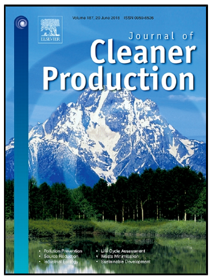


# Debottlenecking of Sustainability Performance for Integrated Biomass Supply Chain: P-graph Approach

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# Debottlenecking of Sustainability Performance for Integrated Biomass Supply Chain: P-graph Approach

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**ABSTRACT**

Biomass supply chain has been extended to cope with the growing concern on sustainability development and cleaner production. Process network optimisation is no longer sufficient to improve the biomass product life cycle. A comprehensive and systematic debottlenecking approach is required to identify and subsequently remove the underlying bottlenecks which hinder the biomass industry from attainment of sustainable paradigm. Therefore, this paper introduced a novel debottlenecking approach that incorporates P-graph framework and sustainability index (SI) to address the aforementioned issue. In addition, analytical hierarchy process (AHP) is applied to determine the appropriate priority scale for each sustainability dimension, including economic sustainability (annual revenue), environmental sustainability (pollutants emission) and social sustainability (safety aspect). Three different scenarios (palm oil mill effluent (POME) valorisation, oil palm frond (OPF) valorisation and biomass selection for gasification) which obtained from a Malaysia case study, are used to demonstrate the effectiveness of the proposed method. The results show that the proposed debottlenecking method is capable to identify the bottlenecks of the research problem easily and efficiently (i.e., all three scenarios show positive outcome since the satisfaction level of the given technology pathways or biomass option have been gradually improved after debottlenecking). On top of that, the strengths and limitations of the proposed method are also discussed in this paper. This research is expected to be beneficial to the nation's biomass industry in the development of biomass industry.

**KEYWORDS**

P-graph, debottlenecking, sustainability index, safety evaluation, biomass supply chain, AHP

## 1. INTRODUCTION

Due to the drastic increment in global energy demand and the snowballing global pressure on cleaner production, the demand for bioenergy is projected to reach 50 EJ by year 2035 (IEA, 2012). In order to meet this growing demand, at the same time, mitigating the environmental risks and maximising social benefits, the implementation of sustainable biomass supply chain management (SBSCM) is a prospective solution (Lam et al., 2015). SBSCM is the operational management of biomass flow within an interconnected chain (e.g., biomass harvesting site, processing hubs, biomass storage, transportation, product distribution centre, etc.) which converts biomass waste into value-added products, with the aims of optimising the sustainability performance of the chain (Hong et al., 2016).

During the synthesis of an integrated biomass supply chain, the economic viability, environmental risk and social impact, must be considered in order to attain the full spectrum of sustainability (Wan Alwi et al., 2016). For instance, Lam et al. (2013) had developed an optimal