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Game theory approach in decisional process of energy management for industrial sector

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ABSTRACT

Intensive energy consuming industrial sectors are the most important actors on global climate change which natural habitat and the environment faced. In this study, by the scope of energy management, decision-making process of the industry and the environment are evaluated in a game theoretic approach. Industry and environment are considered as two players which have conflicting objectives and try to find optimal strategies in governing energy policy. According to concept of study, while industry tries to maintain the sustainability of production with the strategies of fossil fuel, renewable energies, energy recovery and nuclear energy usage, environment exhibits reactive approach to ensure its sustainability. In the flow of study, players' strategies are analyzed by using Multi-Criteria Decision Making (MCDM) methods and by calculating performance efficiency values of strategies, game payoff matrix is obtained. Finally, optimal strategies are found for both industry and environment in orienting their energy policy and results are evaluated. According to results of the payoff matrix, the equilibrium point is the cell (2,1) with the values of 0.5324 and 0.5619. This implies that the environment develops protective reflexes for sustainable nature in case of using renewable energy in industry.

1. Introduction

An indispensable element of life, the importance and impact of the energy for a sustainable world is increasing every day. Until economic crisis that emerged in the 1970s, cheapness of energy costs comparing to labor costs, increased uncontrolled energy consumption. After crisis, input costs are badly affected by production and cost problems.

After 1990s, especially carbon emissions as a result of global warming and climate change, has caused multi-dimensional questioning for negative effects of energy usage in sustainability life circle. To reduce this effect, in 1992, made by the United Nations conference on climate change and development environment, the Kyoto Protocol (1997) was signed for limiting greenhouse gases. In international conference in Copenhagen (November 2009), global agreement on carbon emissions in order to ensure a sustainable world for studies of greenhouse gas emissions is to be brought under control starting from 2012 [1–3].

These happenings contribute formation of a process in industrial sector that energy usage has a considerable amount (approximately one third of world's energy) for input costs which environmental awareness and energy efficiency are based on [4]. But, energy efficiency and productivity in industrial sector should be considered as a whole of economical, environmental, social and political actions. Control of these attitudes is flexible for their specialties. For example, while energy measurability in technological structure and their costs are easily defined, environmental, social and political attitudes are subjective factors in definition.

Nowadays, industrial sector orients their strategies with fossil fuel usage and to avoid the cost and environmental impacts, develops especially energy-saving applications. But for the sectors as cement industry and almost all in manufacturing sectors in which energy costs exceeds 50%, despite the multi-faceted profitability of energy-saving opportunities, measures cannot be immediately taken according to observations. Costs are immediately reflected to the prices of today's economic life. So, in industry sector, energy saving investments is implemented very slowly due to the investment costs and not to prevent production. However, to evaluate the positive and negative impacts of energy use, there is not an effective energy management for businesses, industries and community. In this case, for businesses, industries and even to increase the diversity of the country's energy use, policies in shaping the development of new strategies are emerging as a major problem [5].

Energy strategies are important structure that presents particularly how economic indicators are shaped, the environment and how society might be affected and how do countries implement their energy policy. This structure is deemed to be the

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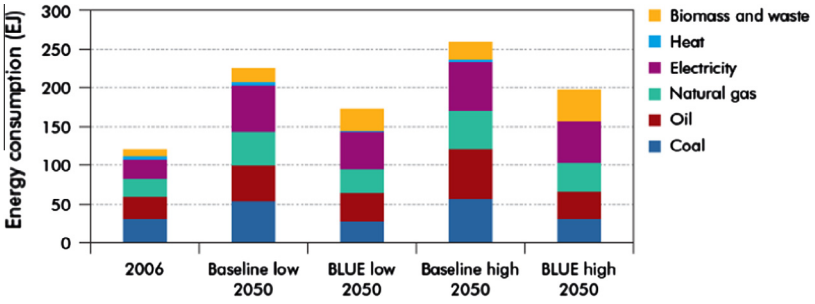

Fig. 1. Energy projections in industry [15].

industry-wide concern or can be addressed in a sectoral basis. In fact, it is observed that there are many searches in industry related to these issues.

Bossilkov et al. [6] study a foundation project on enabling tools and technologies for capturing regional synergies. Their study is aimed at encouraging and facilitating the greater utilization of regional synergy opportunities to improve the overall eco-efficiency of minerals-processing intensive regions. Russel [7] study on reflects of organizational and behavioral aspects of corporate-wide energy management. Case studies show that energy management motives and approaches are somewhat varied—there is no "one size fits all" solution. In addition, industrial energy management strategies must be developed to illustrate the range of opportunities available to industry. The International Energy Agency (IEA) and United Nations Industrial Development Organization (UNIDO) makes a co-operation study to develop a technology roadmap for the application of carbon capture and storage in industry. This roadmap paves the way for low-carbon industrial growth in developed and developing countries by providing a vision of industrial carbon capture and storage up to 2050 [8,9]. Yuanyuan et al. [10] examine a review about current energy conservation and emissions reduction strategies in iron and steel industry. They emphasize that the primary measures mainly focus on the targeted policies formulation and also on clean and high efficient technologies development. Kaufman and Walker [11] conduct a survey about managing energy consumption for higher profitability. In this study, the current economic and regulatory drivers compelling manufacturers to view their energy resources are described as a path to strategic competitive advantage, and for transforming their perspectives to an internal view on how they can manage energy resources from within the plant. Moreover, a methodology is also detailed that can help manufacturers shift their points of view from treating energy as an undifferentiated overhead cost to managing it at a finite level as a cost of producing specific products.

By all studies mentioned above, it can be observed that potential future scenarios are discussed with different approaches in sectoral assessments. Especially, in energy projections with regard to emission estimates, in addition to ozone consumption values in Montreal Protocol or UNEP, country's economic growth rate, the ozone consumption rates and sector data are used. These evaluations are considered as classical approaches [12].

Decision processes dependent on projections, are important processes that affect many elements. In terms of the formation of the irrevocable structures as defining strategic approaches, establishing social and economical foundations and embodiment of future, efficient decision processes are vital milestones. From firms to all industrial sector, energy managements which orients functions as type of energy, efficient usage, minimizing cost and environmental affects, have to control decision processes in right way. For this reason, determination of energy usage strategies should be in priority. This is basically related to country's energy strategy and strategic plan for energy use can contribute to the formation of policies.

Nowadays, artificial intelligence (AI) techniques have importance in decision making process and for future planning. Making predictions for the future in terms of competition and uncertainty, determining effective actors and strategies, assessing all of them with critical factors are main research topics that decision makers mostly focus on. Decision processes for conflicting objectives and uncertain competitive environments are modeled as multi-criteria and multi-person decision making processes. The approaches based on strategies of multi-criteria and multi-objective, which can contribute to the decision process in energy sector, has been studied [13–17]. However, the state of energy assessments taken as reference of primary energy processes like power applications and electricity markets have been made in these studies.

Artificial Intelligence applications will provide significant contributions in embodiment of strategies for the energy sector which has the potential for forming policies and energy usage. In recent studies, it is observed that there are many studies using Fuzzy TOPSIS (The Technique for Order Preference by Similarity to Ideal Solution) and game theory for decision making processes. These strategies and approaches that will contribute to the energy strategies of energy-consuming sectors and energy consumption of sectors has not been established yet. In this study, a game theory approach is presented for energy managements that can be used determining energy usage strategies. This approach is the basic players are the industry and the environment: fossil fuels, renewable energies, energy recovery and types of nuclear energy are assessed as effective. At the end of the study, for energy managements and a sustainable environment, evaluations are presented which defines efficiency of existing energy types and reactions of industry and environment to these efficiencies.

2. Energy usage in industry and energy management

An aspect of social development, manufacturing sector, which is included in industrial sector, is the most important element of economic growth in a country. Data for the year 2007 about 150 EJ of the energy consuming sectors of the industry, approximately 60% of energy in developed countries, and the remaining approximately 40% is consumed in the countries in the OECD. Approximately 90% of the energy needed by the industry is based on fossil fuels irreversible. In the distribution of energy use: coal and its types, liquid fuels, natural gas and electricity are come forward by percentage of 26, 25, 21 and 19 subsequently. Bio-mass, waste heat, renewable energy sources in total consumption are amounted to 9% [18,19]. Energy consumption profile of industry and projections for the year of 2050 is given in Fig. 1.

For industrial applications, energy consumption is a component that threatens the sustainability cost structure. Despite the