An anchor-tenant approach to the synthesis of carbon-hydrogen-oxygen symbiosis networks

Kevin Topolski a, Mohamed M.B. Noureldin b, Fadwa T. Eljack c, Mahmoud M. El-Halwagi d,∗

aThe Artie McFerrin Department of Chemical Engineering, Texas A&M University, College Station, TX 77843-3122, USA
bEngineering Solutions Process Technology Center, The Dow Chemical Company, Lake Jackson, TX 77566, USA
cDepartment of Chemical Engineering Qatar University, Doha, Qatar
dGas and Fuels Research Center, Texas A&M Engineering Experiment Station, College Station, TX 77843, USA

A R T I C L E   I N F O
Article history:
Received 26 September 2017
Revised 20 February 2018
Accepted 21 February 2018
Available online xxx

Keywords:
Eco-industrial parks
Sustainability
Mass integration
Targeting
Design
Synthesis

A B S T R A C T
Sustainable development of industrial cities and eco-industrial parks (EIPs) requires careful consideration and creation of synergistic opportunities among the participating entities. Recently, a multi-scale design approach was developed for carbon-hydrogen-oxygen symbiosis networks (CHOSYNs) with focus on the targeting, integration, and retrofitting of EIPs involving a set of existing facilities. Another important category of EIPs involves the grass-root design of industrial cities in which the participants are not originally known. Instead, “anchor” plants are first invited followed by the consideration and invitation of supporting facilities (referred to as “tenants”) that are to be determined according to integration opportunities with the anchors, other tenants, common infrastructure while accounting for resource limitations, market demands, and environmental regulations. The purpose of this work is to introduce a multi-scale targeting, synthesis, and optimization approach for the grass-root design of EIPs with known anchors. The CHOSYN framework is extended to tackle the case of candidate tenants with the objective of identifying industrial facilities, raw materials, byproducts, products, and wastes that can be effectively integrated with the anchors, among the participating tenants, and with the surrounding markets. Atomic-based and techno-economic targeting approaches are developed to identify benchmarks for mass integration within the EIP and to provide preliminary screening of the type and size of candidate tenants. Next, an optimization framework is developed to synthesize a highly-integrated and cost-effective cluster of anchors and tenants with sufficient design details on the individual facilities and the interaction among the participating plants. A case study is solved to demonstrate the multi-scale targeting, synthesis, and optimization approaches for the grass-root design of EIPs.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Industrial symbiosis is aimed at enhancing the competitive advantage of multiple industrial facilities through synergistic integration of mass, energy, information, and services (Chertow, 2000). An effective implementation for industrial symbiosis is through the establishment of eco-industrial parks (EIPs). An EIP is a special type of an economic zone in which multiple industries, businesses, and services are integrated to facilitate exchange of materials (e.g., intermediates, byproducts, water, and wastes) and energy with the objective of creating synergistic opportunities and enhancing the overall economic and environmental performance of the participating entities and the impacted communities. The benefits of developing EIPs include reduced raw material input while maintaining product output, reduced environmental consequences and reduced capital expenses by sharing unit processes (Lowe, 2001). Multiple examples of EIPs can be found around the world including those of public and private enterprises (Gibbs and Duetz, 2007).

Process systems engineering approaches have been proposed for the design of EIPs. A source-sink framework was proposed by Spriggs et al. (2004) to enable mass integration among multiple plants using the material-recovery pinch analysis developed by El-Halwagi et al. (2003). Optimization approaches for water integration in an EIP were developed to enhance water conservation and cost effectiveness. Chew et al. (2008) introduced an optimization approach for designing interplant water networks. Lovelady and El-Halwagi (2009) adopted a mass-integration framework for the synthesis of water-reuse systems for EIPs. Bandyopadhyay et al. (2010) used segregated target-networks. Lovelady and El-Halwagi (2009) adopted a mass-integration framework for the synthesis of water-reuse systems for EIPs. Bandyopadhyay et al. (2010) used segregated target-
Nomenclature

Indices
\( a \) Atom
\( c \) Key Component
\( c_r^i \) Reactant of Reaction \( r \)
\( c_r^k \) Product of Reaction \( r \)
\( i \) Source
\( j \) Interceptor
\( k \) Tenant Plant
\( m \) Species Sorting-Reaction Stages Superstructure
\( p \) Anchor plant
\( u_i^m \) Interceptor \( j \) Inlet Port
\( u_j^m \) Interceptor \( j \) Outlet Port
\( r \) Reaction
\( u_i^k \) Tenant Plant \( k \) Inlet Port
\( u_j^k \) Tenant Plant \( k \) Outlet Port

Parameters
\( \text{Atom Set}_{c,a} \) Quantity of Atom \( a \) in Component \( c \)
\( F_{\text{Supply}}^i \) Supply Limit on Flowrate of Source \( i \)
\( F_{\text{Demand}}^c \) Demand Limit on Flowrate of Component \( c \)
\( X_{i,c} \) Mole Fraction of Component \( c \) in Source \( i \)
\( Y_{r,c} \) Yield of Component \( c \) in Reaction \( r \)
\( \alpha_{r,c} \) Stoichiometric Coefficient of Component \( c \) in Reaction \( r \)

Positive variables
\( \text{Atom}_{\text{demand}}^a \) Outlet Rate of Atom \( a \) as Products in Atomic Tracking and Economic Data Targeting
\( \text{Atom}_{\text{source}}^a \) Inlet Rate of Atom \( a \) from Sources in Atomic Tracking and Economic Data Targeting
\( \text{Atom}_{\text{unutilized}}^a \) Outlet Rate of Atom \( a \) as Unutilized Components in Atomic Tracking and Economic Data Targeting
\( F_{\text{in}}^c \) Component Flowrate of \( c \) to Reaction Node \( r \) on Species Sorting-Reaction Stages Superstructure Stage \( m \)
\( F_{\text{out}}^c \) Component Flowrate of \( c \) out of Reaction Node \( r \) on Species Sorting-Reaction Stages Superstructure Stage \( m \)
\( F_{\text{Product}} \) Outlet Product Flowrate of Component \( c \) in Atomic Tracking and Economic Data Targeting
\( F_{\text{Recycle}} \) Split Stream Flowrate Exiting Tenant Outlet Port \( v_{i}^{\text{out}} \) to Interceptor Inlet Port \( u_i^m \)
\( F_{\text{Source}} \) Input Source Flowrate of Component \( c \) in Atomic Tracking and Economic Data Targeting
\( F_{\text{Split}} \) Flowrate of Split Stream from Source \( i \) to Interceptor Inlet Port \( u_i^m \)
\( F_{\text{Stage}} \) Component Flowrate of \( c \) on Species Sorting-Reaction Stages Superstructure Stage \( m \)
\( F_{\text{Unutilized}} \) Outlet Unutilized Component Flowrate of \( c \) in Atomic Tracking and Economic Data Targeting

Variables
\( D_{\text{int}} \) Design Variable for Interceptor \( j \)
\( D_{\text{Tenant}} \) Design Variable for Tenant \( k \)
\( O_{\text{int}} \) Operation Variable for Interceptor \( j \)
\( O_{\text{Tenant}} \) Operation Variable for Tenant \( k \)
\( S_{\text{int}} \) State Variable for Interceptor \( j \)
\( S_{\text{Tenant}} \) State Variable for Tenant \( k \)

Stream Flowrate Exiting Tenant Outlet Port
\( v_{i}^{\text{out}} \)

Split Stream Flowrate Exiting Interceptor
\( u_i^m \)

Outlet Port \( u_i^m \) on the Terminal Interceptor Network Stage to Tenant Inlet Port \( u_j^k \)

Extent of Reaction of Reaction \( r \) on Species Sorting-Reaction Stages Superstructure Stage \( m \)

Stream Flowrate into Interceptor Inlet Port
\( u_j^m \)

Stream Flowrate Exiting Interceptor Outlet Port \( u_j^m \)

Mole Fraction of Component \( c \) Entering Interceptor Inlet Port \( u_i^m \)

Mole Fraction of Component \( c \) Exiting Interceptor Outlet Port \( u_j^m \)

Mole Fraction of Component \( c \) Entering Tenant Inlet Port \( u_i^k \)

Mole Fraction of Component \( c \) Exiting Tenant Outlet Port \( u_j^k \)

Overall Reaction Coefficient of Component \( c \) Converted in Atomic Tracking and Economic Data Targeting

Extent of Reaction of Reaction \( r \) in Atomic Tracking and Economic Data Targeting

\( \xi_r \)

Floudas et al. (2016) provided a comprehensive survey of multiscale systems engineering approaches that account for manufacturing, energy, and environmental perspectives.

Recently, a multiscale mass integration approach was introduced by Noureldin and El-Halwagi (2015) to synthesize carbon-hydrogen-oxygen symbiosis networks (CHOSYN). According to this approach, atomic-based targets can be set for the integration of multiple plants within an EIP. Next, multi-scale optimization can
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات