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Strategic Planning for Managing Municipal Solid Wastes with Consideration of Multiple Stakeholders

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Supporting Information

ABSTRACT: Management of municipal solid waste (MSW) involves multiple stakeholders such as government agencies, suppliers, consumers, providers of treatment/recycle services, and transporters. An optimal management strategy should be based on creating synergistic opportunities that benefit the multiple participants. This paper presents a multi-objective optimization approach for the strategic planning of a municipal solid waste management system. The formulation considers the involved tasks such as recycle, reuse, transportation, separation, and distribution. The proposed approach also accounts for the multiple stakeholders with the objective of maximizing the benefit to all the participating stakeholders. The Latin Hypercube sampling technique is adopted to systematically generate weights for the different stakeholders. A case study from Mexico is analyzed where three scenarios are considered. The first one considers that the separation cost is absorbed by each recycling company. The second one assumes that the government is responsible for the separation cost. The third one requires household inhabitants to carry out waste sorting. The optimization approach is used to analyze the results of the various scenarios and to deduce valuable insights on the interaction among the various stakeholders and the building blocks of the supply chain of MSW management systems.

KEYWORDS: *Municipal solid waste, Strategic planning, Waste management, Multi-objective optimization, Multi-stakeholders, Weighting technique*

INTRODUCTION

As a result of population growth and economic development, the generation of municipal solid waste (MSW) has increased drastically. Currently, the average MSW generation is 1.2 kg per person per day with an estimated increase of 1.4 kg/capita/day by the year 2025.[1] Landfilling represents the main option for waste disposal in several parts of the world (Leme et al., 2014).[2] Nonetheless, landfilling is an ineffective way to manage the residues because it causes degradation of valuable land resources, increases the land cost, and creates long-term environmental and human health problems.[3] Therefore, sustainable and efficient waste management systems are needed to improve MSW management.[4]

Developing an optimal MSW management system is a complex task. It involves the optimal selection of the waste collection routes, transfer station facilities, treatment strategies, treatment plant locations, and energy recovery.[5] Recent research efforts have endeavored to address MSW management systems. Warren and El-Halwagi studied the conversion of MSW to hydrogen and liquid transportation fuels.[6] Chen and Chang developed a model to assess the performance of a MSW recycling system in Taiwan.[7] However, aspects such as costing and environmental protection were not considered in this approach. Tan et al. reported an optimization model to integrate the four most used recycling technologies to obtain a cost-effective processing network in Malaysia.[4] Vadenbo et al. presented a multi-objective mixed-integer linear programming (MILP) model for making decisions about the waste and resource management in industrial networks.[8] Rada et al. reported an approach to consider

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Optimal planning for the supply chain of biofuels for aviation in Mexico

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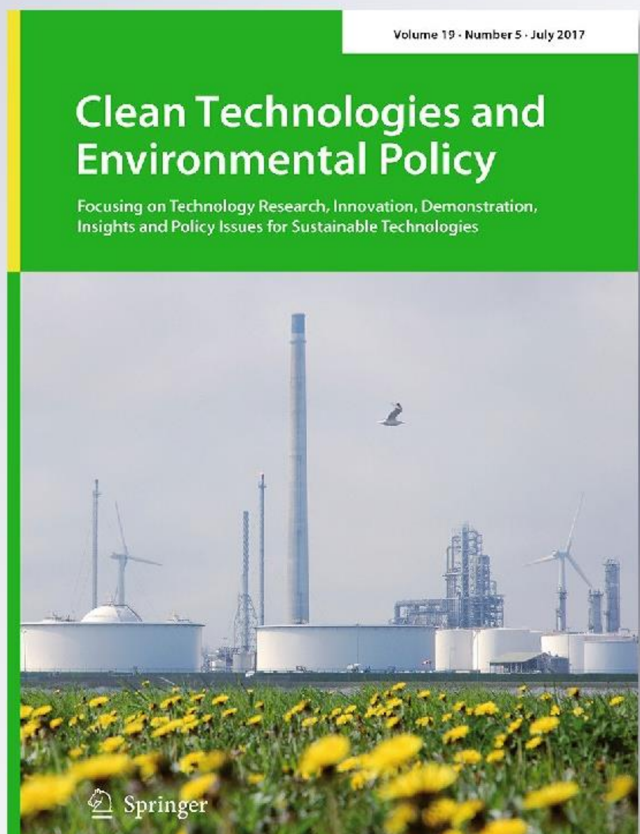

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Análisis de los factores que influyen en el diseño y control óptimo de sistemas de poligeneración: revisión

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Resumen

Los sistemas de poligeneración, debido a su flexibilidad de operación y eficiencia, se han convertido en el núcleo tecnológico de los sistemas de generación distribuida. Sin embargo, el diseño y control de estos sistemas envuelve múltiples factores asociados con el tratamiento de la demanda energética, condiciones ambientales, el diseño de las tecnologías, los costos del mercado energético, impacto ambiental y el impacto social de las nuevas tecnologías. En este trabajo se muestra una perspectiva integral de solución del problema por medio de algoritmos de optimización. Se consideran objetivos económicos, ambientales y sociales asociados a la operación de sistemas de cogeneración y trigeneración. Los modelos analizados permiten determinar la configuración tecnológica y el dimensionamiento del sistema, así como la política de operación.

***Palabras clave*:** Poligeneración, diseño óptimo, optimización multi-objetivo.

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Optimal design of energy and water supply systems for low-income communities involving multiple-objectives

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ABSTRACT

This paper proposes the use of Combined Heat and Power systems for providing water and energy, and thermal and electric utilities, in geographically isolated communities, where the interconnection with the grid is not available. A common design practice is to implement different energy storage technologies, usually batteries, for reducing the gap between energy generation and electric consumption. However, in communities with low incomes, it is not possible to use batteries due to the high capital costs. This work presents a new approach for providing simultaneously electricity and water using the fresh water extraction and storage for reducing the gaps between generation and consumption. The proposed approach is based on a mixed integer nonlinear programming formulation, which accounts for the optimal selection of multiple combined heat and power technologies and the sizing of the water storage and pumping technologies. A multi-objective analysis is presented considering as objective functions the economic costs and environmental impact associated with the space used by the system and water consumption. A community in the mountains of Mexico is presented as case study. The results show that it is possible to provide energy and water at low costs and reducing the environmental impact, reaching a trade-off between the considered objective functions.

1. Introduction

The economic and technological developments have generated multiple satisfiers to society. One of the most important is the electric power supply. According with data of The World Bank, by 2012 around 85% of the world population had access to electricity [1]. It means that there are communities that do not have electric utilities. The main reasons why these populations lack elementary energy utilities are varied. First, the geographical conditions that make difficult to interconnect to the grid isolated communities [2]. Furthermore, sometimes the needed energy is not significant from an economic point view, and to expand the grid to some far locations results in a non-profitable investment [3]. In developing countries, these conditions are remarkable, especially in rural areas where there is concentrated most of the population without access to energy utilities [4]. The situation of these communities is complicated considering the low-income of the local population and the lack of other basic utilities (i.e., water) [5]. A water pumping system is the typical used approach to extract, transport and supply water; but, its operation is limited by the availability of energy sources. In addition, low-income communities frequently have not enough economic resources for covering the costs associated to pumping, and frequently it is needed to transport the water from remote places [6]. Considering this background, integral energy systems capable to provide water and energy at low costs are needed for solving the situation of these isolated communities.

The off-grid and island operation of energy systems have been addressed using technologies based on renewable sources or conventional systems as wind [7], solar [8], wave [9], solar-wind [10], Combined Heat and Power (CHP) [11], biofuels [12], Rankine cycles [13] or hybrid systems using multiple technologies [14]. Despite the development of these systems, it is possible to detect at least two significant problems for implementing the off-grid systems in low income and isolated communities. The first one is the availability of renewable resources, which depends on the geographic conditions. In regions with not significant bio-resources available, or wind or solar low potentials, it is not profitable the use of renewable technologies [15]. This fact leads to the second factor, which corresponds to the low income of the community. Some distributed energy technologies are significantly expensive, even though their efficiency, for applying in low income communities, it is a remarkable problem in developing countries [16]. Batteries have become in the core of the energy storage on off-grid systems, reducing the gaps between the energy generation and consumption [17]. However,

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Mixed Integer Nonlinear Programming Model for Sustainable Water Management in Macroscopic Systems: Integrating Optimal Resource Management to the Synthesis of Distributed Treatment Systems

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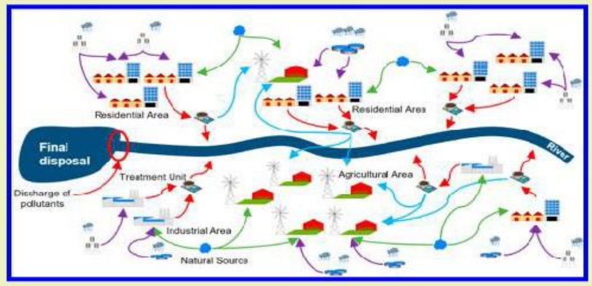
Supporting Information



ABSTRACT: Recognizing the growing pressure on water resources, the literature reports several efforts in the area of mathematical programming to deal with the management of industrial and macroscopic water systems. This paper presents a mathematical programming model which integrates two strategies for sustainable water management. On the one hand, the model allows finding an optimal schedule for the distribution and storage of natural and alternative water sources to satisfy the demands of different users in a macroscopic system, while maintaining sustainable levels of water in the natural water resources. On the other hand, optimal decisions also involve the number, capacity, type, and location of treatment units in a macroscopic system. Our approach results in a mixed integer linear programming (MINLP) multiperiod model which has been solved through the GAMS modeling environment. A case study with different scenarios shows the scope of the proposed approach and the significance of the results.

KEYWORDS: *Sustainable water management, Mathematical programming, Distributed water treatment systems, MINLP formulation, Macroscopic systems*

INTRODUCTION

One of the many concerns for the sustainable development of the current and the future generations, regarding many challenges such as population growth and climate change, is the need for a safe and adequate supply of fresh water. A 40% deficit over the world's water supply is projected under the current management and consumption by the year 2030.[1] Furthermore, the increasing demand of water to produce energy and the lack of control of waste generation and disposal over water bodies only exacerbate the problem of reduced water supply capability.[2]

It is currently believed that there is enough fresh water available in the world to meet all of the demands from the different sectors of society.[3] However, in many regions, due to climate and/or concentration of population in bigger cities, the natural supply of water rarely meets the demand. To face these challenges, there have been many efforts in the area of mathematical programming to assess the feasibility of implementing different technologies to obtain water from nonconventional sources.[4−11] These nonconventional sources include the use of desalinated water, rainwater harvesting, and wastewater reuse.

The above approaches have in common that, no matter the water source, the problem to be solved is one about management of the resources, where the goal is to satisfy the demands of a given system at a minimum cost. One of these approaches[8] considers the use of water collected from rain in addition to the conventional water sources, such as dams and deep wells, in order to satisfy the demand in a macroscopic system.

Another challenge about water management is one concerning wastewater. A substantial effort has been made in the area of process systems engineering to reduce environmental impacts over the water bodies.[12−22] Burgara-Montero et al.[17] proposed a distributed treatment system throughout a watershed to ensure the sustainability, concerning the pollution levels of the natural bodies of water. This approach uses the MFA (material flow analysis) technique to assess the system. In the analysis of these distributed treatment systems, one thing that has not been considered is the use of treated water as

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Article

Fermentable Sugars Production by Enzymatic Processing of Agave Leaf Juice†

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Defining priorities in the design of power and water distribution networks

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A B S T R A C T

This paper presents an approach for designing power and water distribution networks involving the sizing, geographic location, as well as the economic, environmental and social impacts, and taking into account the multiplicity of criteria for the stakeholders involved in the development of operational policies and new facilities. In this paper is presented a method for defining solutions concerning to the design of power and water distribution networks based on a multi-stakeholder environment. A multi-objective model, considering economic, environmental and social factors, is used for illustrating how the different criteria, about priorities of the stakeholders, affect the design of the system and how to propose a solution for achieving a tradeoff between the multiple stakeholders. The proposed method was applied to an electric and water stressed scheme in the north of Mexico, the results show that the minimization of the dissatisfaction of the involved systems can provide an optimal solution that meets the objectives of all stakeholders.

1. Introduction

Energy and water are very important resources for the development of the modern society. The growth of the urban areas, agricultural crops and industrial facilities has increased the use of both resources [1]. The distribution problems have increased significantly because of the availability of water and the current scheme of water and power distribution (centralized distribution) [2]. The development of liberalized electricity and water markets impels the design of new strategies [3], taking into account economic, environmental and social aspects [4]. In the case of water, the first problem is the allocation of water resources. The natural sources of fresh water are limited and the access is restricted by factors such as political issues [5], transportation cost, treatment [6], lack of adequate pricing policy on water supply [7], exploitation limits [8], policies based on rationalization of resources [9] and scarcity [10]. Due to these factors, the current water distribution systems have to consider the external consumption. Usually, water is transported from a source in remote areas. This way, the problems involved in the design of water distribution networks have different dimensions. The economic dimension of water distribution networks has been addressed considering aspects as cost of treatment intended for human consumption [11] or for sanitary use [12], cost of pipelines [13], maintenance of the network [14], pumping [15], efficiency in energy consumption [16], cost of utilities [17] and cost of extraction [18]. The environmental dimension has considered the life cycle assessment analysis [19], emissions generated by system [20] and reducing water losses [21]. The social dimension has focused on improving the behavior of the final user [22], final usage [23] and conflicts in the distribution between different communities and users [24].

The design of power distribution networks has similar problems to the water distribution networks. The economic dimension of the design has considered sizing system [25], reducing energy losses in distributed generation [26], and transmission based on centralized generation [27], increasing the generation efficiency [28], maximizing the profit [29], improving the fuel consumption [30] and the maintenance of the transportation lines [31]. The environmental dimension has focused on the emissions [32], life cycle assessment [33] and water consumption [34]. The social impact involves the response of the system to the behavior of the end user [35] and the economic benefit to local communities [36]. The power distribution

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Optimal Design of Water Desalination Systems Involving Waste Heat Recovery

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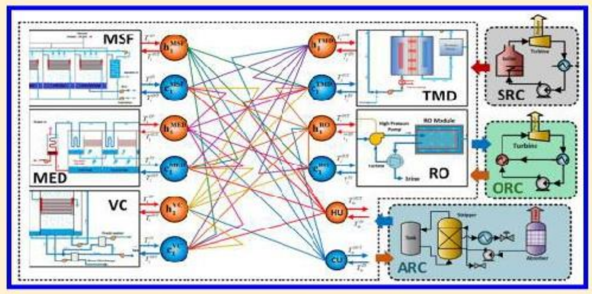
Supporting Information



ABSTRACT: Water desalination appears as an attractive alternative to provide fresh water in several parts of the world. However, this process is very expensive due to the high-energy consumption, and as consequence, significant pollution is produced due to the burning of fossil fuels that yield huge emissions of CO_2. Furthermore, most of the desalination processes yield a lot of waste heat at low temperature, which can be recovered. Therefore, this paper presents an optimization approach for designing water desalination systems involving heat integration and waste heat recovery to reduce the desalination cost, energy consumption, and overall greenhouse gas emissions. The proposed approach accounts for the optimal selection of existing and emerging desalination technologies based on the heating and cooling requirements and incorporating waste heat recovery systems. The integration of the proposed systems provides power and thermal energy to the desalination task. Also, the proposed approach includes the optimal selection of fossil fuels, biofuels, and solar energy as energy sources. The proposed approach was applied to a case study, and the results show that the system that involves the multiple-effect distillation and thermal membrane distillation shows the best economic and environmental benefits involving water sales, power production, and energy savings.

1. INTRODUCTION

Despite the effort to improve desalination technologies, seawater desalination still is an energy-intensive process, and it requires high amounts of fossil fuels, which contribute to global warming.[1] While some countries have high reserves of oil and gas, others depend on fossil fuel imports to satisfy their energy demands. In addition, the continuous increase in fossil fuel prices and environmental restrictions limit the use of this technology.[2] Even so, water desalination still is the best option to satisfy water demands in several water-stressed areas around the world. Nevertheless, it is required to propose integrated energy desalination schemes, where the economic, environmental, and social objectives are considered.

Many efforts have been developed to improve water and energy efficiencies in seawater desalination schemes. In this context, Abduljawad and Ezzeghni developed an optimization approach for multistage flash (MSF) desalination systems; they found that the seawater feed temperature has an important effect on the performance of the plant.[3] Khoshgoftar-Manesh et al. proposed an optimization procedure for coupling multi-effect distillation (MED) and reverse osmosis (RO), where a site utility system was integrated and heat and power were produced to run the desalination system; the results showed a series of Pareto solutions for cost of water versus gain output ratio (GOR).[4] Altaee and Zaragoza presented a mathematical model for integrating MSF and forward osmosis (FO) desalination systems, where the concentration of the MSF unit is sent to the FO unit to improve the process efficiency.[5] Iaquaniello et al. introduced an economic analysis for integrated MED and RO powered with concentrated solar energy and involving thermal storage; the results showed economic benefits where the lifetime plays an important role.[6] Al-Weshahi et al. presented a parametric study for recovering residual heat from an MSF desalination plant through an organic Rankine cycle (ORC); the results showed attractive solutions.[7] Dahdah and Mitsos proposed a multiobjective optimization model for the simultaneous synthesis of MED and MSF, where the model accounted for both standalone or dual purpose desalination (water and power); then, this model was extended adding vapor compression (VC) desalination yielding further thermodynamic and economic advantages.[8,9]

Other strategies include heat integration and heat exchanger network (HEN) synthesis.[10−14] These strategies have been applied into the desalination field. Lu et al. published a process integration strategy to reduce the desalination cost; the

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