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ACS Sustainable Chemistry & Engineering

Research Article

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Optimal Planning of Feedstock for Butanol Production Considering Economic and Environmental Aspects

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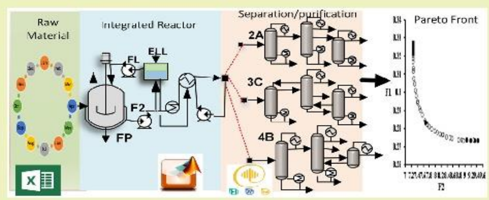
ABSTRACT: This paper presents a multiobjective optimization to obtain the optimal planning of butanol production, considering the optimal selection of feedstock and the correct ratio of fermentable sugars. This multiobjective methodology was applied during both the fermentation and purification process of butanol. The multiobjective optimization problem considers minimizing the total annual cost and environmental impact as objective function. The economic objective function takes into account the availability of bioresources, the cost of feedstocks, the fermentation conditions, and the separation units. On the other hand, the environmental assessment includes the overall impact measured through the eco-indicator 99 which is based on a life cycle analysis methodology. Both objective functions were applied to a case study for the optimal planning to produce biobutanol in Mexico. After the optimization process, we generated a set of solutions represented by a Pareto curve that identifies a group of optimal solutions for both objectives. Considering the best compromise of both targets, the best solution involves initially a raw material with a moderate content of sugars followed by a separation unit designed as a hybrid separation process. This hybrid process considers the inclusion of a liquid−liquid extraction column followed by three thermally coupled distillation columns.



KEYWORDS: *Butanol production, Fermentable sugars, Butanol fermentation, Butanol feedstock planning*

■ INTRODUCTION

The increasing world energy demand has motivated the search for alternative energy sources as a possible substitute in the medium- and long-term for fuels from fossil sources. Those alternatives must also take into consideration the damage to the environment. Reducing dependence on fossil fuel is a key element of the energy policy adapted by many nations.[1] Recently attention has centered on renewable alternatives that could be produced from lignocellulosic raw material to meet the above-mentioned demands. Due to the physicochemical properties that butanol presents, mainly the energy content, there has been increased interest in its development by means of the fermentative route with the intention of implementing it as a fuel.

Current commercial biobutanol processes are based on fermentation of starch or sugar-based feedstocks such as corn[2] and molasses.[3] Most existing biobutanol plants use corn, which competes with food and animal feed. The relatively high cost of corn leads to higher butanol production cost. For this reason, there has been a growing research interest in developing technologies for producing biofuels such as butanol from nonfood cellulosic biomass including whey permeate,[4] dried distillers' grains and solubles,[5] corn fiber,[6,7] corn stover,[8] corn stalk,[7] rice bran,[9] rice straw,[10] barley straw,[6] wheat straw,[11−13] wheat bran,[14] switchgrass,[8] and cassava bagasse.[15] The production of butanol from these materials has a yield and concentration of product similar to those of the fermentations with corn; however, a detailed economic and technical evaluation is necessary to determine the feasibility of these processes.[16]

Commonly, butanol is a chemical with increasing demand and is also considered as a possible biofuel.[17] Nowadays, butanol is almost exclusively produced via chemical routes from fossil fuels through the oxo synthesis also known as hydro formylation. On the other hand, butanol can also be obtained by means of anaerobic fermentation typically using some of the Clostridial bacterium strains, such as *Clostridium acetobutylicum*, *Clostridium beijerinckii*, *Clostridium saccharobutylicum*, and *Clostridium saccharoperbutylicum*.[17,18] This kind of fermentation is called ABE fermentation, since acetone, butanol, and ethanol are obtained as the main products in a typical ratio of 3:6:1.

In contrast with bioethanol, the microorganisms involved in the ABE fermentation have the ability to consume a great variety of substrates which could be enriched in glucose, saccharose, lactose, xylose, starch, and glycerol.[19,20] Recently, some works have shown that Clostridium family strains can also

Received: January 3, 2017
Revised: March 1, 2017
Published: April 6, 2017

DOI: 10.1021/acssuschemeng.7b00015
ACS Sustainable Chem. Eng. 2017, 5, 4018−4030

Process Integration and Optimization for Sustainability (2017) 1:275–292
https://doi.org/10.1007/s41660-017-0022-1

ORIGINAL RESEARCH PAPER

Optimal Design of Water Distribution Networks with Incorporation of Uncertainties and Energy Nexus

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Received: 2 August 2017 / Revised: 6 November 2017 / Accepted: 8 November 2017 / Published online: 1 December 2017

Abstract

The reliability of water distribution networks is susceptible to large impacts resulting from uncertainties. Several factors may contribute to such uncertainties. These include nodal demands, reservoir/tank levels, and availability of system components. Additional sources of uncertainties arise when water-energy nexus is considered. For instance, when water desalination systems that are coupled with power plants are incorporated in the water distribution networks, uncertainties in energy demand influence the design of the water network system. In this work, a multi-objective optimization framework is developed for the design of water networks that involve dual-purpose power plants for simultaneous water desalination and power generation. The multi-objective model accounts for sustainability goals through environmental, economic, and societal metrics such as greenhouse gas emissions, net profit, and number of jobs created, respectively. Fossil fuels, as well as renewable biofuels and solar power, are considered as candidate sources of energy. Water resources include multiple systems such as dams, lakes, rivers, aquifers, and artificial storage lakes. Demands from agricultural, industrial as well as domestic needs in the region are considered. In order to incorporate uncertainty in the proposed approach, a stochastic optimization model is formulated with a probabilistic objective function and constraints. The network has multiple sources as well as demands with varied distributions. In order to find an overall distribution for probability density estimation, a decomposition scheme is applied where each scenario is solved separately as a sub-problem. The solution from sub-problem is used to find the probability using kernel density estimator. The modified model equations lead to a stochastic MINLP problem. The proposed framework and optimization formulations are applied to a case study in the Mexican state of Sonora. From the demand and natural resource distribution, 12 scenarios have been identified and the model is weighted by their probability of occurrence. The results are compared with the deterministic solution to obtain the cost associated with uncertainty.

Keywords Optimization under uncertainty · Multi-objective optimization · Water distribution networks · Dual-purpose power plants · Sustainability · Expected value of perfect information (EVPI)

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Nomenclature

Indexes

g Location of agricultural users
i Existing aquifer
j Deep wells
n Location of existing power-desalination plant
N Number of scenario
o Location of industrial users
p Location of existing water storage tanks
q Possible location of new water storage tanks
r Location of domestic users
s Scenario
u Possible location of new power-desalination plant
x Existing dam as natural resources

ACS Sustainable Chemistry & Engineering
Research Article
pubs.acs.org/journal/ascecg

Optimal Design of Energy Systems Involving Pollution Trading through Forest Plantations

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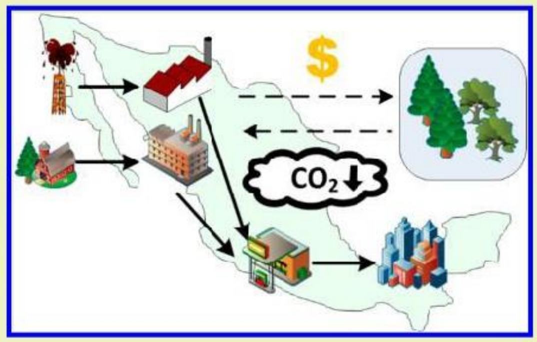

ABSTRACT: The production and use of fossil fuels have caused a drastic increase in greenhouse gas emissions, which is associated directly with the global warming problem. Biofuels and carbon capture through forest plantations are interesting alternatives to address this problem. This paper presents an optimization model for the design of an integrated energy system for producing fuels and biofuels considering the interaction with eco-industries able to capture emissions from biorefineries and refineries and receive a monetary benefit. The proposed mathematical model takes into account the availability of biomass, the production of oil, and a set of existing biorefineries and refineries as well as the possibility to install new eco-industries. The mathematical approach was applied to a nationwide case study for Mexico, considering the creation of new jobs, overall emissions, and net profit as objectives. The results are shown in a Pareto curve, which is useful for making decisions about the interactions between these industries as well as determining the configuration of the supply chain to satisfy the fuel demands.

KEYWORDS: *Biofuel supply chains, Sustainable biorefineries, Optimal planning, Eco-industries, Carbon capture*

INTRODUCTION

Fossil fuels typically generate large amounts of greenhouse gas emissions, which are associated with the global warming problem. It is important to note that small increments in the global temperature involve drastic consequences in the world population. For this reason, Lundgren et al.[1] stated that it is necessary to limit the greenhouse gas emissions from human activities. This way, CO_2 is considered to be a predominant greenhouse gas, which has become an urgent environmental issue (see the work of Sun et al.[2]). Furthermore, several authors have suggested alternatives to address this problem, mainly involving renewable energy sources. In this regard, according to Hong et al.,[3] the use of biofuels is a sustainable way to satisfy the energy needs, because they help to decrease greenhouse gas emissions.[4] Besides, biomass has been identified as a highly potential renewable energy source for producing biofuels, chemicals, and other value-added products using several processing technologies.[5] However, to consider the large scale production of any product, it is crucial to develop tools to aid the decision-making process; for instance, Azapagic and Clift[6] proposed the use of multiobjective optimization to take into account several environmental objective functions. For the case of biofuels from biomass, Torjai et al.[7] stated that the entire supply chain must be analyzed from the economic, environmental, and social points of view. According to Marufuzzaman et al.,[8] biomass is bulky and difficult to transport, impacted by seasonality, and widely dispersed geographically. In addition, Elia and Floudas[9] stated that there is a lack of contributions about the planning of the supply chain from the processing facilities to the final consumers (downriver of the supply chain). Eskandarpour et al.[10] analyzed a set of papers focused on the sustainable supply chain design, and they concluded that there is a lack of works accounting for social objectives. Along this line, Zhang et al.[11] developed an approach for the supply chain design taking into account the total cost, the greenhouse gas emissions, and the lead time as the economic, environmental, and social objectives. Several works have addressed biomass-to-energy supply chains considering different relevant issues.[12] Frombo et al.[13] proposed a decision support system for planning of a system based on energy production from biomass.

Received: December 1, 2016
Revised: January 11, 2017
Published: January 17, 2017

DOI: 10.1021/acssuschemeng.6b02928
ACS Sustainable Chem. Eng. 2017, 5, 2585−2604

Journal of Cleaner Production 165 (2017) 190–203

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Dynamic optimization for the planning of a waste management system involving multiple cities

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A R T I C L E I N F O

Article history:
Received 4 January 2017
Received in revised form
12 June 2017
Accepted 8 July 2017
Available online 12 July 2017

Handling Editor: Yutao Wang

Keywords:
Waste management system
Mixed-integer dynamic optimization
Strategic planning
Municipal solid waste

A B S T R A C T

Consumption habits and population growth have drastically increased the waste production around the world. However, several developing countries do not have an adequate waste management system. This way, a mathematical model for the optimal planning of a waste management system could be a useful tool to make decisions about the design of a waste processing system to promote sustainable public polices and cooperation among multiple cities. Therefore, this work proposes a mathematical formulation for the optimal planning of a waste management system considering waste from different neighboring cities divided in several sites, as well as the dependence over time for the variables and parameters through a set of differential equations for properly capturing the associated dynamic behavior. Results show that given the data of potential locations for sites, landfills, processing plants and consumers, as well as prices of useful products, availability of waste, upper and lower limits, unitary costs for the different activities carried out in the waste management system and initial values for inventory and order levels, it is possible to obtain the optimal selection and location of the entities of the waste management system as well as the plant capacities and material flows to be transported, processed, stored and sold. The proposed mathematical formulation is general and it can be applied to any waste type, involving different landfills, sites, cities, processing routes and processing plants. Although the CPU time increases for considering the dynamic behavior, it is proved that the associated costs decrease significantly.

1. Introduction

The generation of waste is a serious problem around of the world, particularly for countries where the municipal solid waste (MSW) management is not well established (Abarca-Guerrero et al., 2013); which has increased drastically from 0.5 kg/(person day) to 1.7 kg/(person day) in the last years (Ramayah et al., 2012). In fact, according with Ye et al. (2015), the domestic waste disposal consumes many valuable land resources, which destroy the urban landscape, pollute the environment, spread diseases and seriously threaten human health. For example in developing countries like Turkey, solid waste has increased due to industrializing (Arikan et al., 2017).

Additionally, the rapid population growth and changing life standards can change the waste volume and composition, which could cause a difficult waste management (Arikan et al., 2017). For example, if the inhabitants in a city modify their consumption habits from water bottles to water cans, the waste composition will change and the waste plastic volume could decrease. On the other hand, if a city's population increases, then the waste volume probably increases too. In this context, Marchi et al. (2017) stated that the waste sector is an important source of greenhouse gas emissions; for example, for the Siena district in Italy, this sector represents around 12%. For some of the previous reasons, Balaban and Baki (2010) showed that the waste management is a social and a multicriteria decision problem that involves politic, socio-cultural, technical, financial and environmental factors.

Besides, recently the strategic planning of supply chains involving sustainability aspects has been addressed. In this context, Tan et al. (2014) stated that a sustainable and efficient waste

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http://dx.doi.org/10.1016/j.jclepro.2017.07.063
0959-6526/

ACS Sustainable Chemistry & Engineering

Research Article

pubs.acs.org/journal/ascecg

Optimal Design of Multiplant Cogeneration Systems with Uncertain Flaring and Venting

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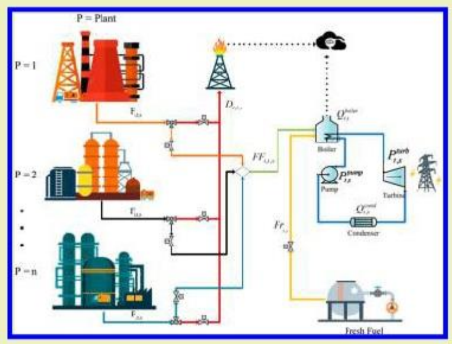
Supporting Information



ABSTRACT: This paper presents an optimization approach for designing cogeneration systems using flares and vents under abnormal conditions from different industrial plants. The aim of the proposed approach is to enhance resource conservation by utilizing waste flares and vents to produce power and heat while reducing the negative environmental impact associated with discharging these streams into the atmosphere. A nonlinear optimization model is proposed to determine the optimal design of the cogeneration system that maximizes the net profit of the system. The model addresses the inevitable uncertainties associated with the abnormal situations leading to venting and flaring. A random generations approach based on historical data and a computationally efficient algorithm are introduced to facilitate design under uncertainty and to enable the assessment of different scenarios and solutions with various levels of risk. A case study is presented to show the applicability of the proposed model and the feasibility of using cogeneration systems to mitigate flaring and venting and to reduce the environmental impact and operating costs.

KEYWORDS: *Flaring, Venting, Abnormal situations, Cogeneration, CO_2 reduction*

INTRODUCTION

Current trends in using fossil fuels are not sustainable. In 2013, 91 million barrels of petroleum per day were consumed worldwide. Such usage also leads to a substantial carbon footprint. In 2013, 11 830.5 million metric tons of carbon dioxide were produced.[1] The energy production sector is the main contributor to releasing greenhouse gases (GHG) as it accounts for about 70% of all anthropogenic GHG emissions.[2] Notwithstanding of the various efforts to replace fossil fuels by sustainable energy forms and to optimize the energy use,[3] there is a critical need to do more toward a sustainable energy future.[4] Renewable energy sources, which include biomass, hydropower, geothermal, solar, wind, and marine energy, supply approximately 14% of the total world energy demand.[5] The United Nations project that the global population will grow from about 7 billion today to 9.3 billion in 2050 and 10.1 billion in 2100.[6] Nontraditional fossil fuels (e.g., shale gas) are expected to play an increasingly important role in meeting the growing demand for energy.[7−9]

In the fossil-based energy industry and chemical process industry, venting and flaring of flammable gases via combustion in open atmosphere flames is a common practice that leads to environmental concerns and economic losses.[10] Globally, approximately 150 billion cubic meters of natural gas are flared each year leading to about 400 million metric tons of CO_2 equivalent to the GHG emissions.[11] Furthermore, flaring produces a number of harmful byproducts such as nitrogen oxides, sulfur oxides, and volatile organic compounds. In the energy and process industries, flaring and venting are standard practices to deal with deviations from the normal operation process (for example, during process upsets, plant start-up or shut-down, and process emergencies), which are known as abnormal situations. The flow rates, compositions, and frequency of flares from abnormal situations are uncertain. The flares can be categorized as emission events and variable continuous emissions. Emission events are frequently discrete episodes (such a plant emergency) in which a very large flow is flared. Variable continuous emissions can occur frequently and these are categorized into multiple modes of operation, depending on the scale of the variability.[12]

Several options have been implemented to minimize industrial flaring. The feasibility of implementing any of these

Received: August 23, 2016
Revised: October 5, 2016
Published: October 26, 2016

DOI: 10.1021/acssuschemeng.6b02033
ACS Sustainable Chem. Eng. 2017, 5, 675−688