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Methodological aspects of applying eco-efficiency indicators to industrial symbiosis networks

Hung-Suck Park [a, b, *], Shishir Kumar Behera [a, c]

[a] Center for Clean Technology and Resource Recycling, University of Ulsan, Ulsan, South Korea
[b] Ulsan EIP Center, Korea Industrial Complex Corporation, Ulsan, South Korea
[c] Department of Chemical Engineering, GMR Institute of Technology, Rajam, 532127 Srikakulam, AP, India

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ABSTRACT

In this study, we proposed eco-efficiency indicator as an integral parameter for simultaneously quantifying the economic and environmental performance of industrial symbiosis (IS) networks. Based on the World Business Council for Sustainable Development definition of eco-efficiency, the eco-efficiency indicators proposed include one economic indicator, and three generally applicable simplified environmental indicators (raw material consumption, energy consumption, and CO_2 emission). Three eco-efficiencies corresponding to three environmental indicators are assessed using seven IS networks that were developed between 2007 and 2012, which are currently operational in Ulsan Eco-Industrial Park (EIP), South Korea. Our results indicate that the eco-efficiency of individual IS networks improved up to 28.7%. Besides, the evolution of seven IS networks comprising 21 companies resulted in an overall eco-efficiency enhancement of about 10%. The proposed eco-efficiency indicators for IS networks can be easily utilized to communicate with decision makers at any level to assist in transforming conventional industrial complexes to EIP. The implications of the study and limitations of the methodology are delineated.

1. Introduction

Rapid economic growth has resulted in unsustainable patterns of consumption of consumer goods and natural resources, especially in the Asia Pacific region (Chiu and Geng, 2004). To maximize resource efficiency while minimizing pollutant emissions, countries such as China, Taiwan, Korea, and Japan in the Asia Pacific region have recently initiated national eco-industrial park (EIP) demonstration programs (Shi et al., 2010; EPA, 2008; Park et al., 2008; van Berkel et al., 2009). EIPs optimize the use of resources through interactions between companies that exchange waste and by-products, and through integrated resource recovery systems (Lowe and Koenig, 2006). Industrial symbiosis (IS), based on the concept of industrial ecology, has gained prominence for improving the sustainability of industrial regions with both public and private benefits (Bain et al., 2010). According to Chertow et al. (2008), three types of symbiotic transactions can occur: (i) utilizing waste from others as raw material (by-product exchanges), (ii) sharing utilities or access to services such as energy or waste treatment, and (iii) cooperating on issues of common interest such as emergency planning, training, or sustainability planning. Among these symbiotic transactions, bilateral exchanges among firms are among the more conspicuous occurrences, and are referred to as the 'kernel' of symbiosis (Chertow, 2007), green twinning, or by-product synergies (Ehrenfeld and Chertow, 2002).

With regard to EIP initiative in South Korea, Ulsan was selected as one of the five demonstration regions (Park et al., 2008). IS networks were existing in Ulsan before 2005, but were unplanned and spontaneous in nature. Starting in 2005, systematic design and development of new networks began through the 'research and development into business' framework devised by the Ulsan EIP center (Behera et al., 2012). The IS networks existing in the national industrial complexes in Ulsan before and after the Korean EIP initiative are shown in Fig. 1.

From eco-industrial development (EID) perspective, the development of a framework to evaluate the effectiveness of IS networks is greatly needed, and is broadly facilitated by two approaches, (i) a triple bottom line (TBL) approach and (ii) a life cycle approach (Kurup et al., 2005). Unlike the life cycle approach, effectiveness evaluation of IS networks by the TBL approach is simple and

* Corresponding author. Center for Clean Technology and Resource Recycling, University of Ulsan, Ulsan, South Korea. Tel.: +82 52 259 1050; fax: +82 52 221 0152.
E-mail address: parkhs@ulsan.ac.kr (H.-S. Park).

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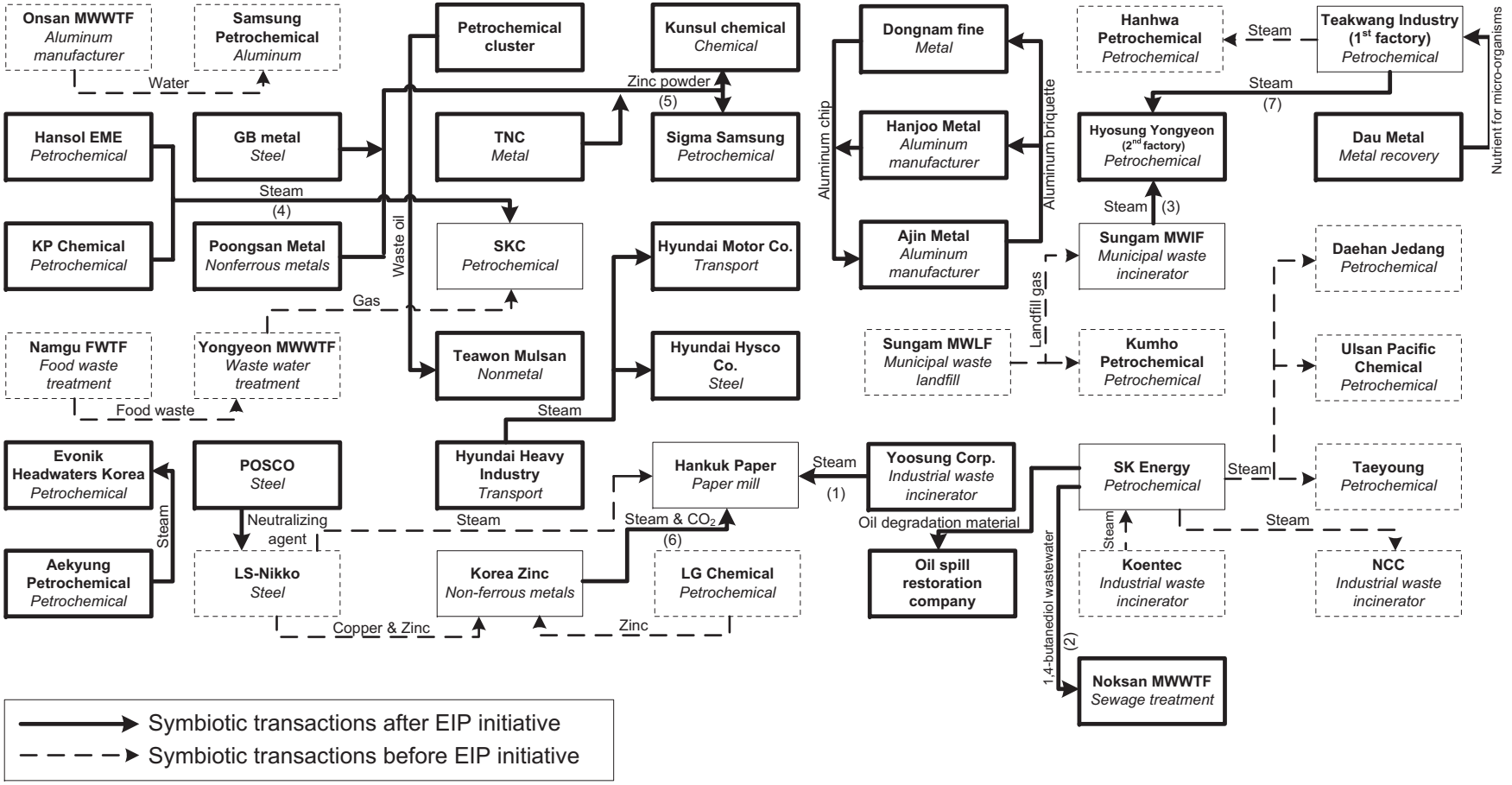

Fig. 1. Symbioses existing in Ulsan EIP (Dashed-lined and solid-lined boxes refer to companies involved in symbioses before and after EIP initiative, respectively, Numbers within bracket along the arrows indicate the analyzed networks, MWWTF: Municipal wastewater treatment facility; FWTF: Food waste treatment facility; MWLF: Municipal waste landfill facility).