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Multi-criteria sustainability analysis of thermal power plant Kolubara-A Unit 2

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ABSTRACT

The paper presents a possible approach for creating business decisions based on multi-criteria analysis. Seven options for a possible revitalization of the thermal power plant "Kolubara"-A Unit No. 2 with energy indicators of sustainable development (EISD) are presented in this paper. The chosen EISD numerically express the essential features of the analyzed options, while the sustainability criteria indicate the option quality within the limits of these indicators. In this paper, the criteria for assessing the sustainability options are defined based on several aspects: economic, social, environmental and technological. In the process of assessing the sustainability of the considered options the Analysis and Synthesis of Parameters under Information Deficiency (ASPID) method was used. In this paper, the EISD show that production and energy consumption are closely linked to economic, environmental and other indicators, such as economic and technological development of local communities with employment being one of the most important social parameter. Multi-criteria analysis for the case study of the TPP "Kolubara"-A clearly indicated recommendations to decision makers on the choice of the best available options in dependence on the energy policy.

1. Introduction

The concept of sustainable development became a leading principle in economic and environmental policy in social organizations starting from the international and the state level to the local level. Sustainability or sustainable development appears as an essential prerequisite and as the end aim of efficient organization of numerous human activities on the Earth. Today, there is wide consensus that the concept of sustainable development brings the hope of renaissance of our planet, but also that the next ten years are critical for the implementation of this concept [1]. The current economic crisis influenced people to feel that it is necessary to react to a number of unsustainable trends in production, consumption, social relations and habits. The foundation of sustainable development consists of three components: economy, society and environment. The EU energy system shows a form of unsustainable development that is characterized by increasing use of imported fossil fuels, and increasing energy consumption and CO_2 emissions. In order to preserve the equilibrium of ecosystems and to encourage economic development, mitigation and changes of these negative developments that effect the sustainability of the energy system becomes a real challenge [2]. The accomplishment of the EU sustainable development policy is based on two documents: the Lisbon Strategy, which adopted an ambitious economic plan and social reforms, and the Gothenburg strategy, which defines sustainable development as the main direction of the development process, which has to ensure the prosperity and improvement of living conditions for present and future generations [3,4].

Hitherto, the research completed with respect to sustainable development of energy systems include reducing greenhouse gas emissions and emissions of polluting gases, improving energy efficiency, increasing the use of renewable energy, and increasing the reliability of energy supply and improving the quality of people's life. Research projects should have a multidisciplinary approach that includes the social-economic impact of future decisions and the impact on markets and customers to the introduction of energy technologies [2,5,6]. Solutions must take into account all aspects of

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Nomenclature

I_{coal}	sub-indicator of coal [t]
$I_{electric\ energy\ production}$	sub-indicator of production of electric energy [kWh]
I_{CO2}	sub-indicator of CO_2 emission per produced of kWh of electric energy [$kgCO_2$/kWh]
I_{SO2}	sub-indicator of SO_2 emission per produced of kWh of electric energy [gSO_2/kWh]
I_{NOx}	sub-indicator of NOx emission per produced of kWh of electric energy [gNOx/kWh]
$I_{electric\ price}$	sub-indicator of electric price [€/kWh]
$I_{investment}$	sub-indicator of investment [€/kWh]
I_{salary}	sub-indicator of salary [€/kWh]
$I_{employee}$	sub-indicator of employee [−]
$I_{project\ in\ l.c.}$	sub-indicator of local community [€/kWh]
$I_{work\ injury}$	sub-indicator of injury at work [1/year]
$I_{sick\ leave}$	sub-indicator of sick leave [h/year]
I_{supply}	sub-indicator of the safety of supply [−]

Abbreviations

ASPID	Analysis and Synthesis of Parameters under Information Deficiency
EPS	Electric Power Industry Serbia
EISD	Energy Indices of Sustainable Development
GIS	General Index Sustainability
GHG	Green House Gases
SRF	Solid Recovered Fuel
TPP NT	Thermal Power Plant 'Nikola Tesla'

sustainable development [7]. There have been a number of studies on sustainability assessment of electricity generation options. Edgar Santoyo-Castelazo and Adisa Azapagic [8] described a new methodological framework and decision-support for a sustainability assessment of the energy system in Mexico, considering the country's key energy drivers and climate change until 2050. The framework comprised scenario analysis by Multiple-criteria decision making (MCDM), which is used to identify the 'most sustainable' energy options. Paper [9] also provides a tool for the decision-makers to evaluate ten power plants using the Preference Ranking Organization Method of Enrichment Evaluation (PROMETHEE II), which outranked the multi-criteria method. Twelve criteria, infinite customized probability assessed the weight scenarios and probability assessment of weighting factors, were introduced. Decision support systems do not provide a definite solution for every case. However, they provide estimations to be used by the decision makers. Renewable energy types of power plant outperform by far fossil fuels and nuclear power plants with regards to their impact on the living standard. A case study in Vietnam showed sustainability assessment of solar and wind power plants by the Analytic Hierarchy Process (AHP) [10]. The study [11] considered and built a MCDM framework for the selection decision of site for offshore wind farms by the outranking method The Elimination and Choice Translating Reality (ELECTRE III). Insightful information was proposed for managers to analyze and select the optimal site for offshore wind farms, which is a critical step towards a successful wind project. This process concerned conflicting criteria involving offshore wind resources, the environment, sea area planning, power grid access lines, economy, society, *etc*. A study of Begic and Naim Afgan [12] presented results of a multi-criteria assessment of the options of the selected energy power system of the Public Enterprise of Bosnia and Herzegovina. Resource, environmental, social and economic indicators were defined. Applying the ASPID method provided a chance to investigate the effects of different constraints among the indicators on the final rating of the options.

The Electric Power Industry of Serbia (EPS) is the biggest enterprise in the Republic of Serbia. The installed power capable of producing electric energy is 8359 MW. 34,509 GWh was produced in the thermal power plants run by EPS in 2014. The Company TPP NT is the largest producer of electric energy in South–East Europe and it is an integral part of the EPS. It has fourteen units of installed power of 3288 MW and produces more than 50% of the total Serbian production per year [13].

This paper illustrates a multi-criteria method for estimating the quality of the considered TPP "Kolubara"-A Unit No. 2. When the different dimensions of the introduced sustainable development are taken into consideration, the index of sustainability was determined using the ASPID multi-criteria method, which aids policy makers, investors and analysts in the decision making process. A ranking of the options is given and the selection the 'most appropriate' technology was performed in accordance with a set of evaluation criteria.

2. Options for the analysis of the sustainability of Unit 2 of TPP "Kolubara"-A

TPP "Kolubara"-A is the oldest active plant within the EPS. Within this thermo-energetic facility are five units with a total installed power of 270 MW. The EPS management's plan is to shut down certain blocks due to their age and low energy efficiency. Among these units is A2 TPP "Kolubara" power 32 MW. Shutting down this unit would cause a fall in production of electric energy and loss of jobs. To extend the life-time of this unit by 20 years, seven options of its possible status have been proposed in this paper. Sustainable development indicators, sets and subsets (indicators and sub-indicators) were formed for each proposed option to help better understand the various dimensions or aspects of its sustainable development. The proposed options are:

1. Revitalization of Unit 2 of TPP "Kolubara"-A (lignite) in the condensational regime - Option 1
2. Revitalization of Unit 2 of TPP "Kolubara"-A based on the co-combustion of coal (lignite) and solid recovered fuel (SRF) in the condensational regime - Option 2
3. Revitalization of Unit 2 of TPP "Kolubara"-A based on the co-combustion of coal (lignite) and biomass in the condensational regime - Option 3
4. Revitalization of Unit 2 of TPP "Kolubara"-A based on the co-combustion of coal (lignite) and waste in the condensational regime - Option 4
5. Revitalization of Unit 2 of TPP "Kolubara"-A by gas-combustion in the condensational regime - Option 5
6. Production of electric energy of 32 MW power from wind generators - Option 6
7. Production of electric energy of 32 MW from solar energy (photovoltaic) - Option 7

2.1. Revitalization of Unit 2 of TPP "Kolubara"-A (lignite) in the condensational regime - Option 1

As part of Unit A2 revitalization, it is necessary to perform activities aimed at improving the coal combustion process, *i.e.*, replacement of the existing boiler to include a low-emission burner, replacement of the complete high pressure cylinder, middle pressure cylinder and low pressure cylinder of the turbine, and replacement of the majority of the automatic and electric