a single boiler, the function has been obtained for various funds intended for donations. Solver plug-in, integrated in Microsoft Excel, using the simplex method, has been applied to generate the solutions. Results of the calculations are presented in Figures 1–6.

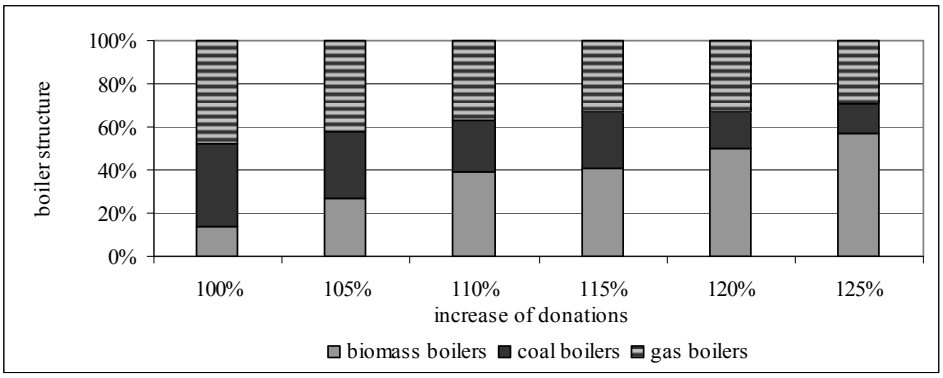

Fig. 1. Optimum structure of boilers in Koniusza commune, depending on the donation.
Source: own study

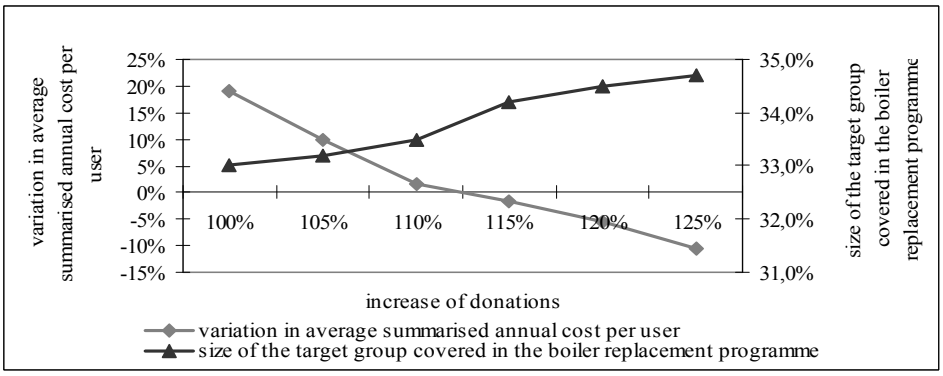

Fig. 2. Optimum distribution of funds in Koniusza commune, depending on the donation.
Source: own study

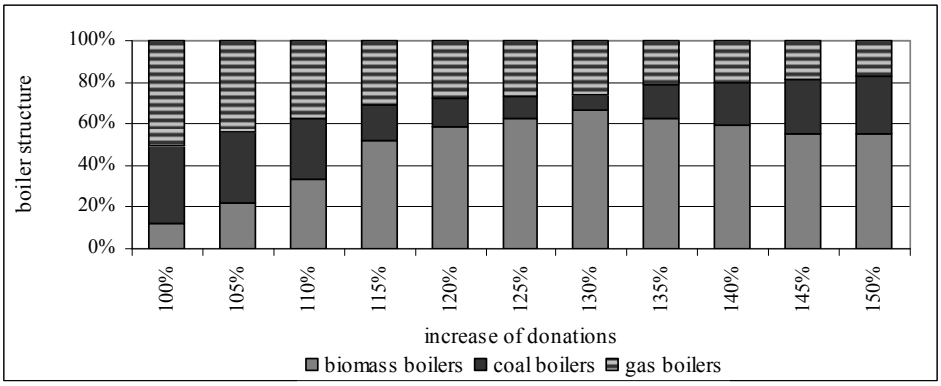

Fig. 3. Optimum structure of boilers in Lanckorona commune, depending on the donation
Source: own study

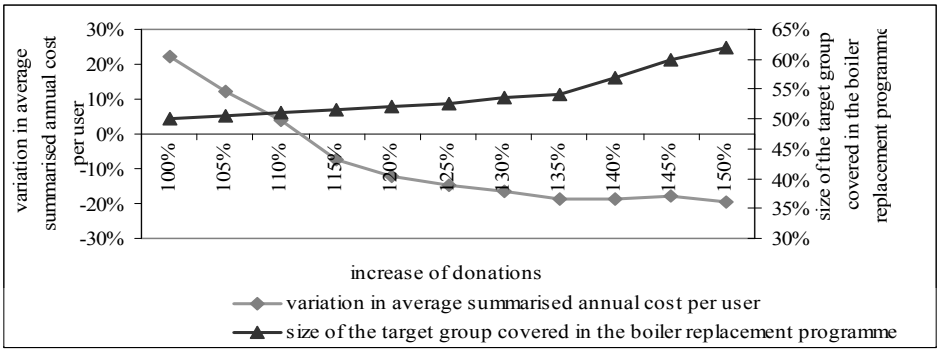

Fig. 4. Optimum distribution of funds in Lanckorona commune, depending on the donation.
Source: own study

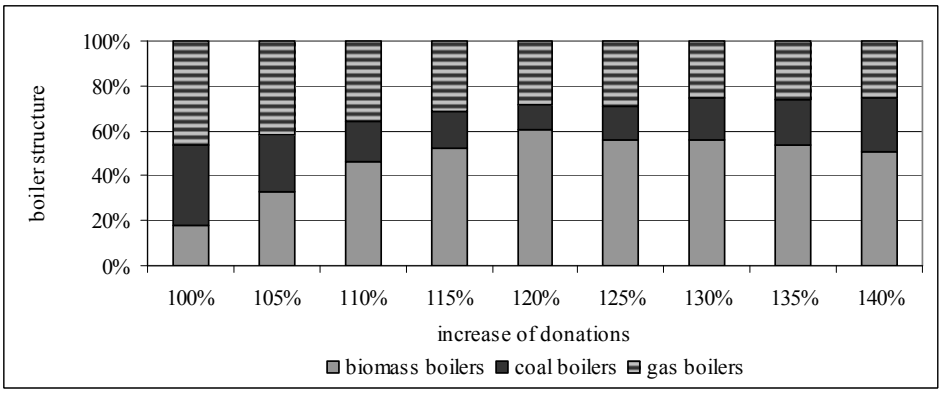

Fig. 5. Optimum structure of boilers in Kocmyrzów-Luborzyca commune, depending on the donation.
Source: own study

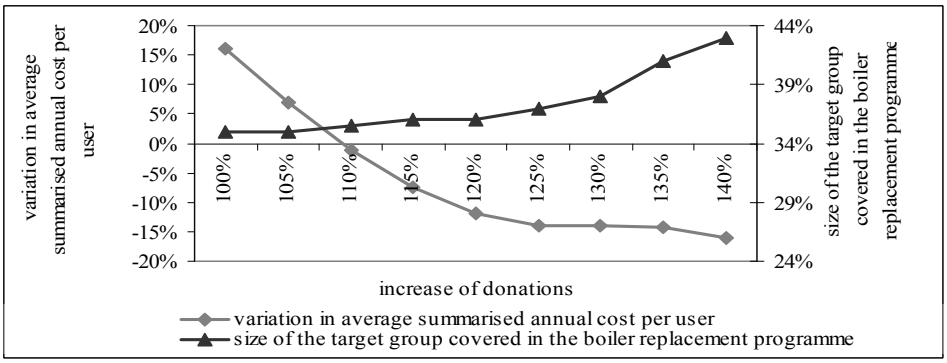

Fig. 6. Optimum distribution of funds in Kocmyrzów-Luborzyca commune, depending on the donation.
Source: own study

CONCLUSIONS

The communes having considerably limited funds available for air pollution minimising activities, aiming at meeting their environmental objectives, should use them mainly to donate the purchase of gas-fired boilers, which may pose approx. 50% of the boilers replaced. The donation programme in this case might cover only a small number of biomass-fired boilers (around 10–15% of replaced boilers), which have the lowest operating cost, on the other hand, they involve the highest investment expenditure.

The replacement of coal-fired boilers with the biomass-fired ones should be supported to an increasingly higher degree, along with the investment resources increase. It has also been found that a relatively small increase of funds intended for the reduction of air pollution, sustaining the optimum structure of boilers for the assumed air pollution structure, can lead to the reduction of the average energy cost by even 20%.

Using the linear integer programming, as detailed in the present study, can enhance the decision-making process in the domain of the optimum distribution of limited funds on air protection.

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