Economic, environmental and social aspects of renewable energy using for small sources of heating

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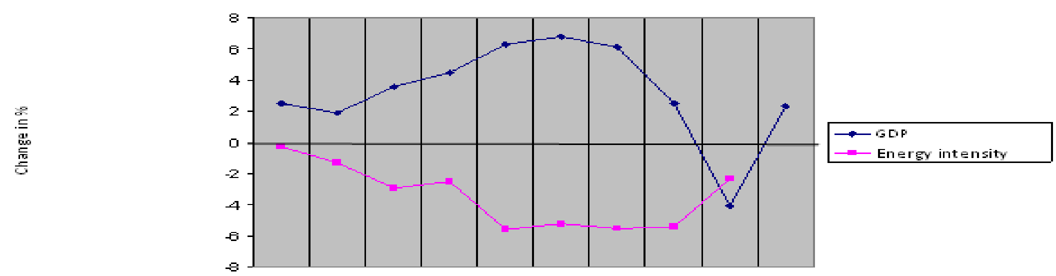
Abstract: Decisions on the selection and promotion of various energy scenarios in the region is not just a matter of economic considerations.The situation concerning use of renewable resources in the EU and the Czech Republic is discussed, focusing on the use of biomass. Alternative resources can contribute very significantly to energy independence and financial advantages for a region. The Vysočina region in the Czech Republic, where the option of expanded assessment is illustrated, was selected for a case study. The suitability of energy sources is assessed from the economic aspect and also environmental and social aspects. As possible variants were chosen natural gas, coal and biomass. These were further evaluated using one of the multi-criteria methods techniques. Use of biomass is a very promising area, which provides opportunities and also specific risks with regard to further development.

Key - Words: sustainable development, energy intensity, renewable energy, household heating, biomass, decision method, multi-criteria methods, energy self-sufficiency

1 Introduction

Energy sources are a key factor for the development of the economy. The creation of gross domestic product is connected to all activities by economic subjects; on the other hand however, these activities are sources of environmental burden. Energy intensity is expressed by the ratio of consumption of primary energy sources to gross domestic product and is one of the most important indicator of economic performance.

Primary energy sources include domestic mined fuels, hydro and wind power, nuclear heat, the balance of imports and exports and changes to stocks of fuel and energy, and are expressed in energy units (in GJ). The GDP at constant prices for 2000 is used for calculation purposes. Fig. 1 shows the inter–annual changes to selected indicators expressed as a percentage. The marked fall in GDP in 2009 was the result of the economic crisis. Position of the Czech Republic in Europe illustrates Fig. 2.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GDP	2,5	1,9	3,6	4,5	6,3	6,8	6,1	2,5	-4,1	2,3
Energy intensity	-0,3	-1,3	-2,9	-2,5	-5,6	-5,2	-5,5	-5,4	-2,3	

Years

Fig. 1 Changes of GDP and energy intensity in years 2001-2010 [%] *Source:* [6,4]

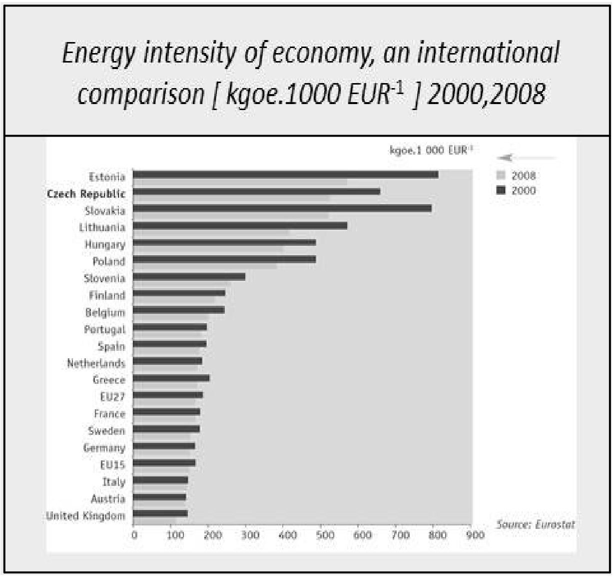


Fig.2 Energy intensity of economy, an international comparison *Source:* [15]

These changes create pressure on advancement in the structure of energy generation and consumption on all levels. The endeavour to increase the proportion of renewable energy plays an important role here [8,9]. This can be noted in many strategic documents and legislative measures [2,11,12], for instance Directive 2009/28/EC on the promotion of the use of energy from renewable resources, which discusses the individual goals of member states and achievement of target values in 2020 with regard to the member states' various starting positions.

With regard to the generation and consumption of electrical energy, prognoses of consumption of electrical energy in the Czech Republic assume that a significant volume must be covered using renewable resources [11,12].

2 Description of the problem

Electricity generation plants using renewable energy resources generated a total of 5854.5 MWh of electricity in 2010 [4,6]. The greater part is still made up of electricity generated by hydroelectric plants; however, this proportion fell to less than half the volume generated from renewable resources for the first time in history, in spite of the fact that, in absolute numbers, the volume of electricity generated by hydroelectric plants rose significantly in comparison to 2009.

The impact of current climactic conditions is apparent with regard to hydroelectric plants; in the case of photovoltaic power stations this is the main reason for a significant increase in installed capacity during 2009 and 2010. Most of the new photovoltaic power stations were connected to the grid during the last months of 2010, and consequently their generation volume is insignificant in the results for 2010.

Likewise, the relative proportion of electricity generated using biogas also increased. On the other hand there was a fall in the proportion of electricity generated by wind-powered power stations and generated from biomass, in spite of the fact that in absolute values electricity generation using all RES increased. In the future, use of biomass will be preferred in the heating industry and its proportion in electricity generation will fall. The current national Action Plan for renewable energy resources counts on the existing situation continuing. Generation of electricity using RES could be significantly higher in 2010, if development of wind-powered power plants continues according to the original forecasts of the Ministry of Industry and Commerce [4,6,12].

Opinions on use of alternative resources differ and change along with the implementation of technologies that enable more efficient use. The potential offered by individual types of alternative resources is not fully utilised.

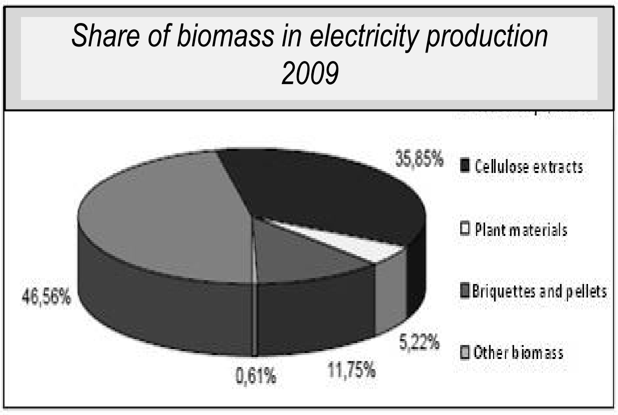


Fig.3 Share of biomass in electricity production *Source:* [6]

Under the conditions in the Czech Republic, biomass has the greatest technically utilisable potential of all the renewable resources for the generation of electricity (Fig.3) and heat. The use of biomass is traditional, particularly in the field of heat generation. Electricity generated from biomass has no problems concerning stability of supplies. There are limits chiefly in relation to accessibility, as growing biomass is only effective within a specific radius of the proposed site of use. Plant biomass is further limited by so-called food safety.

At present 55% of the energy generated is supplied to the grid; the remainder is used for private consumption. The proportion of biomass in green electricity achieved 30% in the Czech Republic. Fig. 4 and 5 complement the current situation in the use of different heating options for small sources.

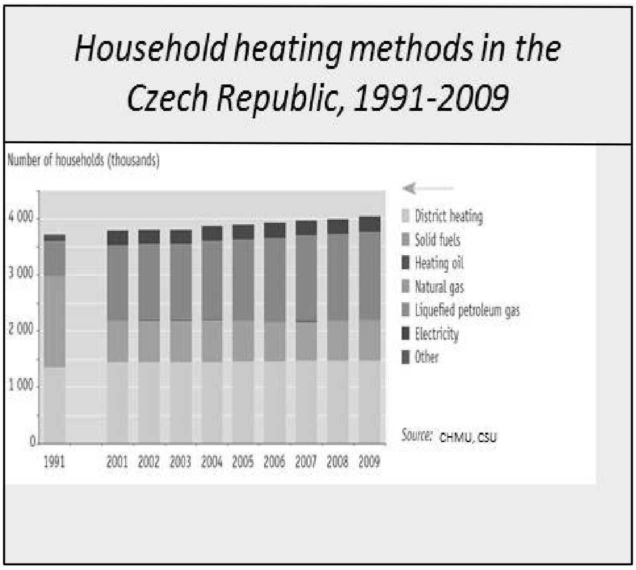


Fig.4 Household heating methods in the Czech Rep.
Source: [6,12]

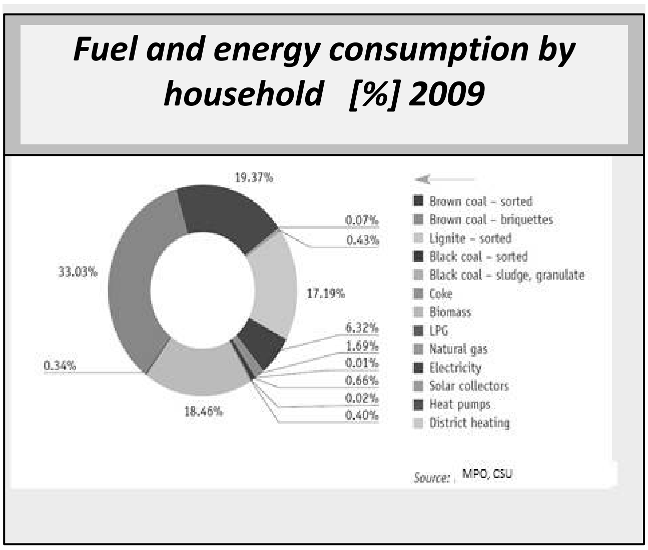


Fig.5 Fuel and energy consumption by household
Source: [6,12]

Technical solutions, laws and concepts for use and also good quality methodological procedures for assessing the efficiency of individual energy resources must be prepared for their extensive use.

Our contribution is devoted to the last condition, and presents one of the examples of how to assess the potential for using alternative resources and use the results to support decisions on energy policy within the region. Regions and municipalities have a range of powers that can be used to affect selection of which energy source is used. Alternative resources can contribute very significantly to energy independence and financial advantages for the region and the municipality. The decision must also include communication with the residents, which should be assisted by the methodology for assessing the efficiency of the specific method of obtaining energy.

The fact that one advantage of using alternative resources is also job creation. One significant advantage is also the reduction of dependence on imports and the use of agricultural production – biomass production and processing is a welcome business opportunity for farmers.

Green energy has extensive support in strategic plans, legislation and in the field of finance. By law each application has prerequisites, which it must be based on. However, in our opinion, this viewpoint pointedly emphasises the economic advantages of the project; the social and environmental advantages, which usually cannot be expressed financially, are not assessed. In our contribution we endeavour to show one of the possibilities of integrating all three pillars of sustainable development into the resulting assessment.

3 Case study of assessment of the use of renewable energy resources in the Vysočina region

3.1 Conceptual approaches to development solutions in the Vysočina region

Promotion of the use of renewable resources for obtaining energy is apparent in a number of policy materials, of which the most important from this aspect is the Programme for the Development of the Vysočina Region [7]. Key goals are determined, which include development of the production of renewable energy. The issue of assuring energy demands is a standard component of development plans for municipalities and micro-regions.

Forecasts are based on general energy plans or studies of energy self-sufficiency.

This also includes assessment of the possibilities of use of renewable resources and potential savings in energy in municipalities, estimates of future requirements and proposals of alternative solutions.

For a number of municipalities, preparing an expert evaluation is financially unfeasible.The most frequently used renewable resource in the Czech Republic is biomass; in the Vysočina region a number of projects of this type have been realised in recent years or are in the preparation phase [7].

This field is realised by means of various programmes. The following criteria in particular are issued for project assessment:

- Project compliance with the Programme for Development and other policy materials
- The project's compliance with declared grant programmes
- Readiness and feasibility of the project
- Provable use of the provided funds for the benefit of the region's development
- Feasible and transparent budget costs
- Credibility of the submitter and its ability to co–finance and realise the action.

The following specific criteria were declared:

- the impact of the project on increased use of renewable energy resources within the region (real impact on the number of residents using this type of energy within municipalities, increase in installed capacity of enterprises or buildings) and
- the value of the submitter's financial share.

The use of renewable energy resources fundamentally depends on specific local conditions. The decision on whether to invest in renewable resources must be preceded by thorough knowledge of the local geographic, climatic, environmental, economic and social context. Long-term monitoring of the locality is frequently necessary.

For assessment of the possibilities in the Vysočina region, known types of renewable energy resources were analysed and the weak and strong points of the opportunity were assessed [3,7], of which the following were selected regarding use of biomass to supply energy:

Arguments for biomass:

Significant biomass potential in the Vysočina region, controlled production of biomass contributes towards formation of the landscape and its care, less impact on the environment than during use of fossil fuels, a renewable resource, which can be produced at the site of consumption and does not burden a larger region with its transport, use of waste biomass contributes to the solution of the waste issue, tax advantages for producers of bio-fuels.

Arguments against biomass:

It is not a completely clean source of power, such as solar or wind power, the production and transport of biomass partially burdens the environment, biomass production requires an extensive area and significant capital investment in production, greater requirements are placed on storage areas, necessity to dispose of ash and fairly complicated manipulation of fuel.

Within the terms of increasing the proportion of renewable resources in energy consumption, the Vysočina region has the greatest potential for production of wood (a large proportion of forested area) and cultivating energy crops. With regard to the fact that forest and wood chips are beginning to be in short supply, cultivating energy crops, which can subsequently be modified by pressing or fermentation for example, seems to be the most promising solution. The most advantageous for this region seems to be growing the Uteusch energy crop – Uteusch Sorrel (Rumex patientia L. x Rumex tianschanicus A.Los.) is a very promising, highly productive energy crop for growing in moderate climatic conditions, it can be grown on the same site for up to 10 years, it achieves high yields per hectare, has zero durance – it does not germinate in subsequent years if ploughed into the soil, and it achieves a calorific value of 18 $MJ.kg^{-1}$. This crop can be used for biogas production and also for manufacturing pellets and briquettes.

3.2 Comparison of traditional and alternative sources of energy

Heating using pellets made from biomass, as one of the best options for the selected region, was used in the comparison of options for alternative sources of energy [3].

3.2.1 Assessment of resource utilisation

The economic assessment is either in the form of a calculation of the economic efficiency for commercial decision – making, or is made from the aspect of the consumer, i.e. this will concern only economic considerations of the return rate of invested funds, the method of financing, taxation of profits, including discounts and consideration of the possible risks, particularly those arising from the uncertainty of the economic environment.

For deciding in these cases it can be relative comparison and evaluation of options (selecting preferred option from two and more applicable options) or absolute evaluation (decision whether to accept or decline individual investment plan), possibly also simultaneous models (decision about a whole investment programme and in its consequences on the whole situation in a region).

The criteria for absolute evaluation or for selection from a certain number of options are minimal cost, maximal efficiency or combination of both. There are currently many methods for investment efficiency evaluation. Each of them is a kind of lead for further analysis and decision making, however, none of them can be used as generally applicable.

It is often very difficult with environmental and social effects to define these in a single economic criterion, such as net profit for production investments. The reason behind is impossibility to make equal appreciation of all kinds of consequences.

There is a whole range of approaches targeted at purely economic evaluation of scenarios. The most important for decision making are: profitability (relation between profit, which the investment or measure brings during the time of its existence and expenditure for acquisition and operations), risk (rate of danger that expected profit will not be reached) and time of investment return (speed of transition back to money). The process of investment evaluation includes:

- Estimation of one-time expenditures for the investment
- Estimation of future profit and risks
- Calculation of capital expenditure of the company
- Calculation of present value of future profits.

Returnability of investment is influenced by many factors which are often not included in the standard calculations of returnability and efficiency. Thus, cash flow is significantly shifted and the result influenced. The sensitivity analysis can provide data such as huge impact of energy prices growth on the discounted period of returnability. The main external factors are:

- Growth of energy prices (one of most significant factors influencing investment returnability)
- Growth of prices of implemented measures
- Improvement of technical characteristics of the product
- Interest rates
- Discount rate
- Investment incentive
- User's behavior.

Commonly used methods of economic evaluation include: comparative calculation of cost, yield and profit – cost methods and comparison based on yield and profitability (e.g. Return On Investment), statistical methods such as Payback Period and method of investment profitability, dynamic methods such as Discounted Payback Period, Net Present Value, Internal Rate Of Return, Profitability Index. Simultaneous methods of investment programs serve for decision making about a portfolio of investment opportunities. Each of these methods may return different results[18, 14].

These purely economic considerations must also be expanded by the aspect of long–term sustainability, i.e. reflection of the impact of the use of this source of energy on the environment and on the social sphere. Integration of these contexts into the decision–making process is not simple, because in many cases this concerns impacts that cannot be assessed financially.

A simple situation, which arises from decisions concerning selection of the most effective method of heating using a small source, i.e. a situation in which the heating period most significantly influences the quality of the air in the region, was selected.

The analysis is based on comparison of parameters of individual options for heating a family house. The results are summarised in Tab. 1.

Table 1 Characteristics of fuels and heating equipment

Fuel	**Characteristics**	**Equipment**	**Output**	**Efficiency**
Coal	Brown, nut, sorted	Boiler with movable grate	20kWh	55 %
Natural gas	Natural gas	Normal gas boiler	26kWh	89 %
Plant pellets	Pellets 6 mm in diameter	Boiler using plant pellets	25kWh	85 %

Source: [5]

Fuel consumption for the production of the same amount of heat that was produced by classic heating methods was also calculated. The amount of consumed fuel was multiplied by the price and the secondary costs related to individual types of heating were calculated. The result is drawn up in Tab. 2.

Table 2 Annual heating costs (aver.)

Fuel	**Annual consumption**	**Unit price**	**Annual costs for fuel EUR**	**Other costs EUR**	**Annual costs for equipment EUR**	**Total costs EUR**
Brown coal	6, 57 t	116 EUR.t-^{1}	762	30	46	838
Natural gas	2 145 m^{3}	0.5 EUR.m-^{3}	1072	118	73	1263
Plant pellets	5, 67 t	146 EUR.t^{-1}	828	7	50	885

Source: [*own,* 5,13,17]

The economic assessment, after efficiency calculation, shows that the best alternative for heating is brown coal with the lowest costs overall. In cases such as seeking alternative resources other criteria, which characterise sustainability of energy use from the long–term aspect, should also play an important role.

Furthermore impact from the aspect of LCA holistic assessment should also be included. Only some of the factors can be converted into monetary units and so only some are included in the cost benefit analysis. [1,3].

3.2.2 Use of the multi-criteria assessment method

Multi-criteria decision making occurs where the decision maker evaluates consequences of his/her decision by multiple criteria; those can be quantitative which are defined in standard scales or qualitative where suitable scale has to be defined together with direction of evaluation, i.e. whether maximal or minimal value is optimal (decreasing or increasing values). The multi-criteria decision making methods solve the conflicts between opposing criteria. These methods aim at summarizing and sorting information about variant projects. According to the criteria nature they can be maximizing or minimizing.

The multi-criteria decision making models visualize decision-making problems where consequences of a decision are evaluated with multiple criteria. Involving more criteria in evaluation brings about difficulties which come from general conflicts of criteria. If all criteria pointed at the same solution, only one of them would be sufficient to select the optimal decision. The aim of the models in these situations is either finding the “best” option according to all viewpoints or eliminating inefficient options and sorting the set of options.

Similarly as in the case of economic evaluation, there are more methods and processes of analysis of options in multi-criteria evaluation. These methods include:

- *Utility function method*

The main principle of this method is solution of the multi-criteria optimization by transferring it to mono-criteria where the utility function is maximized: $\max_{x \in S} U(x)$

$$U(x) = w_1 \cdot f_1(x) + w_2 \cdot f_2(x) + \ldots + w_p \cdot f_p(x) \quad (1)$$

The utility function method derives from the assumption that decision-making subject can assign to each p-tuple of numbers

$f = (f_1(x), f_2(x), \ldots, f_p(x))$,

where x is an element of the set of acceptable solutions, a real number – utility of acceptable solution (option) x, that is number $U'(f_1(x), f_2(x), \ldots, f_p(x))$

Function U is often applied in the form of weighted function,

where $w_i \ldots$ non-negative weights of criterial functions f_i,

where $w_1 + w_2 + \ldots + w_p = 1$.

Criterial functions f_i are supposed to be created by below described method of norming from the original (not normed) criteria functions F_i :

$$f_i(x) = \frac{(F_i(x) - F_{i\min})}{(F_{i\max} - F_{i\min})} \quad (2)$$

where

$F_{i\min}$ or $F_{i\max} \ldots$ minimal or maximal value of i-th criteria function in the set of acceptable solutions S.

- *Indicator TIEQ*

Method Total Indication of Environmental Quality is a modification of the Utility Function Method which represents formalized working process for quantitative evaluation of development plan or “hard” project of a certain type. This allows providing number score and hierarchy of evaluated scenarios (variants). This method is an auxiliary tool for the DSS (Decision Support Systems) on current level of knowledge for a standard task of multi-criteria analysis with the aim to determine the best option for given set of criteria.

- *Synthetic indicator*

This is simplified method of the previous utility function method while criteria function f_i is replaced with transformed value of criterion b_i. The process of calculation of synthetic indicator of a variant is shown in the following Fig.6.

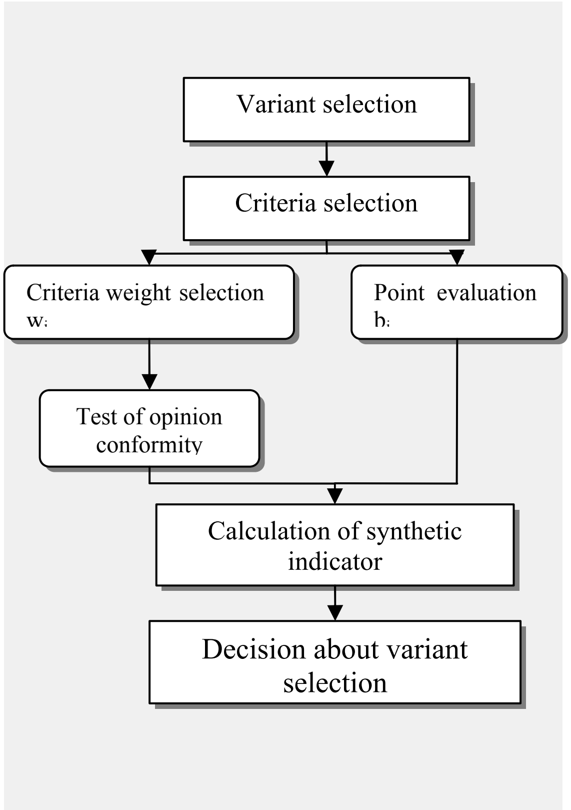


Fig.6 Calculation of synthetic indicator

In the file of selected criteria, all criteria do not have the same relative meaning in the relation to the concrete evaluated intention. This relative, commonly proportional meaning (importance) is shortly marked as criterion weight w_i. In specific cases all criteria may have the same weight, however, usually it is necessary to define weights based on real options and descriptions of criteria indicators.

For weight definition there are many options which include:

- Aspiration levels: the user inserts values which should be at least reached by the option evaluated according to individual criteria. Acceptable option is such an option which reaches aspiration level (e.g. method of given criteria levels)

- Ordinal information about criteria: ordering of criteria according to importance levels (e.g. Fuller's Triangle, order method)

- Cardinal information about criteria: these suppose weight construction which we assign to each criterion (e.g. Saaty's matrix, Mesfessel's pointing method) [10,19].

For the particular problem it is also possible to utilize fuzzy multi-criteria methods, especially methods based on language variable. Fuzzy Set and Verbal Verdict Method is worth mentioning [16,19, 20,21].

This method belongs to the fuzzy type and is based on the fuzzy set theory. It can be applied in various modifications, with direct input of priorities or as a scale in auxiliary points, instead of verbal-numeric scale in relative units, that is together with the TIEQ method (possibility to utilize axiomatic theory of cardinal utility).

Although the calculated values of synthetic indicators include weighted influence of individual variables and, therefore, should have greater information value than separate partial indicators, it is necessary to interpret them carefully. The final value of the synthetic indicator strongly depends on the range of indicator selection and on their information value, i.e. their ability to quantify the state and development in the problematic field.

The following criteria were used for further analysis of 3 variants of fuels:

x_1 - *emissions of pollutants into the air*

x_2 - *balance of* CO_2

x_3 - *origin of solid waste (ash, cinders)*

x_4 - *the consumer's comfort during operation of the heating*

x_5 - *fuel availability*

x_6 - *storage demands*

x_7 - *fuel handling*

x_8 - *efficiency of equipment*

x_9- *impacts of harmful substances on the population*

From the aspect of environmental impact it was initially necessary to calculate the estimated emissions (emission factors for burning fuel and the types of incineration equipment used were used) [11,17]. Subsequently a multi–criteria assessment was performed by calculation of synthetic indicators for 3 variants of individual heating types.

The resulting synthetic indicator (U_j) for individual heating scenarios was obtained as a sum of products of the transformed parameters values (b_j) and weights (w_j).

For variant j:

$$U_j = \sum_{j=1}^{n} b_j \cdot w_j \qquad (3)$$

where b_j is transformed value of criteria x_j and w_j is weight of criterium x_j .

The linear transformations function for transformation and the paired comparison technique for parameters weights was used.

The results are given in Tab. 3.

Table 3: Synthetic indicator of the impact of heating variants

Alternatives	**Synthetic indicator U_j**
Brown coal	7,9
Natural gas	47,6
Pellets	24,9

Source: own

4 Conclusion

During selection of alternatives for generating energy it is not possible to proceed only according to purely economic criteria and analyses must be supplemented by additional non-economic criteria. A multi–criteria assessment can successfully be used as a supplementary method to enable an increase in the exactness of decision-making.

Decision-making with implementation of a limited number of supplementary criteria, which can naturally be expanded, was used as a simple example. In our case it was clear that the worst alternative for the future, from economic point of view, is using gas heating (our 3 scenarios only).

From the aspect of some indicators of sustainable development the alternative of coal came out the worst.The inclusion of multiple factors is necessary as important changes occur and, if data avalaible, to use LCA philosophy. In spite of the interesting result we must point out that even multi–criteria methods remain a supporting means during decision-making; it is necessary to eliminate their susceptibility to a subjective viewpoint.

Efficiency is, therefore, a multidimensional concept, it has various interpretations, the ratio of outputs and inputs can be expressed in different ways according to the purpose. It is possible to express it with financial terms, financial efficiency determine if and for how long the activities can be sustainable in the economic meaning. For the needs of eco-efficiency it is necessary to broaden the conception. The indicated method of multi-criteria evaluation can fulfill this requirement within the limits which have been discussed. Still, the scenarios are evaluated only from a narrow viewpoint of discussed impacts. It is therefore necessary to propose holistic approach of Life Cycle Assessment, the same way as this is being proposed for situations of enterprise impact on the environment.

Acknowledgements:

Financial support of this work was provided by the project of Ministry of Environment of the Czech Republic No. SP/4i2/60/07.

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