AN OPTIMIZATION ALGORITHM FOR EXERGY SUPPLY AND DEMAND EQUILIBRIUM IN THE BUILT ENVIRONMENT

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Overview

The objective of this study is to develop a decision-making algorithm for optimally blending the supply exergy and to optimally allocate them to the demand points in the built environment for maximum average exergy efficiency. The potential positive impacts of the algorithm to the energy efficiency, CO_2 emissions, and fuel savings are demonstrated in a sample project. This sample project involves a dairy farm with three cases of exergy supply scenarios of different energy source bundles. The first case is about all-conventional energy resources, systems, and equipment. The second case includes absorption-cycle cooling system, cogeneration system, heat pumps, and heat and cold storage systems to levelize the peak thermal loads. The third case includes renewable energy sources like a biogas-driven cogeneration system, solar panels, and wind turbines. A simple payback analysis has also been carried out and results show that the third case yields the maximum exergy efficiency and the shortest pay-back period.

The paper is organised as follows: After the overview, the second section briefs about the analysis method of solution that is applied to a case study with different scenarios. This section also includes summary of different scenarios and objective function detail that is necessary for comparison of the scenarios. The third section is about objective function results of scenarios compared with the base scenario.

Methodology

A novel allocation decision-making algorithm has been developed by modeling various scenarios that include all possible alternatives and hybrid combinations of conventional, renewable sustainable energy resources, systems, and equipments. Excel Programming tool was used and an algorithm was developed for analyzing scenarios with the developed decision-making algorithm. All system components of scenarios have been modelled in the tool with their relations. The potential positive impact of the algorithm to energy efficiency, CO_2 emissions, and fuel savings have been investigated and were rated with a sample design regarding a green farm. In this respect, three scenarios were considered with the objective of maximizing the average rational exergy management efficiency. The first case is about fossil fuel-based conventional energy resources, systems, and equipment like boilers, chillers and grid electric power. The second case includes absorption-cycle cooling system, natural gas driven cogeneration system, heat pumps, and heat and cold storage systems. The third case includes alternative fuel, namely biogas, and renewable energy systems like solar panels, and wind turbines. After all energy conversion system requirements and demand inputs collecting firstly energy supplied values by components, their costs for selected capasities and fuel consumptions were calculated. Secondly average rational exergy management value of each scenario were analyzed for different exergy efficiency values among energy supply and energy demand allocations. At the last step, total carbon dioxide emission values of the scenarios were calculated using exergy efficiency values of each components and total power/energy demands. A composite objective function was compared to a basic scenario about furnishing the power and energy demand of the farm. In the composite objective function, the ratio of exergy efficiency improvement, carbon dioxide emissions reductions, and simple payback period reduction between those scenarios were represented with different weighing functions and calculations were made.

Results

According to the sample results, the rational exergy management efficiency was increased to 0.55 in the green farm that had renewable energy use like biogas-fueled combined heat and power, heat pump, and solar and wind energy. In the same scenario, it has also observed in the main scenario that the carbon dioxide emissions of 571 tons CO_2/year were reduced to 61 tons CO_2/year. These results have showed that the relationship between the exergy efficiency,CO_2 emissions, energy/fuel consumption are almost in direct proportions.

The simple payback ratios between the base scenario and others were analyzed by calculating the initial investment costs of energy conversion systems and energy/fuel costs with the determined sample values in those scenarios. Minimized composite objective function values were reached at the last scenario, which has renewable energy methods. These values have indicated maximum ratio of exergy efficiency improvement, carbon dioxide emissions reductions, and simple payback period reduction reached between base scenario and last scenario.

Conclusions

In this study, an analysis method was developed based on the Rational Exergy Management Model. Carbon dioxide emissions, energy consumption, energy efficiency, fuel economy has been analysed for different scenarios of energy resources, systems and equipment blend. According to the basic scenario, rationality of the other alternatives have been discussed. Among the alternatives the exergy efficiency increase by almost two-fold and the decrease in the carbon dioxide emissions is about eight / nine-fold.

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