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Definition of indicators for decision-making to contribute to sustainable development through Cleaner Production and Resource Efficiency by using the AHP method

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Rapid growth within the industry sector creates an array of novel issues that have to be dealt with. Major problems as a consequence of continuous and quick development of industry are as follows: the need for high energy consumption (be it electric or thermal), the increase in the level of environmental pollution, and the treatment of waste.

Countries in transition, characterized by "an industry in the making", need to seriously consider the above-mentioned issues. The industry should be subject to professional analysis (the application of resource efficiency and cleaner production) in order to achieve an adequate use of resources. Furthermore, as a result of increased resource efficiency, the industry sector and enterprises will benefit. Greater effectiveness will undoubtedly encourage the use of cleaner production and the launch of the Resource Efficiency and Cleaner Production (RECP) application in the developing countries (such as the Kosovo case).

This research focused on the promotion of sustainable development based on RECP in Kosovo. Based on RECP, analysis has been conducted with the help of the method of Multi-Criteria Decision-Making – Analytic Hierarchy Process for all levels of decision-making. The process is based on four main pillars of sustainable development: environmental, technical, economic, and social.

Through RECP, there have been identified specific areas in need of improvement in order to achieve the level within the allowed norms of rational energy consumption, minimize environmental pollution and waste, and maximize the profits of the industry sector (enterprises), which, in turn, can lead to the creation of more jobs.

Keywords: Resource Efficiency and Cleaner Production (RECP), industry, energy, AHP method

INTRODUCTION

Sustainable development, which is grounded on resource efficiency and cleaner production, fashions a clear and safe path for countries in the region to achieve their objectives and overcome common challenges. Most countries in the Western Balkan Region face similar issues and, thus, a thorough analysis may bring out a solution that may be applied for all.

In the current era of sustainable development, energy planning has become complex due to the involvement of multiple benchmarks, such as technical, social, economic and environmental [1].

Cleaner production is a fast-growing area with numerous important developments seen over the years, which have led to substantial improvements both in technological process and organization terms [2].

The players of industry, starting from power plants to the aforementioned sectors (in Kosovo's case), are large consumers of energy, environmental polluters, and waste producers of different scales. Energy is a means of economic development by raising living standards and reducing poverty [3]. Undoubtedly, the sustainable development of the industry is unimaginable due to the lack of energy.

Given the factual situation, we have analysed the possibility of applying Resource Efficiency and Cleaner Production (RECP) in Kosovo as the only country that has not considered it as a possible solution.

INDICATORS ASSESSED IN THE DECISION-MAKING ANALYSIS

Undoubtedly, sustainable development is closely related to environmental conservation. The environmental dimension of sustainable development has to do with the idea that all requirements that we have towards the environment can be met without harming the possibilities of others, yet improving the situation for future generations. We have come to a point where we can clearly perceive the effects of environmental degradation and the threat the life on earth is exposed to. In order to define the key indicators for sustainable development, we have considered indicators as in Table 1.

In addition to the three dimensions that RECP considers (environmental, economic and social), we have incorporated the technical dimension, with the aim of defining the main indicators for the Republic of Kosovo.

The analysis of the technical dimension, although not included in the RECP method, examines the main pillars that enable sustainable development in the technical aspect. The analysed indicators evaluate the potential for sustainable energy supply and the type of energy that offers energetic stability for the Republic of Kosovo. Energy supply and its efficient use in production are key to ensuring the healthy functioning of the world economies. Based on that, to ensure sustainability, the supply and use of energy have to apply the principle of minimizing negative environmental impacts and even improving the environment through net-regenerative development [4].

We have also listed other indicators that have an impact on the technical aspect and technical possibilities to achieve the sustainability objectives in this dimension, as in Table 1.

The economic dimension remains the most strategic dimension of sustainable development.

Economic growth and the development of global markets have been coupled with energy use, which have caused an increase in global energy demand and created pressure on the supply of energy resources [5].

Apart from Economic Growth as one of the key indicators in the economic dimension the analysis carried out through the RECP method requires the definition of the most important indicators such as Internal Rate of Return (IRR), Investment Cost (Euro/MW), Operational Cost, and Environmental Cost (externalities).

Through indicator ranking and value assignment using the Analytic Hierarchy Process (AHP), we have managed to "generate the trajectory" to be followed that ensures sustainable development in the economic dimension, particularly in the case of the Republic of Kosovo which is currently in an unfavourable stage (or even the most critical stages of its development).

Surprisingly, social sustainability has attracted less attention in comparison to environmental, economic or technical sustainability. In the pragmatic aspect, social dimension plays the major

Table 1. **Analysed indicators of all levels of the hierarchy of the problem**

Group	Indicators
Environmental	Resource efficiency CO_2 emission tons of carbon dioxide equivalent (tCO_2e) Waste treatment PM emission PM10 – PM2.5 Contamination of soil (km^2) Landscape changes Energy efficiency (%) Efficiency of materials (%) Number of landfills and Number of wastewater treatment plants Number of contaminants m^2 area/MW installed capacity for different technologies
Technical	Securing Clean Energy Security of supply (hours and number of electricity supply interruptions) Availability of energy (MW) Availability of know-how Combined heat and power plants (MW) The use of natural gas (BTU) The use of biomass (MW) The use of wind power (MW) The use of hydropower (MW) Geothermal energy use (MW) Import dependency of energy commodities (%) Geo-political issues Natural disasters Primary domestic energy reserves (MW) Stochastic nature (availability of wind – hours/year) Foreign direct investments (% of GNI) Number of educated engineers (number/100,000) Number of foreign companies (% share in total) Number of educated skilled technicians (number/100,000)
Economic	Internal Rate of Return (IRR) Decreasing energy poverty (% of household incomes for energy bills) Economic Growth (%) Investment Cost (Euro/MW) Operational Cost (Euro/MW) Environmental Cost (externalities)
Social	Safety and Health Good Governance Quality of Life Air Quality (average level of PM) Number of deaths due to air pollution Voice and Accountability (VA) Political Stability and Absence of Violence (PV) Government Effectiveness (GE) and Regulatory Quality (RQ) Rule of Law (RL) Control of Corruption (CC) GDP per capita Human Development Index (HDI)

role in implementing the measures that must be taken to achieve tangible results in function of environmental, economic, or technical sustainability. To understand the level of social sustainability we have addressed these indicators: Safety and Health, Good Governance, Quality of Life, Air Quality (average level of PM), number of deaths due to air pollution, Voice and Accountability (VA), Political Stability and Absence of Violence (PV), Government Effectiveness (GE), Regulatory Quality (RQ), Rule of Law (RL), Control of Corruption (CC), GDP per capita, and Human Development Index (HDI).

The AHP developed by Thomas L. Saaty [6] is one of the most commonly used methods of multi-criteria analysis. This method considers the decision-making process to be a hierarchical process with multiple levels. At the top of the hierarchy stands the goal, whereas the lowest level consists of the possible alternatives or options, and at the intermediate level are the sub-criteria discussed below.

DECISION-MAKING PROCESS

The AHP was developed first by Saaty. AHP is a method for solving complicated and unstructured problems that may have interactions and correlations among different objectives and goals. It is one of the most popular methods of MCDM and has many advantages as well as disadvantages. One of its advantages is its ease of use [7–8]. Multi-criteria decision-making (MCDM) methods are becoming increasingly popular in solving energy selection problems because these problems involve multiple and often conflicting criteria [9].

The process of applying the AHP method has four phases [10].

The first phase contains the disintegration of the problem of decision-making in a series of hierarchical levels, where each one of them represents a smaller number of controllable attributes. AHP is based on mutual comparison of elements in a given hierarchical level relative to the elements of a higher level. As such, if we closely observe the general case of hierarchy with three levels (goal – criteria – alternatives) (Fig. 1), the criteria are compared relative to the goal, in order to determine their joint importance, and alternatives to each of the set criteria.

The data collection phase, on the other hand, is the second phase of the AHP method containing: data collection and (their) measurement.

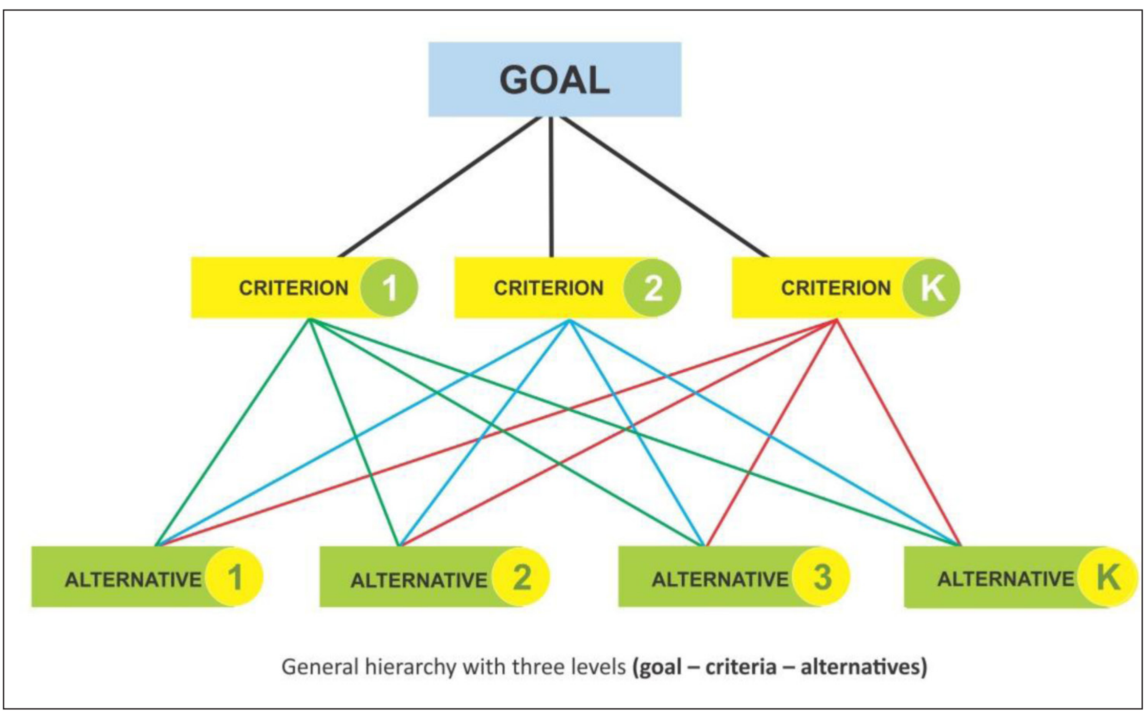

Fig. 1. General hierarchy with three levels (goal – criteria – alternatives) [1]

The procedure follows certain steps, including: assigning a relative assessment in pairs with attributes of a hierarchical level, for given attributes of the first and higher hierarchical level; repeating the process for all levels of the hierarchy. To assign weight, Saaty's "nine-point" scale is used, as shown in Table 2 [13].

Table 2. **Saaty's 9-point scale of pair-wise comparison**

Scale	Compare factor of *i* and *j*
1	Equally important
3	Weakly important
5	Strongly important
7	Very strongly important
9	Extremely important
2, 4, 6, 8	Intermediate value between adjacent scales

The most crucial phase of the AHP method is to estimate the relative weight. Based on matrix A with elements a_{ij}, the priorities of criteria, sub-criteria and alternatives are determined [10]. After the weight is determined, their credibility should also be established. Such a process is completed by determining the consistency of matrix A.

The characteristics of matrix A:

$$a_{ij} = 1;\ a_{ij} = 1/a_{ij} \text{ for } i, j = 1,...,n;\ \det A \neq 0. \quad (1)$$

Determining the weights can be solved as a problem of solving a matrix equation with matrix columns w solution for eigenvalues λ different from 0, i.e. [10]

$$A \cdot w = \lambda \cdot w, \text{ or}$$

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{bmatrix} = \begin{bmatrix} \lambda_1 w_1 \\ \lambda_2 w_2 \\ \cdots \\ \lambda_n w_n \end{bmatrix}. \quad (2)$$

Priority vectors (w) from the pair-wise comparison matrix A can be obtained by solving an eigenvalue problem with the relation [13]:

$$Aw = \lambda_{max} \cdot w, \quad (3)$$

where λ_{max} is the maximum eigenvalue of A [13].

The consistency of assessment, or the index of consistency is calculated as [14]

$$CI = (\lambda_{max} - n)/(n-1). \quad (4)$$

Based on this index we determine the index of inconsistency [14]:

$$CR = CI/R, \quad (5)$$

where RI is Random Index (Table 3).

Table 3. **Random index**

N	Random Index
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

The value of $CR \leq 0.10$ shows that the estimates for a and j are consistent. In case they are not, the evaluation should be repeated.

The methodology is convenient for breaking down a complex, unstructured situation into its component parts, then arranging these parts into a hierarchical order (criteria, sub-criteria, indicators) and assigning numerical values from 1 to 9 to subjective judgments on the relative importance of each criterion/indicator using pair-wise comparison. Saaty suggests that hierarchies are to be limited to six levels and nine items per level. This is based on the psychological result that people can consider 7±2 items simultaneously [11].

Solving/addressing the math problem of MCDM may be required. Further details are thoroughly elaborated by Saaty [12]. The decision (or the goal achievement) matrix, MxN X, aggregates the complete problem-related information and forms the foundation for the problem solution. In the so defined decision matrix we consider that the subjective mapping of the attributes' set (X) onto the criteria set (S) has already been performed, i.e. N is the number of the mapped criteria relevant for the calculation of weights and thus the decision-making.

HIERARCHY OF THE PROBLEM

Analysis of indicators for decision-making that contribute to sustainable development through Cleaner Production and Resource Efficiency, examined four main areas/indicators. On Fig. 2, there is a comparative link between the second hierarchical level and the alternatives. In our case, there are 16 indicators from the second level of the hierarchy that will be compared with the four alternatives (Resource Efficiency, Cleaner Production, New Technologies, Renewable Energy). The whole analysis is done based on the diagram below (Fig. 2). After analysing their data and processing with Expert Choice Software we have obtained the results.

The results will structure a hierarchy which will be a good basis for decision-making and policy-making for introducing technologies for cleaner production that will contribute to sustainable development (case study: Kosovo). Diagrams with the results obtained after processing all the data will be shown in the following chapters.

In addition, the software also performs consistency checks to exclude responses or participants (Table 5).

DETERMINATION OF ALTERNATIVES AND THEIR RANKING

In order to calculate a suitable option to make decisions through RECP that will contribute to sustainable development, we have decided to analyse four alternatives.

The analysed alternatives submitted consider the difficulties and potential of the present energetic situation. Both energy deficiency and the possibility for using new energy resources that enable sustainable development have been taken into account when considering the present situation.

The alternatives have been derived from the results of the products obtained by the complete model analysis. In our case, we have limited the four alternatives to only two levels of the problem hierarchy. Therefore, we have divided the alternatives into two hierarchical levels considering all of the indicators: environmental, technical, economic and social. We have used the same software that we used for achieving the results of the whole model, and we have also used it for ranking alternatives. So, the multi-criteria program/software takes into account the predetermined factors of weight indicators.

The results show (Table 4) that alternative 1 – Cleaner Production has an advantage over other three alternatives. Therefore, it is necessary to work continuously on creating conditions and providing investment in Cleaner Production. Resource Efficiency, Renewable Energy and New Technologies are of extraordinary importance

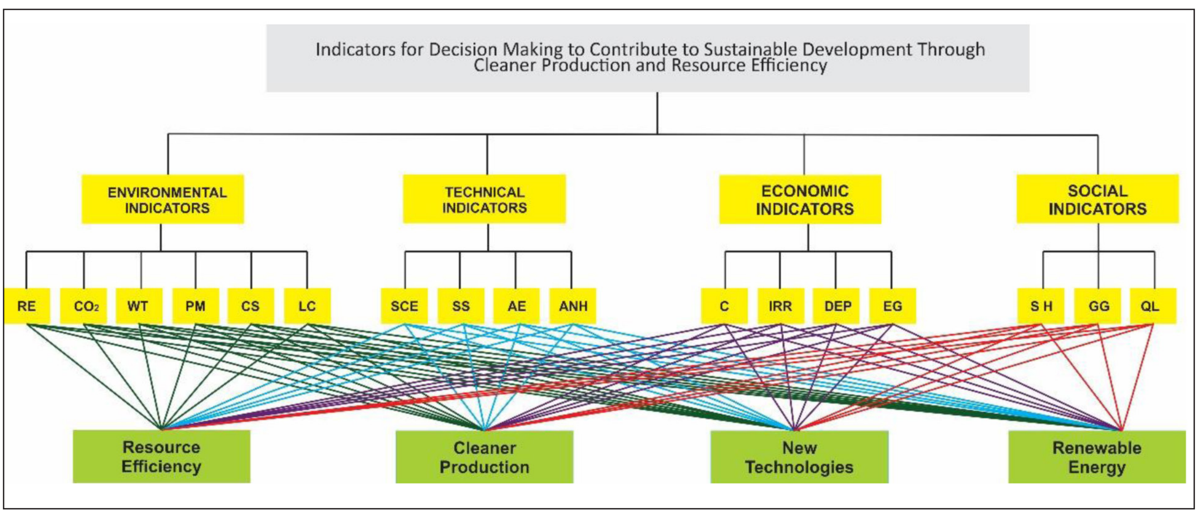

Fig. 2. The comparative link between the second hierarchical level and alternatives

Table 4. **Ranking of alternatives**

Alternative 1	Cleaner Production	0.304	1
Alternative 2	Resource Efficiency	0.301	2
Alternative 3	Renewable Energy	0.295	3
Alternative 4	New Technologies	0.281	4

as alternatives that derive from the analysis of the whole model in which the definition of indicators for sustainable development is made. From this point of view, sustainable development tips the scale towards alternative 1 with a slight advantage over other alternatives. However, alternatives 2, 3 and 4 should not be completely neglected as they represent pertinent alternatives derived by the model. Results of the alternatives are given through visual representations shown in Fig. 4.

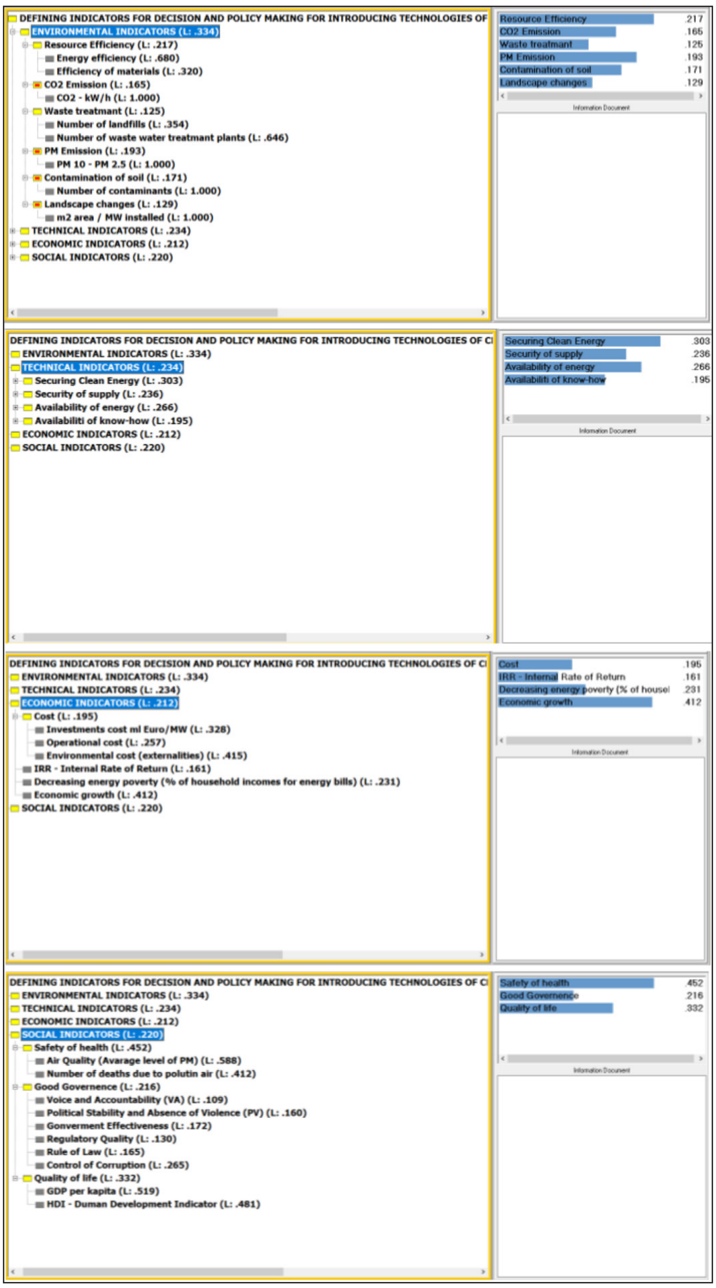

Fig. 3. The program interface through which the calculations for environmental, technical, economic and social indicators have been made

Based on the AHP method, experts carry the dominant role in the ranking of indicators and alternatives. They have contributed through the responses they provided to the questionnaire built under the Saaty rules. We addressed the experts in the institutions (see Table 5) taking into account the importance and experience that these institutions have carefully selecting the link of their positions with the indicators that we have dealt with. Respondents/participants in our analysis were not only part of the academic world, but also decision-makers in respective institutions, such as mayors, heads of departments, board directors, etc. The opinion of university professors is crucial to our analysis. Universities are key stakeholders in teaching, researching and supporting the implementation of cleaner production activities [15].

Table 5. **Profiles and expert institutions that contributed to the research**

No.	Institution	Position
1, 2, 3	University of Pristina Mechanical Engineering Faculty	Professors
4	University of Skopje Mechanical Engineering Faculty	Professor
5	University of Westminster, UK	Master of Economic Policy and Data Analysis
6	University of Tetova, Macedonia	Professor
7	JSC Macedonian Power Plants	PhD in technical sciences, senior engineer for process analyses
8, 9, 10	University of Mitrovica Faculty of Mechanical and Computer Engineering	Professor
11	Universiteti i Prishtines Faculty of Philosophy	Sociologist
12	Mayor of Municipality	Mayor
13, 14	Kosovo Energy Corporation	Engineer
15	District Heating "Termokos" Department of Distribution	Engineer
16	District Heating "Termokos" Department of Production	Engineer
17	District Heating "Termokos" Member of PIU Project Implantation Unit – Cogeneration project	Engineer
18	Ministry of Economic Development	Head of Department
19	Ministry of Transport	Head of Department
20	Ministry of Environmental and Spatial Planning	Head of Department
21	Ministry of Finance	Head of Department
22	Regulatory Office of Energy in Kosovo Member of Board	Board Director
23	University of Prishtina Faculty of Mathematics and Natural Sciences – Chemistry Department	MSc in Analytical and Environmental Chemistry
24	Kosovo Energy Efficiency & Renewable Energy Project Ministry of Economic Development	Engineer
25	EFACEC Contracting Central Europe GmbH Master Business Administration	Regional Director

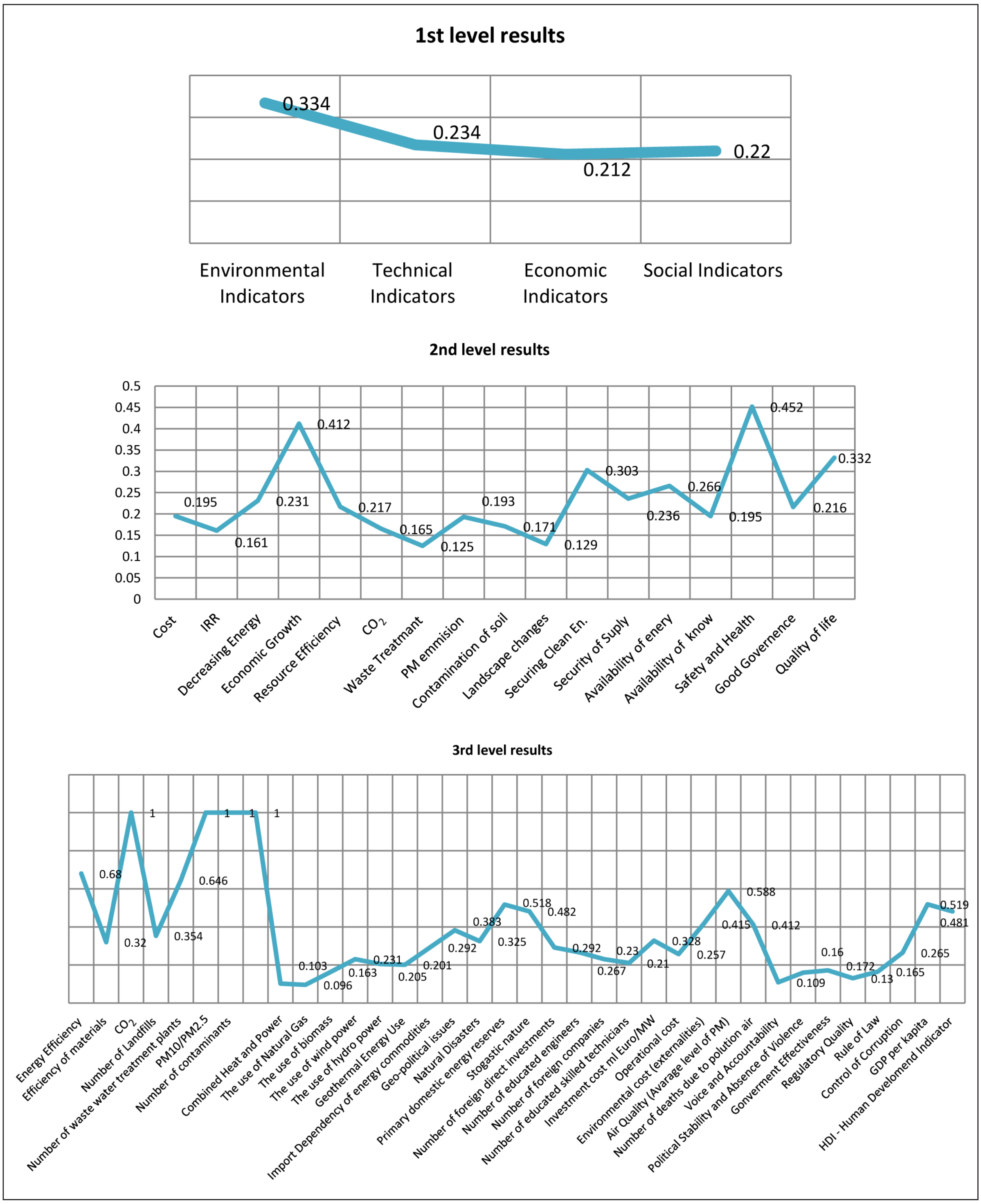

Fig. 4. Graphic presentation of the final results for the environmental, technical, economic and social indicators, distributed in the three hierarchical levels of the model

The complete results of our analysis of all indicators – part of the model for three levels of the hierarchy together with the results obtained by Software Expert Choice are presented in Fig. 3.

CONCLUSIONS AND RECOMMENDATIONS

Using the AHP method, we have set the indicators, identified their weight, defined the hierarchy of the problem and offered alternatives. This does not imply that we are talking about a method through which we can solve real problems that mankind faces nowadays. Nevertheless, we have managed to define our future goal, use and application of other methods in the field of decision-making and multi-criteria policy for Developing Countries (such as the Republic of Kosovo) in projects that enable sustainable development.

The obtained results provide a realistic picture of the adequate steps to be taken in order to improve the situation in the areas with the potential for progress. According to environmental indicators, sustainable development depends on the value of the Resource Efficiency indicator (0.217), as a serious step to be taken by decision-makers and policy-makers in the institutions of the Republic of Kosovo. This will aid the industrial sector in general, with special emphasis on small and medium enterprises, taking into account that the biggest problem they face is related to affordable energy, whereas Resource Efficiency as a practice has no application at all.

From the perspective of professionals who have given their assessment of the hierarchy of the problem, we see that Resource Efficiency, as an alternative to sustainable development, is an important part of decision-making and policy-making being ranked as the second alternative (0.301), while PM Emission (0.193), Contamination of Soil (0.171), CO_2 Emission (0.165), Landscape Changes (0.129) and Waste Treatment (0.125) conclude the rest of the environmental indicators. A great need for the intervention of politicians and decision-makers to correct the indicators in the near future will certainly help the Republic of Kosovo to regulate the environmental parameters in function of sustainable development and pollution prevention, turning it into "normal" and acceptable parameters.

Waste treatment, emission of pollutants, land contamination, and landscape shift are related to the latest indicator of our social indicator analysis, which is closely related to the "performance" of environmental parameters. The change of each indicator, meaning their advancement in each field, even at a minimal level will have an impact on the whole hierarchy of the problem, making the model applicable and usable even in the search of practical results.

Based on the data introduced in the model, Energy Efficiency (0.680) is a dominant indicator from the third level at the environmental indicators. Certainly, no different result was expected given a high and unbearable cost of electricity "for the industry" as well as the lack of a thermal energy network. So, the indicator that needs to be addressed in a sensitive way has to do with the increase of Energy Efficiency as an appropriate form to provide affordable energy supply. Energy is a fundamental part of the operation of SME and as such is a fundamental part of the treatment through the Cleaner Production process.

Securing Clean Energy (0.303) is the most important indicator in the whole second level of the problem hierarchy of technical factors. Statistically, the basic problem in the functioning of industry and enterprises of all levels turns out to be the problem of power supply. In terms of planning to improve the parameters of clean energy security, Kosovo has drafted/approved strategic documents. The results from our research show that we are dealing with the most important indicators through which the sustainable stability and development will be achieved.

Economic indicators are of great importance not only in our analysis as a theoretical treatment but also at the practical level. The weight of the indicators tested have yielded expected results which express their domination through Economic Growth (0.412). Economic Growth has a fair relationship with the performance of the industry sector and enterprises which operate at the country level.

By improving the performance of this industry and these enterprises, we will achieve the "reflection" of economic indicators that guarantee sustainable development. Economic indicators should be attempted to improve in each case by addressing the four alternatives in a serious, professional and competitive way through the process of decision-making and policy-making.

The Safety and Health indicator (0.452) naturally turns out to be the dominant indicator in the second level of the hierarchy, through which security and health are seen to be the most important issues in the domain of social indicators. Air Quality (0.588) should be treated with great care and priority as one of the indicators that would affect the improvement of Safety and Health in order to reduce the number of deaths due to air pollution (0.412).

Within the second level of the hierarchy, Quality of Life (0.332) is ranked second to Safety and Health followed by Good Governance. Quality of Life is a complex indicator which embeds the GDP value, as well as the Human Development Index (HDI).

Good Governance, in this case, has been examined based on six "standard" indicators on which also it depends. The main indicator through which Good Governance is achieved and then is pursued in a sustainable development, is called Control of Corruption (0.265). Government Indicators (0.172), Rule of Law (0.165), Political Stability and Absence of Violence (0.160) and Voice and Accountability (0.109) are also listed as the five other indicators that play a crucial role in improving governance.

Results from analysis will be used as a foundation for Developing Countries (Kosovo) institutions in the logic of identifying/analysing adequate steps in the right direction. Besides, it will also positively contribute in developing Kosovo's thermal energy planning, creating clear strategies for the processes and identifying indicators in decision-making area.

The research has raised many new questions and opens ways for new potential research in this area of study. The Republic of Kosovo in particular, and the region in general, need to address these issues in the future in order to define more indicators that have an impact on the sustainable development of their respective territories.

The span of the applicability of this particular model can easily expand to include other countries in the region. With some minimal alterations, the model can reach a broader acceptance in the region. As for the term "wider", it is comprised of institutional inclusion of the proved scientific methods and techniques in decision-making, as well as applying existing models and studies from one country into another country in the region of Western Balkans.

Moreover, the model (besides contributing towards the identification of problems) will offer these solutions:

• To identify, define, and plan the most crucial criteria in the hierarchy of the sustainable supply of thermal energy;

• To alter/modify models which will be established carefully for each different case specifically;

• To establish the model to solve similar problems, in accordance with the recommendations for further work, by the use of analytic hierarchy process.

• Our analysis can also be utilized for similar cases in the field of decision-making concerning thermal energy.

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EKONOMINIŲ RODIKLIŲ, SKIRTŲ SPRENDIMAMS PRIIMTI DĖL DARNAUS VYSTYMOSI TAIKANT ŠVARESNĘ GAMYBĄ IR IŠTEKLIŲ NAUDOJIMO EFEKTYVUMĄ, APIBRĖŽIMAS ANALITINIO HIERARCHINIO PROCESO METODU

Santrauka

Sparčiai augantis pramonės sektorius sukuria daug naujų iššūkių, kuriuos reikia spręsti. Pagrindinės problemos, susijusios su nuolatine ir greita pramonės plėtra, yra: didelis energijos sunaudojimo (būtent elektros ar šilumos) poreikis, aplinkos taršos lygio augimas ir atliekų tvarkymas.

Pereinamojo ekonomikos laikotarpio šalims, kurioms būdinga „besivystanti pramonė“, reikia rimtai apsvarstyti minėtus iššūkius. Siekiant tinkamai panaudoti išteklius pramonėje, turėtų būti taikoma profesionali analizė, paremta išteklių naudojimo efektyvumo ir švaresnės gamybos principais. Be to, dėl didesnio išteklių naudojimo efektyvumo pramonės sektorius ir įmonės gaus papildomos naudos. Didesnis efektyvumas neabejotinai paskatins ekologiškesnę gamybą ir „Išteklių efektyvumo ir švaresnės gamybos“ (angl. *Resource Efficiency and Cleaner Production*, RECP) įdiegimą besivystančiose šalyse (pvz., Kosovo atvejis).

Šiame tyrime daugiausia dėmesio skirta darniam vystymuisi skatinti, pagrįstam „Išteklių efektyvumu ir švaresne gamyba“ Kosove. Vadovaujantis „Išteklių efektyvumo ir švaresnės gamybos“ principu, analizė atlikta pramonės sektoriuje, taikant daugiakriterinį sprendimų priėmimo metodą – analitinį hierarchinį procesą visais sprendimų priėmimo lygmenimis. Procesas grindžiamas keturiais pagrindiniais darnaus vystymosi pagrindais: ekologiniu, techniniu, ekonominiu ir socialiniu.

Naudodamiesi „Išteklių efektyvumo ir švaresnės gamybos“ principais, nustatėme konkrečias sritis, kurias reikia tobulinti, kad būtų pasiektas leistinas racionalus energijos naudojimo lygis, sumažėtų aplinkos tarša ir atliekos, būtų maksimizuotas pramonės sektoriaus / įmonių pelnas, kas paskatintų naujų darbo vietų kūrimą.

Raktažodžiai: išteklių efektyvus naudojimas ir švaresnė gamyba, pramonė, energetika, AHP metodas