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Reduction of CO_2 emission by INCAM model in Malaysia biomass power plants during the year 2016

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ABSTRACT

As the world's second largest palm oil producer and exporter, Malaysia could capitalize on its oil palm biomass waste for power generation. The emission factors from this renewable energy source are far lower than that of fossil fuels. This study applies an integrated carbon accounting and mitigation (INCAM) model to calculate the amount of CO_2 emissions from two biomass thermal power plants. The CO_2 emissions released from biomass plants utilizing empty fruit bunch (EFB) and palm oil mill effluent (POME), as alternative fuels for powering steam and gas turbines, were determined using the INCAM model. Each section emitting CO_2 in the power plant, known as the carbon accounting center (CAC), was measured for its carbon profile (CP) and carbon index (CI). The carbon performance indicator (CPI) included electricity, fuel and water consumption, solid waste and waste-water generation. The carbon emission index (CEI) and carbon emission profile (CEP), based on the total monthly carbon production, were determined across the CPI. Various innovative strategies resulted in a 20%–90% reduction of CO_2 emissions. The implementation of reduction strategies significantly reduced the CO_2 emission levels. Based on the model, utilization of EFB and POME in the facilities could significantly reduce the CO_2 emissions and increase the potential for waste to energy initiatives.

1. Introduction

The rise in energy demand and the corresponding rise in greenhouse gas (GHG) emissions are causing climate change (Kerdsuwan and Laohalidanond, 2011). Fig. 1 illustrates CO_2 emissions by region from 1990 to 2030. CO_2 emission levels are estimated to increase drastically for some regions of the world within 40 years. One key approach to addressing climate change is to replace fossil fuels with renewable energy for electricity production. Thus, reliance on fossil fuels without any conservation effort or increase in renewable energies to fulfill our energy demand will eventually lead to catastrophic global impacts.

The development of non-fossil fuel energy sources is essential for reducing GHG, avoiding fossil fuel resource depletion and coping with fluctuating fossil fuel prices (Talebian-Kiakalaieh et al., 2013; Maceiras et al., 2011; Santori et al., 2012). CO_2 emissions can be substantially reduced if biomass replaces fossil fuels for power generation. Indeed, unlike fossil fuels, burning renewable biomass is considered neutral in GHG emissions (Ibrahim, 2016). Trees take in carbon dioxide from the atmosphere and convert it into biomass; whether trees are burned or decompose naturally, they release the same amount of carbon dioxide (Cho, 2011). Also, the carbon that is released when biomass is burned is re-absorbed by other plants in their growth cycle. However, when fossil fuels are burned, they release CO_2 that has been trapped for centuries, adding carbon to the atmosphere (Biomass Power Association, 2011). Fig. 2 illustrates that renewable energies generate significantly lower GHG emissions compared with fossil fuels including natural gas, oil and coal.

Given Malaysia's tropical biodiversity, conversion of waste (biomass) to energy is a promising approach to establishing sustainable energy production. Waste management was originally adopted for the purposes of waste volume reduction and maintaining high levels of public hygiene. However, over the years, waste management concept has evolved to include the concepts of waste prevention, waste recycling and waste to energy (Hadidi and Omer, 2017; Chen, 2016; Schwarzbock et al., 2016). Malaysia is ranked as the world's second largest palm oil producer, next to Indonesia. In fact, Malaysia's palm oil production exceeded 21.25 MMT in 2014, and has been increasing annually since 2009. Malaysia's palm plantation area and amount of crude palm oil production

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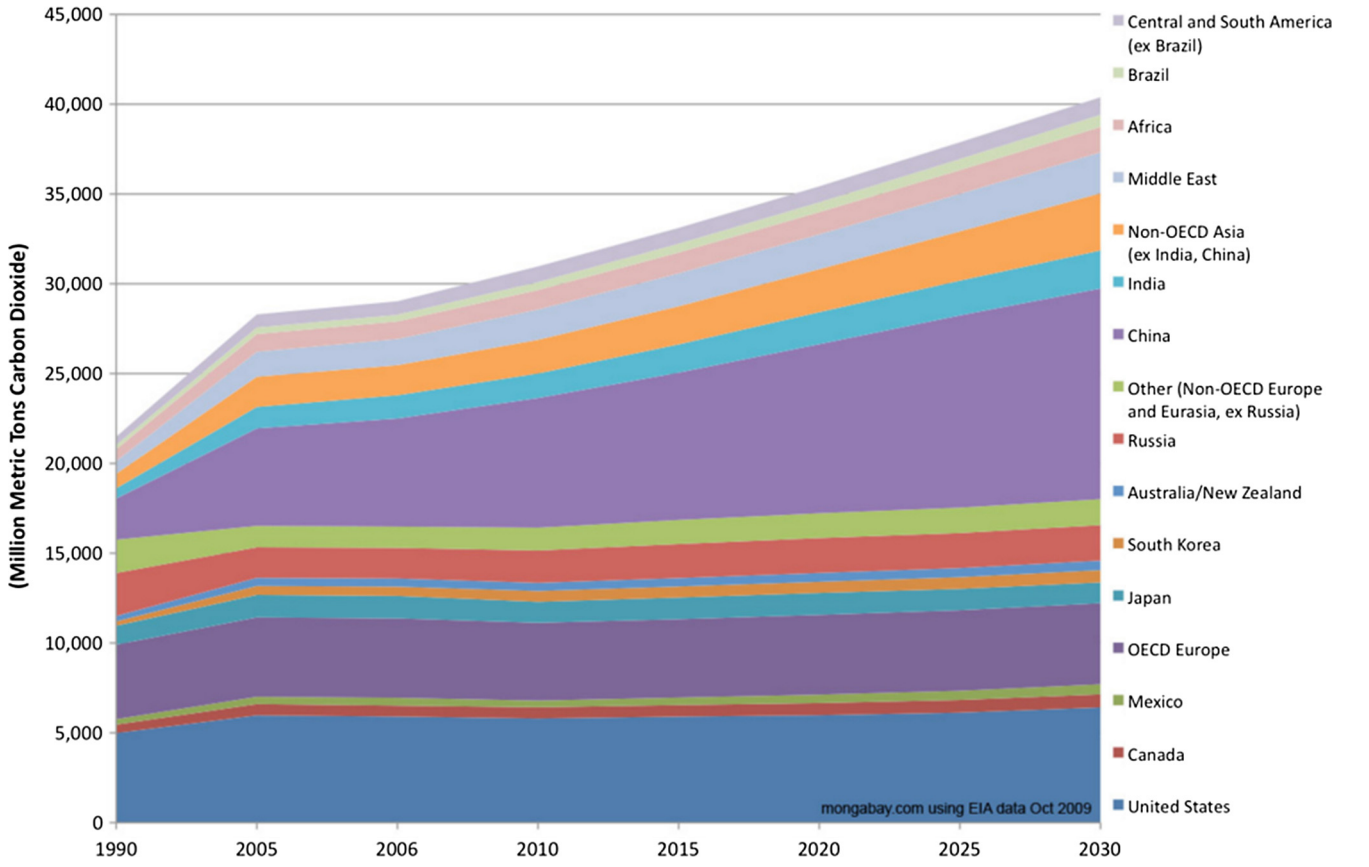

Fig. 1. World CO_2 emission levels by region between 1990 and 2030.

significantly increased from 4.7 to 5.4 million hectares and 17.6 to 19.8 million tonnes, respectively, between 2009 and 2014 (Aditiya et al., 2016).

The oil palm industry yields a tremendous amount of biomass waste such as frond, trunk, mesocarp fibres, palm kernel shell, empty fruit bunches (EFB), and palm oil mill effluent (POME). These wastes are a potential source for energy generation. However, only a small portion of this waste is currently utilized for steam and electricity generation (Mahlia et al., 2003; de Souza et al., 2010). A large fraction is simply burned or used as landfill (Lahijani and Zainal, 2011). Thus, the government and industry alike are seeking ways to utilize this massive oil palm industry wastes. For instance, heat from EFB combustion can be captured in a boiler to produce steam. POME, the voluminous liquid waste from the oil palm industry, is retained in ponds to reduce its toxicity and releases methane gas. If harvested properly the valuable methane fuel can be used for electricity, steam or heat generation.

In accordance with global efforts to produce renewable energy and reduce CO_2 emissions, Malaysia has developed strategic plans for increasing its share of renewable energy sources. Iskandar Malaysia, an innovative economic development zone in Johor has developed a Low Carbon Society Blueprint, called IM 2025, with a target to reduce carbon intensity by 58% by 2025 from 2005 carbon level. The Malaysian government designed a roadmap to make this economic development zone a "strong sustainable metropolis of international standing" by 2025, producing only 18.9 $MtCO_2qe$ GHG emissions, 40% lower than the projected amount (Low Carbon Society Blueprint for Iskandar Malaysia 2025, 2014).

Life cycle assessment (LCA) is a common tool used to study environmental impacts associated with all stages of a manufactured product's life cycle, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. For example, the environmental impacts in the different parts of the palm oil supply chain have been identified using LCA in nurseries (Halimah et al., 2010), fresh fruit bunches (Zulkifli et al., 2010), crude palm oil (Vijaya et al., 2010a), and bio-char from empty fruit bunches (Harsono et al., 2013). LCA is also used for palm kernel oil (Vijaya et al., 2010b), refined palm oil (Tan et al., 2010), bio-hydrogenated diesel from palm oil (Boonrod et al., 2017), GHG emission of palm biodiesel (Abdul-Manan, 2017), and impact of palm oil feedstock on products (Martinez et al., 2017). Alternatively, a simpler integrated carbon accounting model (INCAM) considers direct and indirect carbon emissions (Hashim et al., 2015).

The main objective of this paper is to apply the INCAM model to determine the amount of CO_2 emissions from two biomass thermal power plants that use oil palm waste to produce energy. In this paper, two case studies are analyzed. The first case study investigates the CO_2 emission from Bio-Xcell company, a central utility facility situated in Iskandar Malaysia which uses EFB to produce steam. The other company, Kulim Group Oil Palm Mill use POME as an alternative fuel for firing gas turbines to produce electricity. From the model, various innovative strategies are proposed to reduce CO_2 emissions. The findings from our study provide basic, useful data for developing renewable energy policies to lower CO_2 emissions from the industrial sectors in Iskandar Malaysia region.

2. Methods

The steps to determine the reduction in CO_2 emissions levels with the INCAM model are illustrated in Fig. 3. Initially, each process is divided into smaller scoping units known as carbon

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