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FACILITATING GREENHOUSE GAS EMISSION REDUCTION IN PALM OIL SECTOR USING MARGINAL ABATEMENT COST CURVE METHODOLOGY

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Abstract: At present, the palm oil sector is one of the greenhouse gas (GHG) emitters in Indonesia. Numerous reduction strategies have been developed for operational and technical measures, but the industry is relatively unaware of how much potential for mitigation exists and how much it would cost to realize this potential. Policymakers use marginal abatement cost curves (MACC) to analyze and rank existing abatement measures based on costs and mitigation potential to design cost-effective decarbonization policies. The objective of this study is to propose a MACC methodology framework for calculating the potential for emission reductions and cost savings relative to a reference technology. The results of this study show the structure of MACC methods combination reference, in which eight elements serve as references to create a methodological framework. Then, the methodology framework, consisting of identify, generate, and validate phase, is created to assess and evaluate the four main parameters which are cost savings, abatements, complexity, and benefits for each technology to support decision-makers making a more suitable decision about which actions to take to accomplish maximum emission reduction target. Further experimentation is recommended to test the proposed framework to rank the mitigation technology in the palm oil sector.

Keywords: MACC methodology framework, potential emission reduction, bottom-up approach, palm oil sector.

Introduction

Over the past several decades, palm oil production is already one of the world's leading suppliers of fats and oils. Due to population growth and increased energy demand, the demand for palm oil is increasing. In 2016, palm oil made up about 30% of worldwide oil and fat manufacturing. Indonesia and Malaysia, the two biggest palm oil suppliers, make up about 85% of the world's palm oil supply (Omar *et al.*, 2018; Council of Palm Oil Producing Countries, 2021). Over the previous five years, the region of palm oil plantations in Indonesia has increased significantly, with a total land area of 12.76 million hectares in 2018 (Badan Pusat Statistik, 2018). Accordingly, the palm oil milling industry has experienced a significant increase over the past decade. Palm oil mills (POMs) require a significant amount of electricity and steam to process fresh fruit bunches (FFBs) into different products (Foong *et al.*, 2018). Data shows that palm oil production contributes greenhouse gases among 16.6% and 27.9% of total emissions from Indonesia and Malaysia (Sjogersten, 2020). Reducing palm oil GHG emissions should be a priority action by which this sector can significantly contribute to offsetting global warming and promoting environmental sustainability.

Numerous applications of reduction strategies with high-accuracy technology have been developed for operational and technical measures (Abdullah *et al.*, 2015). However, the palm oil industry is relatively unconscious of how much potential for mitigation exists and how much it would cost to realize this potential (Pambudi *et al.*, 2018). The palm oil industry is one of the main carbon dioxide contributors, which must be handled immediately at the lowest possible cost. Assessing the abatement costs of GHG is a crucial phase in realizing emission reduction (Duan *et al.*, 2018).

The marginal abatement cost curve is an instrument for examining the connection respectively climate issues and technology variation (Kesicki, 2013). A marginal abatement cost curve (MACC) is a beneficial method for estimating CO_2 mitigation options and comparing various abatement measures (Huang *et al.*, 2016), as well as visual context on the cost of abatement of a particular technology and the potential for a set of mitigation measures (Muangjai *et al.*, 2020). The MACC estimate could be used as a guide for improving environmental and energy policies, like trading systems for carbon emissions.

Jackson (1991) is the first scholar to apply MACC to a climate change perspective as a visual characterization of arranged energy measures that compares mitigation potential to marginal costs (Jackson, 1991). Also, to make decarbonization rules that are good for the economy, policymakers used MACC to rank and prioritize easily accessible ways to cut carbon emissions (Ponz-Tienda *et al.*, 2016). A MACC displays the shadow price relating to a GHG boundary condition of increasing severity level against the volume abated and clearly illustrates the association between the marginal cost per unit of abatement and emission reductions (Zhang *et al.*, 2017). The MACC was designed to demonstrate the amount of GHG that could be reduced at comparable costs compared to a reference technology. Comparisons were made between low-emission alternatives and the baseline or reference model (Melo & Jannuzzi, 2015). The cost of various measures for greenhouse gas emission reduction was converted into comparable units, e.g., £/t CO_2, by MACC (Dunant *et al.*, 2019).

According to our findings, MACC was applied to evaluate the cost-effectiveness of energy efficiency enhancements and CO_2 emissions in numerous industries. Numerous experiments have utilized this methodology for technology valuation and project comparisons for potential GHG emission reductions in country-specific and global scenarios (Vogt-Schilb & Hallegatte, 2011; Lee & Wang, 2019). MACC is used in various industries, including power generation, construction, agricultural sectors, shipping, residential, transportation, and policy formulation (Taylor, 2012; Jones, 2014; Luu *et al.*, 2018). It is becoming increasingly popular because it simplifies the complex relationship between efforts to reduce emissions and the rate of abating one unit of CO_2 emissions (Sjostrand *et al.*, 2019). However, no similar studies use the MACC method to calculate the potential for emission reductions and cost savings in the palm oil sector. This study aims to propose a MACC methodology framework that considers factors other than cost and emission reduction and can be applied to the palm oil sector for calculating the potential for emission reductions and cost savings relative to a reference technology.

The remaining part of this paper is systematized as follows. Section 2 discusses the bottom-up MACC, and the final two sections describe the combination reference in MACC studies, the methodological framework, and our conclusions.

Materials and Methods

MACC Bottom-up Approach

The MACC can be constructed at the regional, corporate, or societal levels utilizing one of three approaches: Bottom-up/model-derived, top-down/non-model-derived or hybrid (Tang *et al.*, 2020). Every approach has distinct benefits and disadvantages that might resolve various issues. The bottom-up method's major benefit is its significant level of technological detail. It has the drawbacks of not collecting system-wide interactions, ignoring characteristics, and having inaccurate baselines (Delarue *et al.*, 2010; Kesicki & Strachan, 2011; Wächter, 2013).At the sectoral level, the top-down approach could be used to evaluate how markets respond to external pressures, such as a policy action that has been taken or is about to be taken, and how it affects the system as a whole. Moreover, complicated economic modelling is frequently required to determine the emission levels and costs of various policies, so they are a negotiated settlement and do not fit empirical correlations (Levihn *et al.*, 2014; Huang *et al.*, 2016). The hybrid model combines the strengths of the bottom-up and top-down methods. The hybrid approach, however, has not yet been extensively utilized due to the large relevant data (Jiang *et al.*, 2020). The following equation was used to determine the particular abatement costs of GHG emissions based on a technology *i* with respect to a reference technology *j* using bottom-up approach:

$$\text{Marginal Abatement Cost}_t^{ij} = \frac{\Delta C_t}{\Delta E_t} \quad (1)$$

With ΔC_t is (total annual costs technology *i* (\$) in *t*) − (total annual costs Business as Usual technology *j* (\$) in *t*) and ΔE_t is (total annual GHG emissions Business as Usual technology *j* (tons) in *t*).

As shown in Figure 1, the quantity of each GHG abatement alternative is expressed on the horizontal axis while the related cost of each alternative is expressed on the vertical axis.

The area of each abatement alternative is the additional investment value to implement the alternative relative to the baseline or reference model. A positive value of MAC represents the presence of a cost to decrease GHG emissions corresponding to the baseline scenario, whereas a negative value of MAC suggests a net benefit to decreasing GHG emissions relative to the baseline (Blok & Nieuwlaar, 2021). Alternative 1 has a marginal cost of -50 and "delivers" about 100 units of CO_2 reduction, while alternative 4 has a marginal cost of almost 20 and "delivers" about 100 units of CO_2 reduction. Because alternative A has the highest cost savings compared to other alternatives, it should be prioritized in terms of resource allocation.

Results and Discussion

Combination Reference of MACC Methodology

Based on the literature review, there are currently no general criteria for selecting the type of GHG emissions, countries, sectors, and methodologies. Figure 2 illustrates the combination reference used in MACC studies. The bottom-up method is the dominant option that is broadly used, such as a widely known study performed by McKinsey & Co. since it can help us understand a high level of technological detail even though it does not obtain system-wide relations and behavioural aspects that are ignored. As a result, the step-wise graph is more commonly used to demonstrate the magnitude of potential cost savings and emission reductions. In the innovation and improvement of MACC methods, numerous energy supply and demand models are used to enhance the implications of

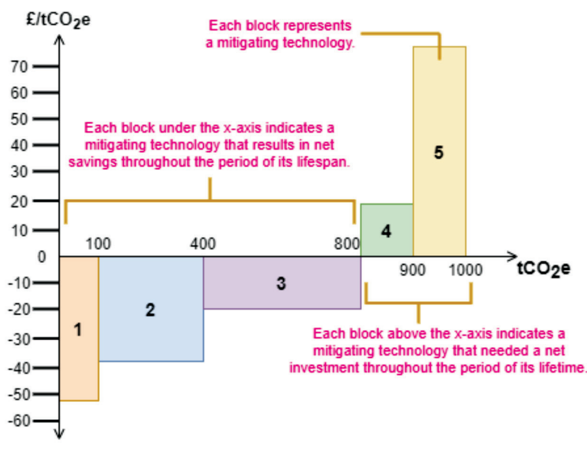

Figure 1: Illustration of MACC for five mitigation alternatives

technological change and explore the influence of market behaviour changes (Huang *et al.*, 2016).

There are still a few studies that have focused on the reliability of outcomes and the validity of ranking problems. One of the MACC's discussed flaws is its limited ability to consistently rank selected technology with negative economic values, making guaranteeing the best-value outcome difficult (Taylor, 2012; Ward, 2014). Several scholars determined the CO_2 MAC in multiple sectors and established MACCs employing various modelling methodologies. CO_2 gas is one of the most considered GHG emissions in determining marginal abatement costs between all of the research on the bottom-up and top-down approaches because it is the foremost GHG that currently compensates for almost three-quarters of emissions and has become a high international priority.

Lastly, research involving the calculation of the marginal cost of emission abatement always necessitates the use of an object of research in the form of a sector or country. Existing published studies have concentrated primarily on the residential, building, power, transportation, and agriculture sectors. Throughout the last five years, literature has been abundant on China's emissions reduction costs. Although China has become the biggest GHG producer, a more country-specific MACC observation is required, primarily for developing countries such as Argentina, Indonesia and India.

MACC Framework

This study considers factors apart from cost and abatement amount to prevent MACC false interpretation and use them for action prioritization, ranking energy-efficient technologies, and measures. Better ranking and choice of GHG reduction measures allow decision-makers to become more optimistic in further assessing emission reductions for the selected measures and establishing more reasonable national emission reduction goals.

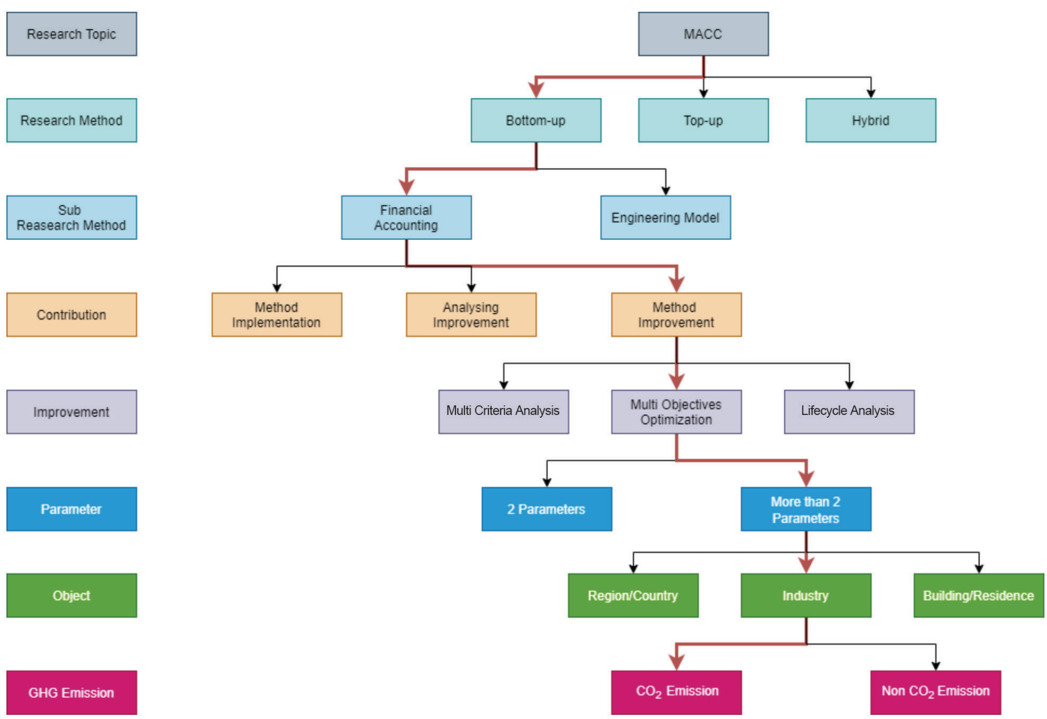

Figure 2: Structure of MACC methods combination reference

Low-cost mitigation options sound very appealing, though there is reason to believe they are not always the easiest to implement based on the evaluation of emission reduction measures. As a result, there has been a proliferation of such misunderstandings as governments or policymakers have been educated to believe that the least expensive technology options always appear to be the most appropriate. The facts have proven otherwise.

Additionally, MACC is frequently criticized because it is too restricted in explaining the difficulties and challenges that impede the deployment of abatement alternatives (Swart, 2019). It is also stated that emission reduction alternatives should be ranked based on marginal costs and associated benefits (Ward, 2014). Further, one statement against using MACC for prioritization seems to be that interactiveness in behavioural aspects, technology factors, and complexities are neglected when considering marginal costs (Kesicki & Ekins, 2012). The bottom-up MACC project can be extended by establishing abatement option-specific knowledge of the difficulties and benefits of deployment. By better reflecting on the barriers and benefits, this approach will provide more comprehensive information for policymakers to prioritize and choose the most effective emissions reduction measures.

Finally, the palm oil sector's efforts to enhance sustainability and lower greenhouse gas emissions have grown. Many companies are using a variety of new and better ways to run their businesses that lead to lower emissions (Walker *et al.*, 2018). Based on MACC methods combination reference, the current study proposes a MACC methodology framework with enhancement using a new ranking algorithm for cost saving, CO_2 abatement potential, complexities, and benefits as depicted in Figure 3.

This method will be implemented for Indonesia as the main palm oil supplier with Malaysia. Research and development for CO_2 emission reduction in the palm oil production sector are also required to verify sustainable development. Reducing GHG emissions throughout the production chain can help reduce global impacts while providing additional energy. The findings are meant to assist policymakers in determining GHG emission reductions along with implementing possible low-carbon technology, evaluating palm oil policies before 2030, and developing new policies consistent with national and global climate mitigation goals.

Conclusion

This study determined the MACC structure of combination reference and methodology framework for calculating emission reductions and cost savings in the palm oil industry. The proposed methodology consists of three phases identify, generate, and validate. The method is created to assess and evaluate four main parameters: Cost savings, abatements, complexity and advantages for each technology/action. The ranking or technological priority will be shown on the MACC, which usually assesses only two parameters. The customized algorithm could help decision-makers take appropriate action. Further experimentation is recommended to test the proposed framework to rank the available measures and identify the most acceptable ones for implementation, which would improve comprehension.

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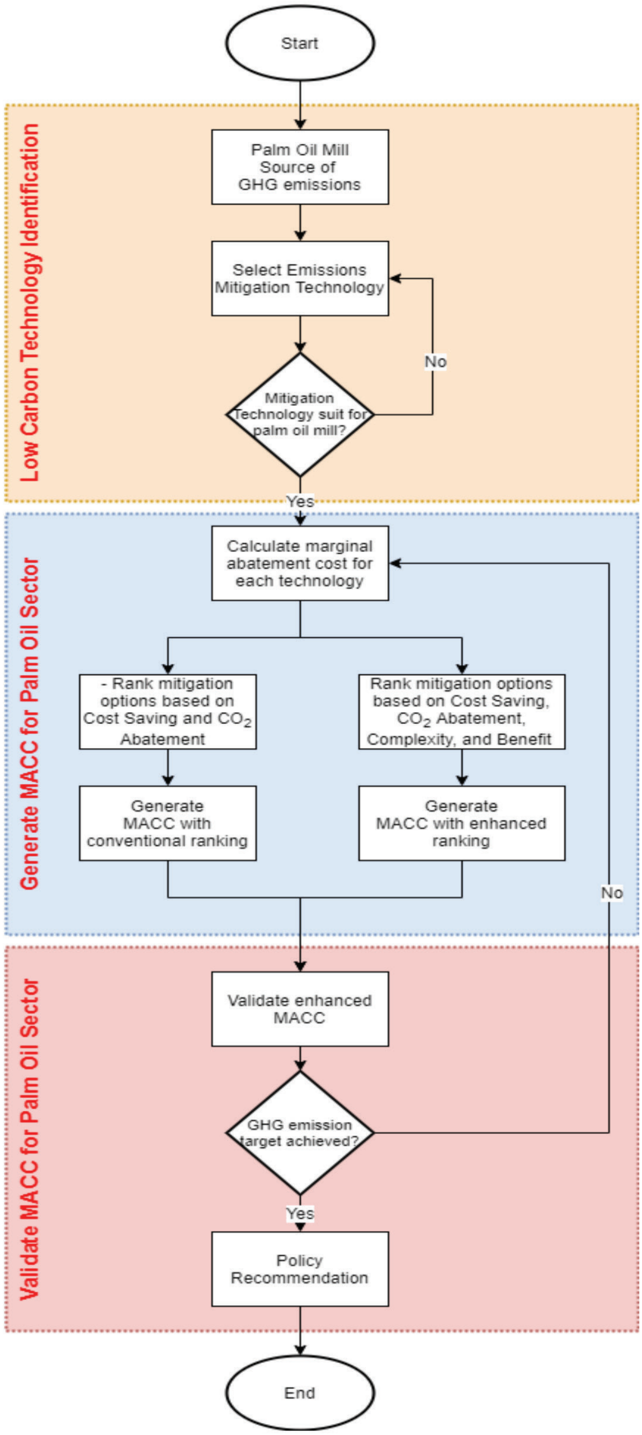

Figure 3: MACC methodology framework for the palm oil sector

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