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Sensitivity analysis of the evaluation of power plants impact on the living standard using the analytic hierarchy process

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ABSTRACT

Ten types of power plant were evaluated as to their impact on the living standard. Power plant evaluation incorporates a number of criteria that can be assessed either objectively or subjectively. Objective assessments are usually quantitative and are based on real data, while subjective assessments are rather qualitative and derive from decision makers' intuition, culture and experience. Because of diversity of decision makers' opinions, subjective assessments are due to vary. Several scenarios should therefore be examined in order to evaluate what happens under different assessments. Even objective assessments can vary because of data changes due to technology and socioeconomic evolution. This is why the application of a sensitivity analysis is required in order to examine result changes under different input data. This analysis should cover all criteria and subcriteria as well as their possible combinations in the different levels of the hierarchy tree.

The results show that the five types of renewable energy based power plant rank in the first five positions regardless of criteria weight variations, due to their balanced high scores against them. Only biomass drops to the eighth position when quality of life has 100% weight. Nuclear power plants show impressive score and ranking variations between the first position for 100% quality of life weight and the tenth for 100% socioeconomic aspects weight. Natural gas based power plants rank slightly higher when quality of life importance increases while coal/lignite and oil have slightly better rankings when priority is given to socioeconomic aspects.

1. Introduction

During the last decades, electricity generation contributed to socioeconomic development and changed people's lives radically. Power plants based their operation mainly on coal and lignite while health and environmental damages were not examined as there were no historic data and their importance was undervalued [1,2]. Today, electricity demand is growing rapidly leading to construction of new power plants. Resources are depleting and sustainable solutions are explored. Global warming is no more ignored and international agreements and protocols are signed in order to prevent proliferation of greenhouse gases [3–9].

Lately, health issues raised as harmful consequences of power plants, are rising rapidly [10–12]. Financial development and the rise of living standards led people to cope with the bad side effects caused by factors that sustained this development for many years. Evaluation of power plants is not simple as several criteria are involved to cover every aspect of modern society. Multicriteria analysis and externalities assessment can be applied to evaluate electricity generation systems on the living standard [13,14]. A detailed analysis requires building of a model, the availability of appropriate data and the combination of objective and subjective evaluations.

The analytic hierarchy process (AHP) is one of the most widely accepted methods used in multicriteria analysis to decompose complex problems into the appropriate hierarchy [15,16]. It incorporates the measurement of scores of alternative solutions against criteria and subcriteria grouped appropriately in several levels of the hierarchy tree. AHP also requires the assessment of criteria weights on which the overall synthesis evaluation is based.

2. Power plant evaluation overview

In order for sensitivity analysis to be carried out, an overview of the multicriteria evaluation of power plants impact on the living standard using the analytic hierarchy process [17] is presented in this section. In this paper, ten types of power plant were examined under two main criteria, namely "quality of life" and "socioeconomic aspects" (level 2). These criteria were further decomposed in twelve subcriteria within levels 3 and 4 of the hierarchy tree, presented in Fig. 1. Eleven of these subcriteria are end node subcriteria, that is they are no further divided to other subcriteria.

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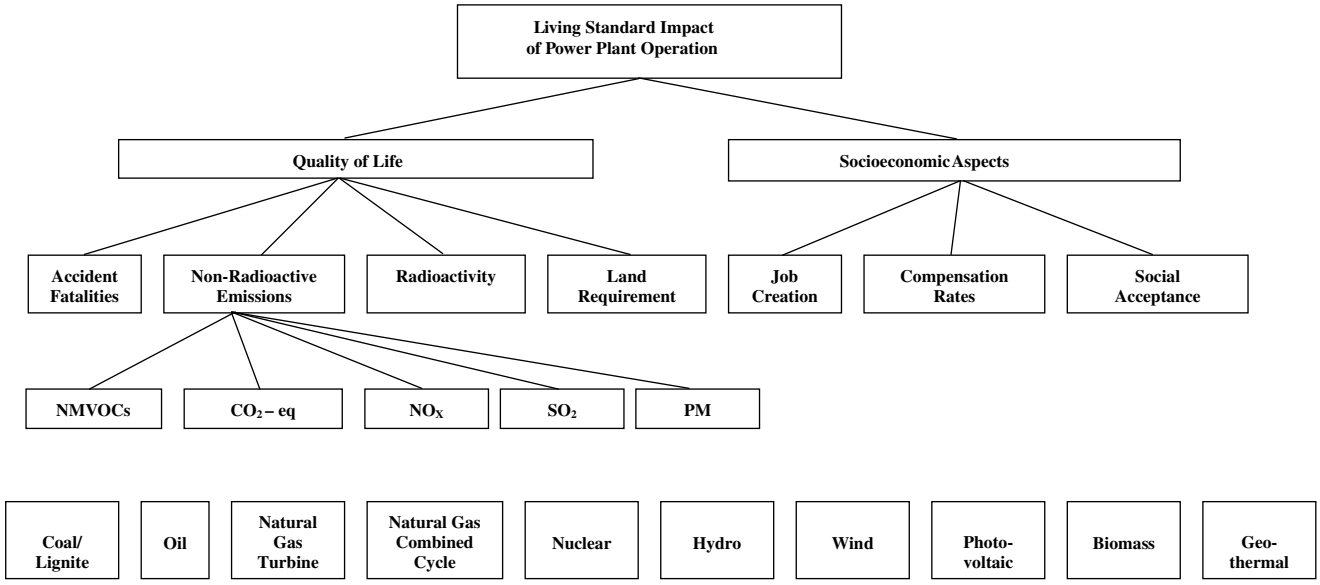

Fig. 1. The hierarchy tree for optimisation of the living standard impact of the power plant operation.

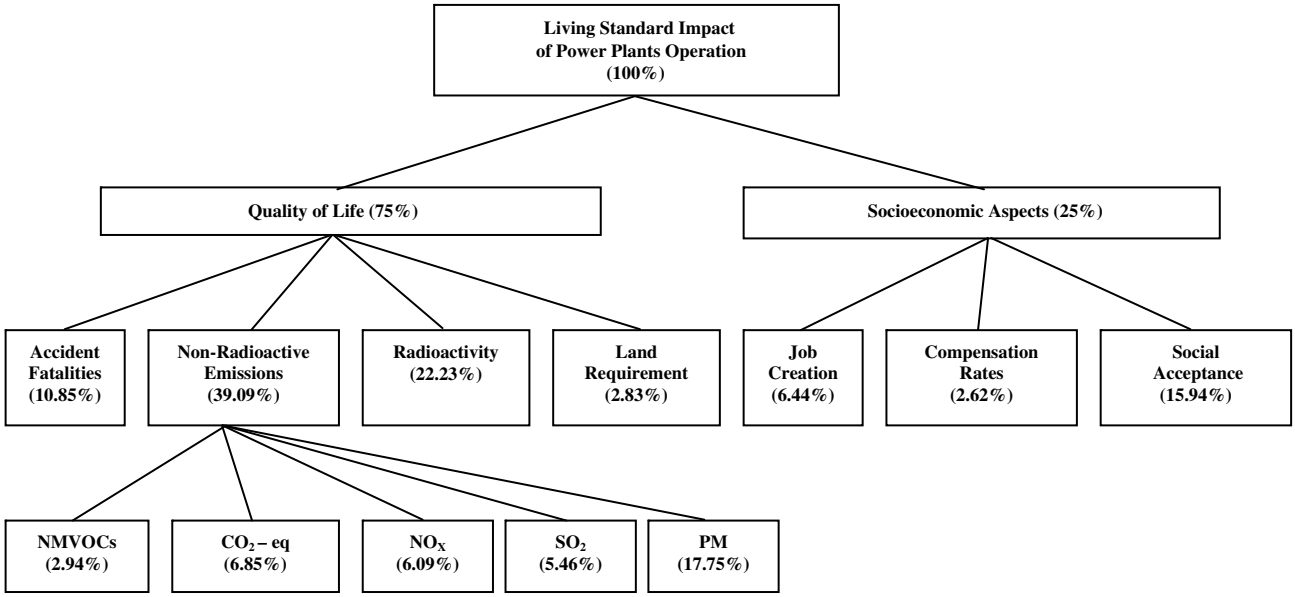

Fig. 2. Global criteria and subcriteria weights.

Fig. 2 presents the global criteria and subcriteria weights [17], that is the percentage contribution of each of the overall score of each of the ten types of power plant. Fig. 3 presents the local criteria and subcriteria weights which are the percentage contribution of each of them with respect to their parent node. For example, particulate matter has 17.75% global weight which means that it contributes by 17.75% to the overall score or the goal which is the living standard impact evaluation (see Fig. 2). On the other hand, its local weight is 45.4% with respect to its parent node which is non-radioactive emissions, that is it contributes 45.4% of the overall score of non-radioactive emissions (see Fig. 3).

Sensitivity analysis examines how alterations of criteria weights affect the overall power plant scores and rankings. Tables 1 and 2 present the detailed results grouped by end node criteria or type of power plant [17]. These form the "reference scenario" under the "initial" assumptions that were made and will form the basis on which sensitivity analysis will be applied.

According to power plant scoring (see Tables 1 and 2) and the criteria and subcriteria weights (see Figs. 2 and 3) the ranking of the ten types of power plant appears in Fig. 4.

What is most impressive is the fact that the five renewable energy power plants rank in the first five positions, which is in accordance with public opinion for clean and sustainable development. Sensitivity analysis will present the classification alteration in the overall ranking of these ten types of power plant under different criteria weighting.

3. Sensitivity analysis

When evaluating a situation many factors can change, either because data change or due to decision makers' different points of view. Especially when assessments are subjective or there is uncertainty, many possible cases should be examined [18]. Alternate scenarios have been widely applied in the energy sector