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A DEA/Goal Programming Model for Incineration Plants Performance in the UK

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Abstract

Incineration plants in UK carry out two important tasks: reduction of waste disposed to landfills, and power/heat production from waste incineration distributed to the grid. However, incinerating waste produces, except for desirable outputs like exported power, harmful emissions, too. In this work, a DEA/Goal Programming model is presented to assess the performance of each incineration plant. Data from 22 incineration plants have been collected regarding capacity (waste and power), power exported, annual availability and levels of harmful emissions. The proposed model provides an allocation of the examined incineration plants, by shutting down a plant if it doesn't meet environmental targets. Additional constraints are considered regarding levels of power exported and annual availability. The model is solved for multiple scenarios regarding the number of incineration plants that will be eventually installed. Results are provided regarding the optimal allocation of each incineration plant and the optimal values of under and over achievement of each environmental target. Additionally, a comparative analysis is conducted on the scores derived from the proposed method and DEA models that handle both desirable and undesirable outputs. No differences between the two rankings are derived by applying statistical analysis.

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1. Introduction

A total of 170 million tonnes of waste is produced from households and businesses in England and Wales each year [*Sambrook L, 2015.*]. There are multiple ways of handling and treating municipal waste. These are: a) landfilling, b) mass burn with energy/heat recovery, c) waste recycling and finally d) waste composting [*Daskalopoulos E, et al, 1998*]. Regarding landfilling, a waste reduction has been reported in years 2005 – 2006. This

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waste reduction in UK over the past years is partly ought to Directive 1999/31/EC [*Directive C. DIRECTIVE 1999*], which imposed regulations and set targets regarding biodegradable municipal waste. An alternative way of reducing waste is by incinerating it. With municipal waste incineration, there are benefits (power export, heat produced) but also undesirable excipients (harmful gas emissions, bottom ash etc). However from bottom ash, ferrous and non-ferrous products can be derived. Concentrating mostly on the hazardous gas emissions from municipal waste incineration, several studies are presented which provide information regarding concentrations of gas emissions. Thus, it has also been reported that municipal waste incineration can help in greenhouse gas (GHG) emissions reduction, under specific conditions [*Papageorgiou A et al, 2009*]. Except for the contribution in GHG reduction, during incineration procedure for power/heat production, it has been reported that polychlorinated biphenyls (PCB) and polycyclic aromatic hydrocarbons (PAH) are emitted [et al, 2003]. Life cycle analysis (LCA) is also another tool of assessing environmental impact of wastewater [*Gallego A, et al, 2008*] and MSW facilities [*Zografidou E, et al, 2015*].

2. Methodology

The need to assess incineration plants is of great significance as multiple characteristics must be taken into account. One of the methods that handle this multi-dimensional analysis is Data Envelopment Analyis (DEA). However, as DEA is a methodology that provides efficiency scores based on pre-determined inputs and outputs, information regarding the performance and each Decision Making Units (DMUs) is extracted. Integrating Goal Programming (GP) and DEA, decisions regarding not only efficiency assessment, but also regarding the selection (or not) of a DMU is possible, setting goals modeling multiple aspects of the problem (economic, environmental, social etc). [8].

In this paper a hybrid GP/DEA model is presented. The model integrates binary variables in order to demonstrate which incineration plant is selected based on environmental and operational targets. The proposed model is based on an existing GP/DEA model [*Izadikhah M, et al, 2003*] and extends its features by providing additional information to Decision Maker (DM). The proposed GP/DEA model selects the entities (DMUs) based on a selection of environmental goals and operational constraints. This characteristic allows the model to examine the DMUs (in this case incineration plants) that over or under perform based on the goals.

The data used in this paper are derived from environmental agencies and papers published in the relevant literature and are selected to capture model environmental, capacity and operational characteristics of each incineration plant. The production process that is assumed in this case is that based on waste and power capacity of each incineration plant, exported power and harmful gasses and particles are emitted. Also, annual availability of each plant is taken into account, even if, it is not part of the production process.Decision variables are considered in this model in order to select those incineration plants, and eventually the number of incineration plants that must operate in order to satisfy environmental constraints, and to maintain the power exported to the grid. As these two characteristics (power produced and harmful gas emissions) are linearly dependent (i.e. the more power generated, the more the environmental pollution) and are therefore taken into account in the form of goals (for gas emissions) and of constraints (for power generated). Annual availability is considered also in this model, as based on statistical analysis, the more the annual availability is independent from power exported to the grid. Scenarios regarding the number of possible facilities that will be selected are also conducted.

With the proposed formulation, it is possible to evaluate and eventually select that incineration plant that satisfies a series of data that are defined in advance from the DM. Due to the flexibility of GP modeling, it is possible to incorporate, except for straightforward data for technical, economic and environmental characteristics of each incineration plant, data regarding people's opinions and views towards these plants.

2.1 Mathematical Formulation

2.1.1 Nomenclature