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Integrated transdisciplinary technologies for greener and more sustainable innovations and applications of Cleaner Production in the Asia–Pacific region

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ABSTRACT

In the last decade, the integrated transdisciplinary concepts and technologies for greener and more sustainable innovations and applications of Cleaner Production in the Asia–Pacific region have been developed and implemented extensively. The endeavor to develop more precise, reliable, and cost-effective tools and methods to assess the sustainability of the desired products and processes from Cleaner Production have been achieved. Regarding the two conferences, the International Conference on Green and Sustainable Innovation (ICGSI) and the International Thai Chemical Engineering and Applied Chemistry Conference (ITIChE2015), these conferences were co-organized to bring experts and researchers together from within and outside the Asia–Pacific region to foster development of new research ideas on green and sustainable innovation. The selected articles from these events are included within this Special Volume together with articles from the Cleaner Production community outside these events. The papers cover a wide range of topics relevant to the Cleaner Production concepts and applications, especially for greener and more sustainable innovations and of applications of life cycle assessment, ecological footprint, and other environmental and ecological assessment tools for making improvements in agricultural products, biodiesel and biogas production, CO_2 reduction and utilization, and expansion of usage of alternative and renewable energies. The examples of life cycle thinking-based assessment techniques, together with progress in innovative technologies and their applications, strongly reflected the improvements made in practical applications of Cleaner Production in the Asia–Pacific region, in recent years.

1. Introduction

Due to continuing world population growth in conjunction with drastic increases of human overconsumption, the demands for resources, especially energy and food are rapidly expanding at rates that are unsustainable (DEDE, 2015; Kudoh et al., 2015; Gheewala, 2012). The rapidly increasing demands for fossil-carbon based energy are causing many environmental problems pertaining to global warming and climate changes through increasing greenhouse gas (GHG) emissions (Yang and Wang, 2015; Weng et al., 2016; Jones and Phillips, 2016), ozone layer depletion (Cao et al., 2016), and natural resource depletion (Khan et al., 2016); and are causing many public health problems (West et al., 2013; Khan et al., 2016), and are causing increasing inequities and social upheavals. Transdisciplinary research concepts, policies, and technologies designed to help to ensure progress towards making societies and regions more green and more sustainable therefore, are being fostered and promoted (Damen, 2010; EPPO, 2014).

With regard to those problems, the balance between conventional energy and alternative energy supplies is crucial (Raman and Mohr, 2014; Psomopoulos et al., 2009; Wang et al., 2015). The alternative renewable energy sources, for example—solar, biomass,

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wind, hydroelectric, geothermal, tidal and ocean thermal energies—and the improvements of their utilization efficiencies, have been and are being focused upon by many researchers. Among these, biomass-derived biofuels are one of the practical alternatives to conventional fossil fuels (Gheewala, 2012; Raman and Mohr, 2014; Kudoh et al., 2015). However, an expansion of biofuel feedstock cultivation without proper management will lead to multi-environmental impacts in the near and long-term future.

Moreover, due to worldwide problems of global warming (Fernandez and Abanades, 2016; Jones and Phillips, 2016) and increasing global energy demands (Kudoh et al., 2015; Wang et al., 2015), the utilization of greenhouse gases, especially CO_2, as a renewable carbon source to produce value-added chemicals, has attracted much interest for application of promising alternative technologies (Van-Dal and Bouallou, 2016; Donphai et al., 2016b; Luu et al., 2016). Among these technologies, the CO_2 hydrogenation reaction is one of the most attractive ways to approach the environmentally friendly synthesis of sustainable chemical feedstocks and fuels (Kiatphuengporn et al., 2014; Zhou et al., 2015). Previous research on CO_2 hydrogenation has mainly focused on a variety of factors affecting the performance of catalysts, i.e., catalysts and supports (Ren et al., 2015; Chinniyomphanich et al., 2016), promoters (Angelo et al., 2015; Rafati et al., 2015), types of reactors (Papaioannou et al., 2009), and operating conditions (Riaz et al., 2013). With respect to the concept of Cleaner Production, many attempts have been made for the research and development with lower energy consumption and less greenhouse gas emission-based production and consumption (Kiatphuengporn et al., 2016b; Donphai et al. (2016a).

This Special Volume (SV) of the Journal of Cleaner Production (JCLP) was initiated based upon the 5th International Conference on Green and Sustainable Innovation (ICGSI2015), and the International Thai Chemical Engineering and Applied Chemistry Conference for its 5th symposium (ITIChE2015) that was held in Pattaya, Thailand during November 2015. The conference planners had the objectives to encourage innovation and creativity, design, production and usage of new and improved products, and the implementation of new, cleaner structures, systems, processes, products and services, and to stimulate the development and implementation of prevention oriented governmental policies and educational programs. This was achieved by joining with ITIChE2015 in the symposium, which brought researchers from inside and outside the Asia–Pacific region to join together and to foster development of new research ideas and to plan co-work on green and sustainable innovation and application.

This SV was directed towards a wide variety of research articles relevant to environmental life cycle assessment for green expansion of agricultural products and biofuels, and green and sustainable process development through innovative technologies, as well as for promoting best practices, programs, and local initiatives on green and sustainable production related projects in the Asia–Pacific region. Although, initially intended to only include selected papers from the joint conferences, additional papers related to green and sustainable innovation were included from scientists who did not attend the conferences.

The framework diagram of the focal areas addressed in this SV is presented in Fig. 1.

2. Key aspects for green and sustainable innovations and applications and key findings and approaches from the papers in this Special Volume

Regarding the increases in energy and resource demands, the production capacity expansion of agricultural and bioenergy products is increasing continuously (OAE, 2014; Raman and Mohr, 2014). The life cycle assessment of greenhouse gas (LC-GHG) emissions of sugarcane harvesting practices in the central region of Thailand, the ecological footprints of rainwater and irrigation water for the production of rubber products and crude palm oil, and substance flow analysis and soil–water assessment of the nutrient flows—are the key tools for sustainable environmental challenges (Gassman et al., 2007; Silalertruksa et al., 2012; Uusitalo et al., 2014). These tools can be used to more appropriately control and manage the environmental problems that result from production capacity expansions, and therefore help us to make progress toward more effective and efficient green and sustainable production.

The contributions in this SV included an array of research topics and themes principally in—life cycle assessment (LCA) of agricultural products (in this issue: Pongpat et al., Musikavong and Gheewala, Jakrawatana et al., Sawaengsak and Gheewala) and biofuels (in this issue: Permpool and Gheewala, Lecksiwilai et al., Kaenchan and Gheewala, Shane and Gheewala, Boonrod et al.), green and sustainable CO_2 reduction and utilization (in this issue: Kiatphuengporn et al., Siriworarat et al., Yutthalekha et al., Kaewwichit et al.), and green and sustainable energy and products (in this issue: Srinophakun et al.,2016a,b, Chuichulcherm et al., Srinophakun et al.,2016a,b, Pacaphol and Aht-Ong, Suwanvaipattana et al., Charoen et al., Binoj et al.).

2.1. Life cycle assessment and ecological footprint of agricultural products

The multiple processes related to agricultural products including sugarcane harvesting, rubber product processing, and maize production were focused upon in this SV by means of life cycle assessments and ecological footprint analyses.

Pongpat et al. (in this issue) reported on assessments of sugarcane harvesting practices in the central region of Thailand based on the climate change impact due to the life cycle-greenhouse gas (LC-GHG) emissions. The results indicated that manually cut, green cane produced less LC-GHG emissions but the processes faced labor shortages, while a mechanized harvesting showed moderate GHG emissions. Additionally, the insufficient cutting machines and manpower also led to cane burning. As a result, they indicated that the largest GHG emissions came from the land preparation stage affects soil microbiology, and the composition of exhaust gases from cane burning, while the harvesting practice did not contribute significantly to LC-GHG emissions.

The ecological footprints of rubber products and palm oil mills were assessed and reported by Musikavong and Gheewala (in this issue) using the Thailand database. The rubber products including ribbed smoked sheet (RSS), ribbed smoked sheet bale (RSSB), Standard Thai Rubber (STR), and concentrated latex were examined via LCA, using the system boundary from 'cradle-to-gate.' It was found that the ecological footprints of rainwater and irrigation water for the production of fresh latex and cup lump, and fresh fruit bunches (FFB) in Thailand were more than 92% of the total ecological footprint. The production of RSS had a high potential for reducing the ecological footprints, followed by that of concentrated latex and STR, respectively. Accordingly, the alternative methods for reduction of ecological footprints of RSS production should be used for green and sustainable expansion of rubber and oil palm industries.

Jakrawatana et al. (in this issue) introduced a framework linking substance flow analysis and soil—water assessment tools to document the nutrient flows in the area with various climates and land conditions. The substance flow analyses were conducted by integrating spatial allocations of material's flows to evaluate the total quantity of nutrients during a specific time period; this approach was used to document such flows in a maize production