Wood-based Solid Biofuel in Malaysia: Export Status and Policy Review

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Abstract

The widespread use of fossil fuel has led to severe environmental consequences, such as climate change and pollution. As a remedial response, the global energy landscape has decidedly shifted from fossil fuels to renewable energy sources, such as solar energy and biofuel for bioenergy. As a country rich in resources, Malaysia has had a golden opportunity to dwell on the production of the second-generation biofuel, also known as the wood-based solid biofuel (WBSB). This review paper intends to provide an overview of Malaysia's WBSB production and export industry, focusing on the current export status for the products and the policy frameworks that support the industry in Malaysia. The export status of five WBSB products (wood pellet, briquettes, charcoal, fuelwood, and wood chips or particles) are appraised based on its export status and global ranking. In addition, related biomass or biofuel policy and the effect it has on the progression of the biofuel industry were analyzed and consolidated. The findings show that the biofuel industry in Malaysia, specifically those concerning WBSB is average at best compared to its neighbors in Southeast Asia, Vietnam and Indonesia in the export of wood pellets and charcoal, respectively. However, in recent years, Malaysia has become increasingly competitive in the export of pellets and chips, which are becoming one of the top 10 global exporters. Furthermore, government policies and initiatives aimed at promoting sustainable forestry practices and stimulating the bioenergy sector have facilitated the growth of the biofuel industry, such as the Green Technology Financing Scheme (GTFS) IV of the National Biomass Action Plan. In general, this review outlines the current export state of WBSB products, while highlighting the key policies that govern biomass and biofuel production to identify areas for potential improvement to enhance competitiveness and sustainability in Malaysia's biofuel industry.

Keywords: biofuel, wood-based solid biofuel, policy, Malaysia

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1. Introduction

The need for alternative energy sources has become increasingly urgent due to growing concerns about climate change, the depletion of fossil fuel reserves, and the environmental and health impacts of conventional energy production. As global energy demands continue to increase, the reliance on fossil fuels such as coal, oil, and natural gas has led to significant greenhouse gas emissions, contributing to global warming and air pollution [1]. Furthermore, the finite nature of fossil fuel resources poses a threat to long-term energy security and economic stability [2]. Sustainable energy development further drives the need for an energy transition, and Covid-19 stresses the importance of the continuity of energy supply [3]. To address these challenges, alternative energy sources, including solar, wind, hydro, geothermal, and bioenergy, offer sustainable and renewable options that can reduce carbon footprints, enhance energy independence, and promote environmental sustainability.

Investing in and transitioning to these alternative energy sources is crucial to building a resilient and sustainable energy future [4]. The selection of various renewable energies offers a promising avenue to meet world energy demands while reducing the dependence on fossil fuels and, at the same time, alleviating the negative environmental effects. As the world engages with acute issues such as climate change, energy security, and sustainable development, the exploration of alternative sources of energy that are both renewable and sustainable, has gained considerable attention [5]. One of the oldest but most reliable types of renewable energy is primary biofuels, which refer to solid wood-based biofuels such as wood pellets and chips [6].

Wood-based solid biofuels (WBSB) or also known as wood-based energy are energy sources derived from organic materials such as residues from forestry and agricultural activities, as well as dedicated energy crops [7]. Most WBSB products are produced through highly mechanized conversion procedures that involve pulverization and densification, such as pellets and briquettes, but some may be used as is, such as fuelwood and wood chips. These second generation biofuels are derived from non-food biomass and are used to generate renewable energy through combustion, as an alternative to already depleting non-renewable energy sources such as coal and fossil fuels [8]. WBSB products such as fuelwood and chips are used rudimentarily as fuel for heating and cooking, whereby densified and even torrefied WBSB products such as pellets and briquettes have better properties, such as higher energy density, leading to more efficient combustion and higher heat output [9].

The growing interest in WBSB has long been shown to be an alternative to conventional fossil fuels [10]. Hence, countries such as Vietnam and Indonesia are investing more and more in research and development, as well as commercialization activities [11]. Meanwhile, in Malaysia, the option for renewable energy production from the WBSB product offers a compelling opportunity to address both the negative environmental impact of fossil fuel use and the challenges of energy security. It uses the rich sources of biomass of the nation, such as those of the booming forest sectors, to mitigate the energy crisis [12]. With a rich tapestry of tropical forests and a well-established timber industry, Malaysia has significant potential for mobilizing wood-based biofuels as a sustainable energy source [13].

Essentially, the initiation of the WBSB is in line with Malaysia's pledge to reduce greenhouse gas emissions, diversify its energy mix, and promote renewable energy sources, following the submission of its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat in 2005 [14]. Similarly to China's transition towards environmental stewardship and carbon net zero for ecological civilization, investments in renewable energy sources and the promotion of energy conservation further support the pathway to achieve these objectives by providing a renewable alternative to fossil

fuels, thus contributing to efforts to mitigate climate change [15]. As a signatory to international agreements such as the Paris Agreement, Malaysia recognizes the importance of transitioning to cleaner and more sustainable energy systems, even implementing numerous policies and action plans to support the cause [16]. These policies will be discussed in more detail later.

Furthermore, the development of the wood-based biofuel industry has the potential to stimulate economic growth, create employment opportunities, and improve rural development, particularly in regions with abundant forest resources [17]. Using forest residues, agricultural waste and dedicated energy crops, as aspired to in the 2020 National Biomass Strategy, Malaysia can unlock the latent energy value of these resources and catalyze the growth of a bioenergy sector that is both economically viable and environmentally responsible [18]. According to International Trade Data, Malaysia has achieved some commendable accomplishments in the production and export of wood pellets, reaching the top 10 wood pellet exporters in 2022 [19]. However, Malaysia's export position is still weak compared to our neighboring country, Vietnam, which is known to be the second largest wood pellet exporter, just behind the United States, since 2018 [20].

This paper sets the stage for a comprehensive exploration of the WBSB industry in Malaysia, examining the current export status of selected WBSB products such as wood pellets, briquettes, charcoal, fuelwood, chips or particles, and the supporting policy framework that catalyzes the biofuel movement in Malaysia. By outlining the current export predicament and the policies that support them, it will provide more accessible information on the subject while encouraging the participation of stakeholders and future collaborators. The purpose of the paper is to discuss the status and development of the export of WBSB products, especially in terms of market demand and trends. The evolution of Malaysia's biofuel policies with respect to the development of biomass into biofuels is then to be analyzed. The progression of policies may include the setting of the direction of biofuel development, the establishment of rules and regulations, and the allocation of resources and incentives.

2. Status of Wood-based Solid Biofuel

Biofuels are produced from conventional or easily accessible feedstocks, such as food crops, vegetable oils, and sugar crops. These biofuels have been used for several decades and are derived from biomass sources that are also used for food production [21]. However, WBSB, which is classified in the second-generation biofuel categories, is derived from organic materials that are not food, such as forestry and agricultural biomass and dedicated energy crops [22]. The production and distribution infrastructure of these biofuels requires great overhead, such as pelleting facilities and storage; however, once set up and readily accessible, it has been proven to be easier to integrate these biofuels into existing energy systems [23]. The type of wood-based solid biofuel included in this review are wood pellet, briquettes, charcoal, fuelwood, and wood chips or particles. Each product will be introduced further and discussed based on their export status, market position, and demands based on detailed commodity trade data from comprehensive databases such as Food and Agriculture Organization of the United Nations, United Nations Comtrade and the International Trade Centre.

2.1. Wood pellet

Wood pellets are one of the most popular types of WBSB that is produced by compacting residues such as sawdust, wood shavings, or other wood residues. The cylindrical pellets, which are small, are a type of renewable and sustainable energy that serves as an alternative to fossil fuel, widely used for heating purposes such as industrial heating applications, as well as cooking [24]. The

raw material for the production of wood pellets is obtained in the form of wood residues such as sawdust, wood shavings, wood chips and other by-products of the wood industry, which are produced during the processing of wood and wood products [25]. Production involves feeding wood particles into pellet mills, where they are compressed under high pressure, to form small cylindrical pellets [26]. The natural lignin present in lignocellulose acts as a binding agent, making the use of glue generally unnecessary.

The wood pellet industry in Malaysia began to develop in the early 2000s, driven by the growing demand for renewable energy and the need to responsibly utilize biomass waste [27]. For Malaysia, the export of wood pellets began in 2013, probably initiated after the introduction of the National Biomass Strategy and the Renewable Energy Act (REA) in 2011. Export activities then expanded after 2017, when Malaysia exported more than half a million kilograms of pellets, becoming one of the top 10 largest wood pellet exporters. In fact, in 2023, Malaysia is the eighth largest exporter, with nearly USD 122 million worth of wood pellets exported. This shows that Malaysia has slowly become a competitive producer and exporter of wood pellets and is on its way to challenge the reigning Southeast Asia country, Vietnam, which is the second biggest exporter of wood pellets worldwide in 2022. According to data from the United Nations Comtrade, there is a huge demand for wood pellets worldwide, usually used for heating purposes and electricity generation. In Figure 1 is the wood pellet export from Malaysia from 2013 to 2023, which shows a steady increase in export value. Figure 2 shows that there is substantial demand for Malaysian wood pellets, and current top importers include the Netherlands, Japan, Korea, France, and Denmark.

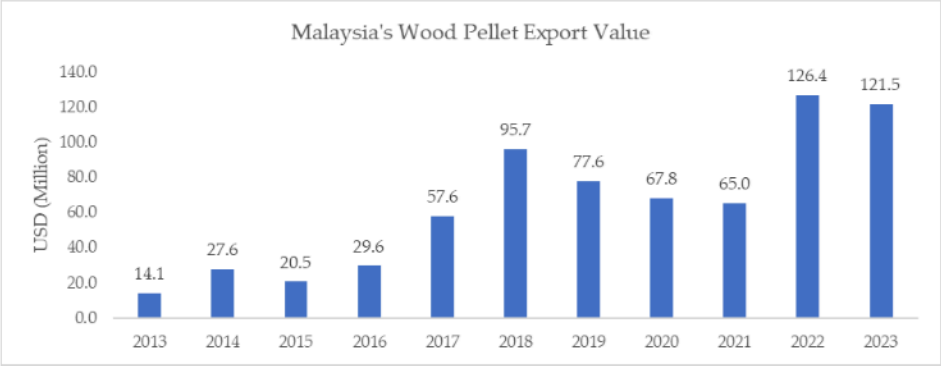

Figure 1: *Malaysia's wood pellet export value (2013 to 2023) [20]*

2.2. Wood briquette

Wood briquettes, also known as biomass briquettes, are compressed blocks made from various types of wood residues or biomass materials. These briquettes serve as a renewable and efficient alternative to traditional fuels and are often used for heating purposes [28]. Specifically, for wood briquettes, they can be made from various wood residues such as sawdust, wood chips, bark, and other biomass materials. The production of briquettes includes the briquetting process, where the ground material is then compressed into briquettes under high pressure [29]. Briquettes from woody materials naturally release lignin to act as a binder; however, some materials need binders such as clay and lime to agglomerate.

The wood briquette industry in Malaysia made significant progress in the early 20th century, mainly due to the need to manage agricultural and forest residues more sustainably. Similarly

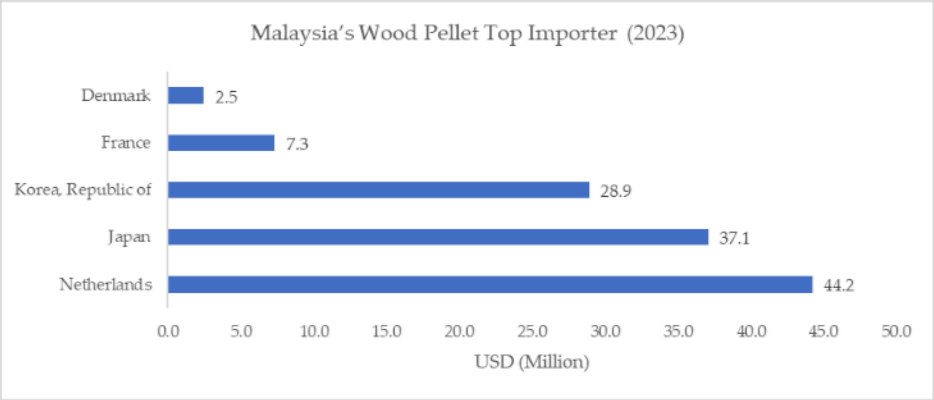

Figure 2: *Malaysia's wood pellet top importer (2023) [19]*

to wood pellets, the REA 2011 encourages the establishment of the industry due to the booming investments, where Malaysia started exports in 2012 [30]. Based on Figure 3, Malaysia's first year export increased to USD 7 million in value and continued to be stronger in subsequent years. However, in 2017 and beyond, the export value of Malaysian briquettes has fallen to an average of 20 million dollars per year and is declining, due to the increased competition of countries in Central and Eastern Europe (CEE) such as Croatia, Latvia and Lithuania, which has still been dominant up to now [19]. Their strategic location probably gave them a competitive advantage with easy access to key markets such as countries in Western Europe. In comparison, Malaysia has slowly established itself as a worthy exporter by obtaining the 17th biggest exporter in volume of briquettes in 2022, climbing one place higher from 2021 with a difference of more than USD 3 million in export value. Figure 4 shows the top importers for Malaysian wood briquettes in 2023, including Japan, Brunei, Singapore, and New Zealand, with Japan having the highest import value of USD 6.9 million.

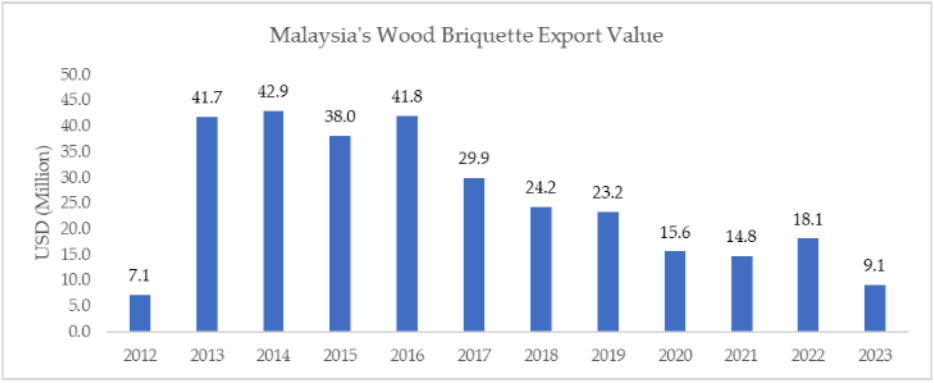

Figure 3: *Malaysia's wood briquette export value (2012 to 2023) [19,31]*

2.3. Wood Charcoal

Wood charcoal is a black porous substance obtained by controlled burning of wood in the absence of air. The process of converting wood into charcoal is called carbonization or pyrolysis [32]. In this

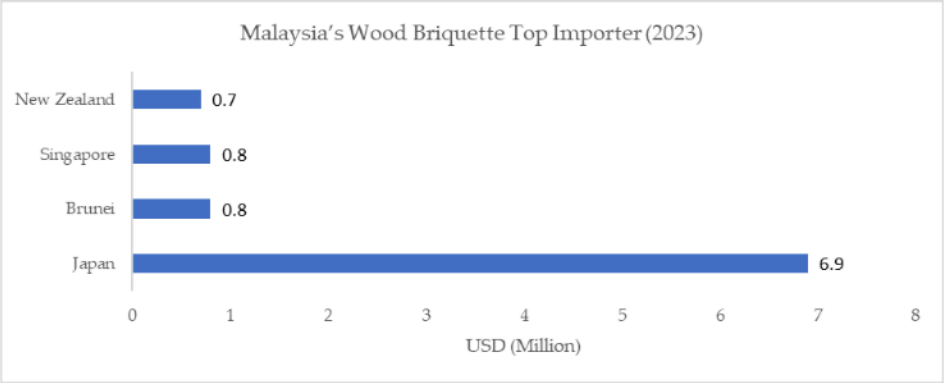

Figure 4: *Malaysia's wood briquette top importer (2023) [19]*

process, wood is heated in the absence of air, preventing complete combustion. As wood is heated, volatile compounds, water, and other elements are removed, leaving carbon-rich charcoal [33]. Charcoal has been used as a fuel source for cooking, heating, and industrial processes for centuries.

The abundance of mangrove forests in Malaysia contributed to the early beginnings of the wood charcoal industry in Malaysia. Charcoal production is deeply intertwined with the cultural and economic development of the country, as is that of Kubang Badak and Langkawi [34]. Today, the export of Malaysian wood charcoal globally started in 2012, as shown in Figure 5. In its early stages, Malaysia has shown an impressive and steady entry with approximately USD 20 million in export value until 2014, when the export value increased from then on. However, there is an apparent decrease in export value from 2020 onward, which is likely due to the disruption caused by the Covid-19 pandemic. During the pandemic, most of the supply chain for goods and products was disrupted, which eventually forced some businesses to close [3]. Fortunately, the trend of the export value of wood charcoal from Malaysia remains above the USD 20 million threshold, where Malaysia holds the 17th position as the top exporter for wood charcoal. However, compared to Indonesia, which is the number one wood charcoal exporter for five consecutive years since 2019, Malaysia could potentially improve to take it to the next level. However, there are still global demands for Malaysian wood charcoal such as China, Singapore, the United Arab Emirates and especially Japan, which represents 88% of the export value, as shown in Figure 6.

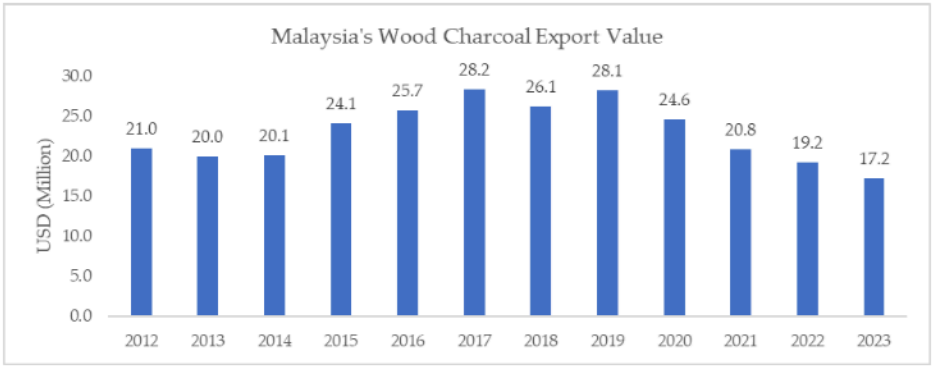

Figure 5: *Malaysia's wood charcoal export value (2012 to 2023) [20]*

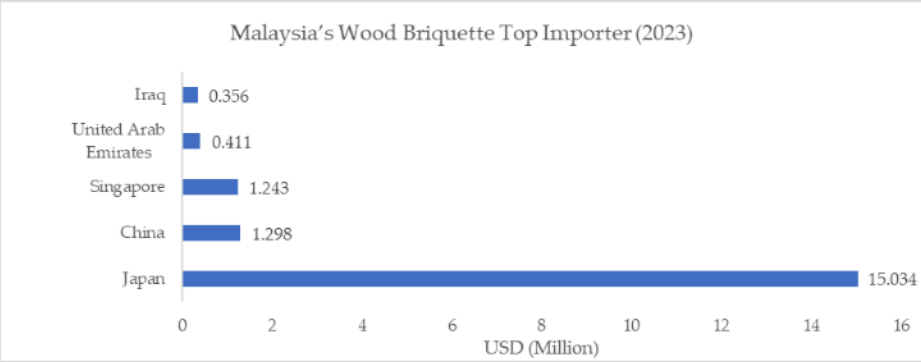

Figure 6: *Malaysia's wood charcoal top importer (2023) [19]*

2.4. Fuel wood

Fuel wood usually refers to a category of wood that functions as a very basic source of fuel for various purposes, such as heating and cooking. It is one of the oldest forms of wood that has been used as a form of energy for human activities throughout history. Fuel wood can be obtained from various types of wood, including branches, logs, and wood residues. It may come from both renewable and non-renewable sources, depending on the sustainability of existing harvesting practices or none of them [35]. Fuel wood is commonly used for heating purposes in residential settings, where it can be burned in stoves, fireplaces, or traditional open fires. In many parts of the world, especially in rural areas, fuel wood is a primary source of energy for cooking [36]. However, fuel wood can also be further processed to produce other products, such as chips for chipboards or briquettes.

Since the British colonial period, fuel wood has been a primary source of energy for domestic use in Malaysia, especially in rural areas. Even after Malaysia gained independence in 1957, the use of wood as fuel continued due to the limited access to modern energy sources [37]. Today, the use of fuel wood is limited due to the available alternatives, particularly fossil fuel. Thus, Malaysian fuel wood demand stopped after 2016, as shown in Figure 7, where fluctuations can be seen since 2012, showing an instability in demand. In addition to the shift in the use of energy and cooking fuel, the decrease in the trade in fuel wood is plausibly contributed by the negative effect of unsustainable fuel wood harvesting that leads to deforestation and forest degradation. Hence, most countries implemented stricter regulations in harvest practice to promote sustainability [39].

2.5. Wood chips or particles

Wood chips or particles are small pieces of wood that result from the chipping or shredding of larger pieces of wood. These chips are commonly produced from various types of wood, both hardwoods and softwoods, because of wood processing mills. Wood chips have applications in a variety of industries, including landscaping, gardening, biomass energy production, and industrial processes [40]. Based on Figure 8, wood chips or particles export started in 2012 and has been gaining momentum ever since due to its various applications, especially as an intermediate product in the bioenergy section. In the first six years, 2012 to 2017, the average value obtained through the export of wood chips or particles was limited to approximately 25 million USD only; however, in 2018 there is a surge in the export of wood chips and particles from Malaysia with a steady increase of more than 20% year by year [20].

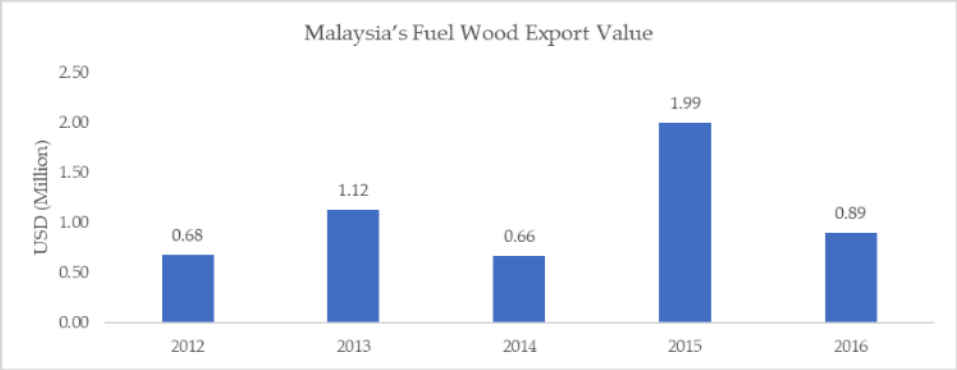

Figure 7: *Malaysia's Fuel wood export value (2012 to 2016) [20]*

In the global market, Malaysia has been shown to gain traction in the export of wood chips, as it is the 9th largest exporter of wood chips or particles in volume in 2022. However, in 2023, there is a substantial drop in the export value of over USD 20 million or approximately 30% difference. The importation of wood chips and particles was driven by many factors, including economic, environmental and industrial needs, as importing wood chips and particles is more cost-effective than producing its own supply domestically for certain countries [41]. The demand for Malaysian wood chips and particles is demonstrated by imports from leading countries such as China, Japan, and Indonesia, as shown in Figure 9.

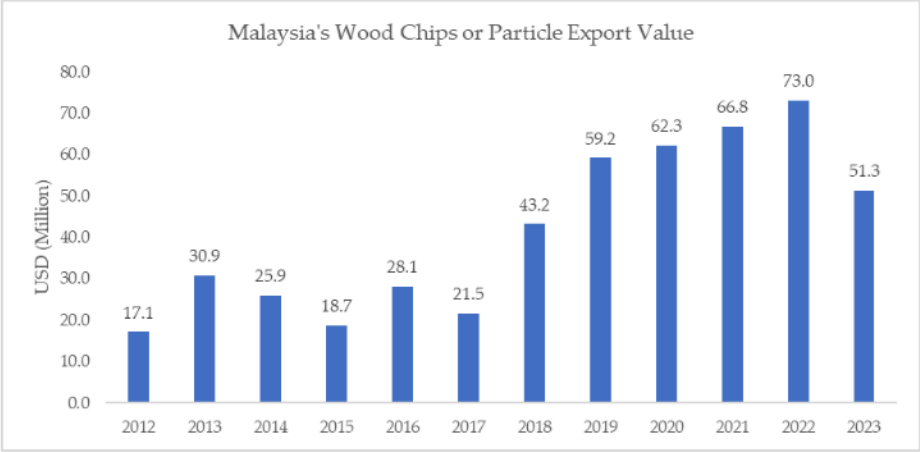

Figure 8: *Malaysia's wood chips or particles export value (2012 to 2023) [20]*

3. Malaysia's Biomass and Biofuel Policy

Biomass and biofuel policies play a crucial role in driving the development of bioenergy in Malaysia as they promote renewable energy sources, reduce greenhouse gas emissions, and improve energy security by diversifying energy supplies [42]. These policies stimulate rural economies, support agriculture and forest sectors, and contribute to waste management efforts while fostering innovation and technology development in the bioenergy sector. In addition,

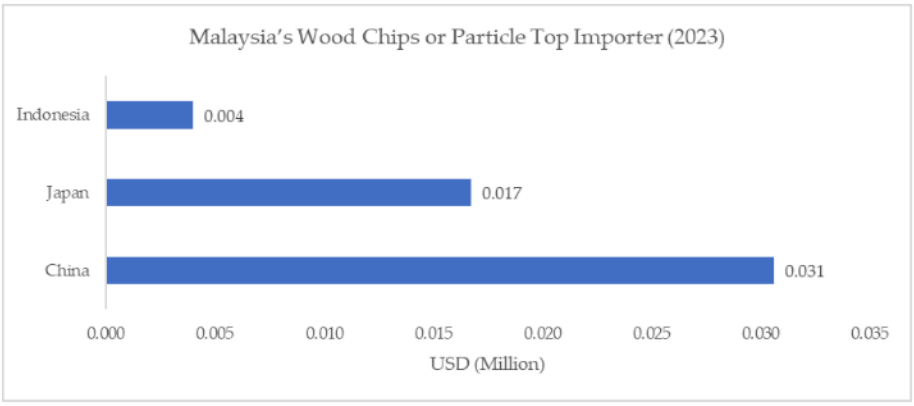

Figure 9: *Malaysia's wood chips or particles top importer (2023) [19]*

they improve air quality, drive international cooperation, and ensure the long-term sustainability of energy production, thus playing a vital role in the resolution of energy, environmental and economic challenges [43].

Malaysia has a diverse range of policies that cover various sectors and issues, reflecting the country's goals for economic development, social welfare, environmental sustainability, and good governance. The policies surrounding Malaysia include economic policies such as the most current Rancangan Malaysia Kedua Belas (RMK 12) or the 12th Malaysia Plan [44], social policies such as the National Community Policy [44], environmental policies such as the National Environmental Policy of Malaysia [45], and energy policies such as the National Biomass Action Plan 2023-2030 [46], which will be further discussed later. The policies that are focused on this paper are those related to biomass and biofuel development, as well as bioenergy. Related content in developmental policies such as the National Development Plan under the Ministry of Economy will also be discussed, along with tailored policies that specify all things related to biomass, such as the National Biomass Action Plan.

3.1. The Malaysia Plan

The Malaysia Plan, also known as the National Development Plan, is a series of comprehensive, long-term development blueprints that outline the government's strategies, policies, and priorities for economic and social development over a specified period. The plans serve as guiding documents for national development, setting goals, targets, and initiatives to achieve sustainable growth, improve living standards, and address key challenges facing the country [44].

Key components of the Malaysia Plan include vision and goals, where each Malaysia Plan articulates a vision for the country's development and sets overarching goals and objectives to be achieved during the plan period. These goals are aligned with the government's broader development agenda and aspirations for the nation. The Malaysia Plan outlines strategies and policies for key sectors of the economy, such as agriculture, industry, services, infrastructure, education, healthcare, and the environment. Identifies priority areas for investment, intervention, and reform to drive sectoral growth and development [47].

The Malaysia Plan's main function is to allocate resources, such as financial, human, and natural, to support the implementation of development programs and projects. It includes budgetary allocations and funding mechanisms to finance priority initiatives and infrastructure projects. Other key components of the Malaysia Plan include the overseeing of projects, past

and present, in which involves mechanisms for monitoring progress, tracking performance indicators, and evaluating the effectiveness of policies and programs. This component of the Malaysia Plan performs recurring or continuous assessments based on the outcomes, impacts, and implementation challenges. Through persistent monitoring, it will allow suggestions and actions for adjustments and refinements to the plan. Clearly, the Malaysia Plan emphasizes coordination and collaboration between various bureaus, such as government agencies, ministries, and other stakeholders, to ensure the effective implementation of development initiatives. It involves mechanisms for inter-agency cooperation, partnerships with the private sector, and engagement with civil society to leverage resources and expertise [44].

As an example, the most current Malaysia Plan, which is the 12th Malaysia Plan, provides the framework for the government's strategies, policies, and priorities in achieving sustainable and inclusive development in the various economic sectors. It builds on the achievements and challenges of previous plans and aligns with Malaysia's long-term vision of becoming a high-income nation by 2030. Regarding the biomass and biofuel industries, the importance of renewable energy and sustainable utilization of biomass resources has been emphasized since the 10th Malaysia Plan as part of Malaysia's energy strategy and economic development agenda. It highlighted the importance of diversifying Malaysia's energy sources and reducing its dependence on fossil fuels, recognized biomass as a key component of the renewable energy mix, and emphasized the need to promote its use for power generation, heating, and other applications. A summary of the evolving biomass and biofuel issues in the Malaysia Plan is shown in Table 1 below.

Table 1: *Summary of biomass and biofuel related content in the Malaysia Plan*

Malaysia Plan	Biomass and Biofuel related content
9th Malaysia Plan	• The first Malaysia Plan that incorporated the importance of renewable energy initiatives • Supports the enhancement of local potential for homegrown renewable energy-based technologies • Promotes development of palm oil for biofuel development • Provides B5-blended diesel designated pump station • Improvements of the accelerated capital allowance financial incentives linked to renewable energy initiatives • Provides promotional programs and courses to raise public awareness on the management and planning of everything related to energy
10th Malaysia Plan	• The first Malaysia Plan that emphasizes the importance of energy security and its role in the transportation sector, making biofuel blends compulsory for the transport sector • Establishment of the New Energy Policy (2011–2015) that focuses on energy security, economic efficiency, and environmental and social considerations • Establishment of Energy Efficiency Master Plan • Energy subsidies reduction to achieve market pricing by 2015
11th Malaysia Plan	• The first Malaysia Plan that accentuates energy sustainability by producing own renewable energy, targets generation of 7.8% electricity using biomass, biogas, solar and mini hydro by 2020 • Increased capacity of experts in the biomass, biogas, solar PV and mini hydro through SEDA • Implementation of Feed-in Tariff (FiT) mechanism to promote investment in renewable energy production • Increased biodiesel blending requirements to 15% in automotive fuel via the B15 program in all sectors by 2020
12th Malaysia Plan	• The first Malaysia Plan that focuses on sustainability in economic circular concept, aiming to significantly reduce greenhouse gas emissions through the enforcement of renewable energy • Identified and included five sectors as primary biomass sources: plantations, forestry, agriculture, livestock, and fisheries • Launched the National Biomass Strategy Action Plan 2023-2030 (PTBN2030) for integrated planning, regulation, and reassessment of the biomass sector • Co-firing projects and biomass hub establishment

3.2. Biomass and biofuel policies

According to Chaudry et al., most Asian countries are still struggling to make significant progress in terms of their Total Factor Energy Efficiency (TFEE), where substantial amounts of carbon dioxide are still emitted according to their notable energy usage [48]. In addition, countries such as Indonesia, specifically in the Sulawesi region, show a barrier to adopting renewable energy due to various factors such as high operational costs and complexity of environmental regulatory regulations [49]. Therefore, effective policies are crucial in promoting bioenergy and energy efficiency as they provide incentives, regulations, and support systems that drive investment, innovation, and the adoption of sustainable energy practices, helping to reduce greenhouse gas emissions and foster energy security. In Malaysia, policies that support bioenergy and energy efficiency play a key role in advancing the nation's renewable energy goals and reducing its carbon footprint. Malaysia has implemented various policies and initiatives to promote the sustainable production and utilization of biomass and biofuels such as the National Biomass Strategy 2020 and its successor, the National Biomass Action Plan 2023-2030 [46,50]. The development of biomass and biofuel policies could be followed from the National Biofuel Policy, which still focuses on the Five-Fuel Diversification Policy, which still targets the use of fossil fuels [50]. However, as policy progresses, the utilization of energy has changed to promote a greater use of renewable energy to reduce the nation's dependence on fossil fuels that are declining.

The policies related to biomass and biofuel include the National Biofuel Policy [50], the National Green Technology Policy [51], the National Biomass Strategy 2020 [18], the National Biomass Action Plan [46], the National Renewable Energy Policy and Action Plan [52], the National Energy Policy [53], the National Policy on Climate Change [54], the National Transition Roadmap for Energy [16], the National Agricommodity Policy [55] and the Malaysian Renewable Energy Roadmap [56]. These policies aim to encourage sustainable energy use through incentives, regulatory frameworks, and strategic programs aligned with Malaysia's commitment to green growth and the global climate agenda. Table 2 includes a summary of related biomass and biofuel policies.

Most of the production and export of the products began after the launch of the National Biomass Policy in 2011, as presented by the status of the export of wood pellets and briquettes. Export of renewable energy in the form of WBSB started as early as 2012, just after the instigation of the first biomass policy in Malaysia. Biofuel policies can stimulate economic growth by creating new markets for agricultural products used in biofuel production. This potentially could also lead to increased exports of biofuel feedstocks and biofuels such as WBSB products. Biofuel or bioenergy-related policies, such as mandates for the blending of biofuels with conventional fuels, create a stable demand for biofuels. This demand encourages both domestic production and international trade in biofuels. Incentives such as the incentive for pelletization capacity from the National Biomass Strategy that supported the increase in pellet production may also kick start the era of wood pellet export, as well as the increasingly competitive positioning of Malaysia in the wood pellet market, with honorable mention of Malaysia obtaining the seventh highest exporter in 2022.

4. Conclusion

The export of WBSB products from Malaysia still has a long way to go, as it is still far from capturing a significant amount of market share in the industry. However, the state of export of the WBSB product is far from disappointing. Some of the products are shown to gain a competitive edge in the race to be the largest exporter in the industry, such as wood pellets and wood chips or

Table 2: *Summary of biomass and biofuel related policy in Malaysia*

Policy	Summary
National Energy Transition Roadmap	• Reduce the dependence of Malaysia on the non-renewable fuels such as coal and oil through flagship projects across six key sectors: energy efficiency (EE), renewable energy (RE), hydrogen, bioenergy, green mobility and carbon capture • Expedite energy shift and revise energy generation technique to improve climate resilience • Transition Malaysia's energy system from fossil fuel-based to greener energy through the development of the Responsible Transition (RT) Pathway 2050 • Escalate renewable energy (RE) utilization 40% to 70% by 2050
National Biomass Action Plan 2023-2030	• Generation of sustainable development advantage such as green wealth creation, socio-economic development, and net-zero emission target through circular economy practices
National Policy on Climate Change	• Address the challenges posed by climate change • Promotes renewable energy to reduce greenhouse gas emissions • Aims to achieve 45% reduction in carbon intensity by 2030 • Updated in 2023
National Agricommodity Policy	• Establishing circular economy through agricommodity biomass. • The eight recognized commodities to focus includes palm oil, rubber, timber, cocoa, pepper, plant-based fibers (kenaf and other plant-based fibers), biomass and biofuels
Malaysia Renewable Energy Roadmap	• Outlines the strategic plan to increase the share of renewable energy in the national mix • Aims to achieve 31% renewable energy share in the national installed capacity mix by 2025
National Energy Policy	• Outlines the strategic direction for the national energy sector • Aims to advance the nation's energy sector to be resilient and sustainable • Ensures energy supply security

particles. For wood pellet export, Malaysia has been gaining momentum in the relay as it is listed as one of the top 10 largest exporters in the world, number seven in 2022, falling behind Vietnam, which remained the second biggest exporter, five years in a row. Meanwhile, the export of wood chips or particles is also impressive as it has risen to 9th rank, while our neighboring country, Indonesia, topped the list at number one. Through the outlining of the status of the export from Malaysia, information of the situational shape of the economic growth based on WBSB exports are accessible.

Policies such as the 2011 National Biomass Strategy practically started most of the export activities of WBSB products from Malaysia, providing support in terms of financing and tax exemption. The effort of the Malaysian government is commendable based on the revolution of policies. As we can see in Tables 1 and Table 2, Malaysia slowly increases the promotion of the use of biofuels or renewable energy from one policy to the other. The 2006 National Biofuel Policy first included the addition of renewable energy in the fuel diversification policy, and by the National Energy Transition Roadmap (NETR), it aspires to increase the usage of renewable energy by up to 70%. Malaysia's efforts to develop a wood-based biofuel policy reflect a broader commitment to sustainable energy practices and the circular economy. The country has made significant strides in integrating biomass, including wood-based resources, into its energy mix through comprehensive policy frameworks and strategic action plans. By leveraging its rich biomass resources and implementing strategic policies, Malaysia is paving the way for a more sustainable and economically resilient future. The progression of the policies in Malaysia shows a more committed direction in the development of biofuels, providing a wide array of rules and regulations, allocation of resources, and incentives that allow progress in this aspect.

Despite the effort and good results of the policies, WBSB in Malaysia still faces several challenges that hinder its widespread adoption and development, and to the extent of rivaling neighboring countries such as Vietnam and Indonesia. One significant challenge is still the limited infrastructure for biomass collection, transportation, and processing, which hinders the efficient scaling of production capacity, despite incentives from the available policies. The lack of standardized quality control measures and variability in feedstock sources present obstacles in ensuring consistent and high-quality WBSB production that can present a big disadvantage in our export competitiveness. In addition, there is a need for clearer and more supportive policy frameworks to provide incentives for investment, research, and development in the bioenergy sector, addressing issues such as feedstock supply, market incentives, and regulatory standards. Furthermore, technological advancements are essential to improve the efficiency of biomass conversion processes, reduce production costs, and improve the overall competitiveness of Malaysian WBSB in both domestic and international markets.

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