National Biomass Strategy 2020: New wealth creation for Malaysia's palm oil industry

AGENSI INOVASI MALAYSIA

in collaboration with

MiGHT
Malaysian Industry-Government Group for High Technology

Contents

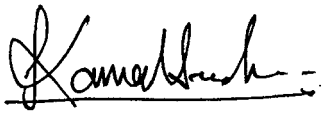
Foreword and acknowledgements

This report is the result of an extensive collaboration of the Malaysian Government with private sector companies as well as domestic and international research institutes and academia to assess how Malaysia can gain more revenue from its palm oil industry through utilisation of the associated biomass. An explicit goal of the study was to determine how Malaysia can develop new biomass sectors with the aim of creating higher value-added economic activities that contribute towards Malaysia's gross national income (GNI) and creating high value jobs for the benefit of Malaysians.

This work builds on previous efforts and more than 100 reports and publications including but not limited to the Biomass Roadmap prepared by the Ministry of Science, Technology and Innovation (MOSTI), the Climate Change Response paper by Malaysian Life Sciences Capital Fund (MLSCF), multiple research papers and statistical data sets of the Malaysian Palm Oil Board (MPOB) and material prepared for the Palm Oil NKEA and ETP Chapter 9. These efforts provided an invaluable starting point for this National Biomass Strategy 2020. In addition a survey of palm oil mills and plantations was conducted to obtain input from over 170 plantations and 70 mills. This work was an inclusive effort that involved more than 50 entities from Government, academia and industry, and over 120 individual stakeholders. An advisory panel and a stakeholder lab were convened twice to ensure that the views of the many stakeholders that would be involved in making this opportunity a reality for Malaysia were fully understood and reflected in this strategy.

This strategy provides clarity on the value of Malaysia's oil palm biomass, and the complexity associated with capturing that value, given the many potential uses, each with a different risk-return profile. It highlights the importance of a portfolio approach to utilising Malaysia's oil palm biomass, and the importance of acting quickly to ensure Malaysia does not lose out on this opportunity. This paper also provides data on the cost of mobilising Malaysia's oil palm biomass and a perspective on what volume of biomass can be cost-effectively mobilised to ensure global competitiveness.

We wish to acknowledge the support and contributions of all collaborating government agencies, academic and research institutions and private sector partners.



Dato' Dr. Kamal Jit Singh
CEO Agensi Inovasi Malaysia

Executive summary

Malaysia currently generates about 11 percent of GNI from the agriculture sector. In the process of creating this value, a significant amount of biomass is generated every year across a variety of crops, including but not limited to palm oil, rubber and rice. Within agriculture, by far the largest contributor to GNI is the palm oil sector, contributing about 8 percent or almost RM 50 billion. The palm oil sector correspondingly generates the largest amount of biomass, estimated at 80 million dry tonnes in 2010. This is expected to increase to about 100 million dry tonnes by 2020, primarily driven by increases in yield. As a result, this National Biomass Strategy 2020 focuses on oil palm biomass as a starting point, which may later be extended to include biomass from other sources.

The vast majority of the oil palm biomass being generated today is returned to the field to release its nutrients and replenish the soil. The biomass returned to the field as organic fertiliser plays an important role to ensure the sustainability of fresh fruit bunch (FFB) yields. However there is also the potential to utilise this biomass for a variety of additional end uses, including but not limited to the production of wood products, pellets, bioenergy, biofuels and biobased chemicals. Due care and caution must be taken to balance the amount of biomass that is left in the field for its nutrient value versus that utilised for higher value-added uses.

The different uses have very different risk-return profiles, given different technological maturities, global demand potential and competitive dynamics. Not surprisingly, the highest-value opportunities – biofuels and biobased chemicals – carry also the highest technology uncertainty and competitive risk. A portfolio approach is critical for the nation to ensure there is a combination of short to medium-term investments into immediate opportunities and longer-term investment in higher value-added opportunities.

A conservative scenario of utilising an additional 20 million tonnes of oil palm biomass by 2020 for higher-value uses has the potential to contribute significantly to the nation's economy. In addition to a significant incremental contribution to GNI of RM 30 billion by 2020, this National Biomass Strategy 2020 offers Malaysia a way to meet its renewable energy target, reduce emissions and create about 66,000 incremental jobs. This strategy also offers an opportunity for Malaysia to build several biofuel and biobased chemical downstream clusters to ensure the nation benefits from the downstream value creation potential.

From a supply-side perspective, by 2020 Malaysia's palm oil industry is expected to generate about 100 million dry tonnes of solid biomass. This includes not only the empty fruit bunches (EFB), mesocarp fibres (MF) and palm kernel shells (PKS), but also the oil palm fronds and trunks. Excluded from this figure is palm oil mill effluent (POME). On current course, most of this solid biomass will remain in the plantations

as fertiliser, with a small but increasing amount being utilised for bioenergy given the introduction of a renewable energy feed-in-tariff system.

Biomass should not be removed from the field without consideration of its nutrient value and protection to the top soil. However there is the potential to retain in the field the portion of the biomass that has the highest nutrient value but the lowest downstream value, as represented by its carbohydrate content, and replace the balance with inorganic substitutes. Moreover, converting the mostly unused POME into biogas for either powering the mills or selling power into the national grid would contribute towards the renewable energy target of Malaysia – 410 MW of installed biogas capacity by 2030. This initiative alone would reduce the nation's carbon dioxide (CO_2) emissions by 12 percent and free up significant biomass for higher value-added uses. Taken in combination, this has the potential to free up 20–30 percent of the available solid biomass for higher value-added uses without affecting palm oil yields. This of course is a decision each palm oil mill will have to make based on its long-term commercial and sustainability merits.

Assessing the various costs of mobilising oil palm biomass today – harvesting, collection, pre-processing, substitution and transportation to a downstream hub – on the order of 25 million tonnes of biomass can be mobilised at globally competitive costs, i.e., at a cost of less than RM 250 per dry-weight tonne.

On current course (i.e., business as usual), approximately 12 million tonnes of solid biomass will likely be utilised for non-fertiliser uses by 2020, primarily for wood products and bioenergy. An additional 20 million tonnes could be mobilised for additional uses such as pellets, biofuels and biobased chemical industries. In total, this is approximately 30 percent of the solid biomass the palm oil industry is expected to generate annually by 2020.

Pellets is a natural entry point, as the technology is reasonably mature, the cost of developing infrastructure relatively low (i.e., RM 30–40 million per plant with a capacity of 100,000 tonnes) and the payback of 3–5 years relatively quick. Hence, while pellets enable profitable mobilization today, they also act as a buffer. Should higher value biobased chemicals materialize earlier or should Malaysia capture a bigger share of the global biobased chemicals market, biomass can be diverted from pellets to capture these higher value opportunities. These business as usual uses of wood products, bioenergy and pellets provide an opportunity to generate value from biomass today, with the potential to generate revenue of RM 200–1,000 per dry tonne of solid biomass input. In parallel, resources should be expended to invest in longer-term projects around biofuels and biobased chemicals. These have higher risk and are expected to reach commercial scale only in the 2015–2020 timeframe, however have the potential for significantly higher value creation – on the order of RM 1,000–3,000 of revenue per dry tonne of solid biomass input. The biggest long-term opportunity for Malaysia is in biobased chemicals, with a forecasted global market size of RM 110–175 billion by 2020.

A critical success factor will be the mobilisation of biomass, both with regards to logistics – how to move it efficiently from plantations to centres of production – and cost – to ensure globally competitive costs. While larger plantations will be able to participate in this opportunity given their individual scale, there is still merit in the use

of partnerships to reduce risk. And it will be critical to create best-practice cooperative structures to enable smaller plantations and small holders to participate.

As the world's second largest producer and largest exporter of palm oil, this is a natural opportunity for Malaysia to capture, with a significant prize. However achieving full potential will require significant coordination and cooperation among multiple stakeholders. The development of partnerships and cooperative structures among plantation owners is critical to mobilise the biomass, and Entry Point Projects (EPP) are being used to accelerate this opportunity. Two new EPPs have already been defined for pelletisation capacity and the launch of an industry consortium to catalyse development of conversion technologies. In addition, two existing palm oil EPPs have been expanded in scope. Finally, a set of Government policies are in the process of being finalised to reduce the risk to the private sector associated with accelerating this opportunity.

Introduction

Oil palm is the most important agricultural crop of Malaysia. Overall, the palm oil industry is the 4th largest contributor to the country's GNI accounting for about 8 percent or almost RM 50 billion of GNI. Globally, Malaysia is the second largest producer and the largest exporter of crude palm oil. To date, government support for downstream activities has been targeted at palm oil based products such as oleochemicals and, more recently, at strengthening the role of the private sector in this industry as part of the Palm Oil National Key Economic Area (NKEA). At the same time, the palm oil industry generates significant amounts of biomass every year (see *What is oil palm biomass?*), which is mostly used as fertiliser in the plantations.

The National Biomass Strategy 2020 lays the foundations for Malaysia to capitalise on its biomass by channelling it into higher value downstream uses. While the initial strategy focuses on the palm oil industry, the largest producer of biomass in Malaysia, the scope may later be extended to include biomass from sources such as rubber, wood or rice husk.

The strategy identifies opportunities by which Malaysia can achieve significant additional contribution to GNI, increased wealth and job creation from its palm oil sector. It provides a 2020 oil palm biomass to wealth scenario, which will drive the development of national clusters in the biofuel and biobased chemicals industries as well as fulfil the national renewable energy target for biomass to energy. Further, the report emphasises the most immediate priorities that Malaysia can consider as it embarks on the journey towards implementation. The successful realisation of the vision outlined by the National Biomass Strategy 2020 will rely upon strong collaboration among many government agencies. In addition, it will require the support of the private sector and academic and research institutions.

What is oil palm biomass?

Six types of oil palm biomass are produced as by-products of the palm oil industry: oil palm fronds, oil palm trunks, empty fruit bunches, palm kernel shells, mesocarp fibre and palm oil mill effluent.

In the plantations, oil palm fronds (OPF) are available throughout the year as they are regularly cut during harvesting of fresh fruit bunches (FFBs) and pruning of the palm trees. Additional fronds as well as oil palm trunks (OPT) become available in the plantations during the replanting of oil palm trees every 25 to 30 years.

In the mills, empty fruit bunches (EFBs) remain after the removal of the palm fruits from the fruit bunches. Mesocarp fibre (MF) and palm kernel shells (PKS) are recovered during the extraction of crude palm oil (CPO) and palm kernel oil (PKO), respectively. In addition, palm oil mill effluent (POME) accumulates as a liquid biomass at the mills.

Six different types of oil palm biomass exist in plantations and mills

Biomass type	Description	Site of production
Fronds	Leaves of oil palm tree	Plantation
Trunks	Tree trunks available at end of plantation lifecycle	Plantation
EFB	Remains after removal of palm fruits	Mill
Shells (PKS)	Remains after palm kernel oil extraction	Mill
Fiber (MF)	Remains after oil extraction from mesocarp	Mill
POME	Liquid by-product from sterilisation and milling process of FFB	Mill

Assessing the best uses of Malaysia's palm oil biomass

Malaysia could benefit from an additional RM 30 billion contribution to GNI by utilising the biomass from the oil palm industry for higher value-added downstream activities. This would result in more and better jobs for Malaysians, as the country would begin producing high-value products out of a resource that is currently little used in advanced industries in Malaysia. A concerted effort by government, academia and the private sector with private investment on the order of RM 20–25 billion cumulatively over the next 5–10 years and Government involvement in the form of policies and targeted investments to reduce risk is necessary for the nation to achieve this goal by 2020.

Different uses for biomass have very different risk-return profiles, given different technological maturities, global demand potential and competitive dynamics. Malaysia already benefits from producing wood products and animal feed today. Biomass-to-energy plants are being built to take advantage of the Feed-in-Tariff. Moreover the first pellet plants, which will allow the export of oil palm biomass, are currently being set up.

The bigger prize is in higher value, higher risk applications. Producing biofuels and biobased chemicals from biomass would offer increased wealth as well as new and better jobs. However, the technologies to convert lignocellulosic biomass into biofuels will only be available on a commercial scale between 2013 and 2015 as illustrated in Exhibit 1. An additional 3–5 years of optimisation of this technology platform will be required for cost-competitive production of biobased chemicals. The development of research and commercial capabilities as well as the know-how to convert lignocellulosic biomass into sugars will allow Malaysia to tap into the high-value opportunities in biobased chemicals.

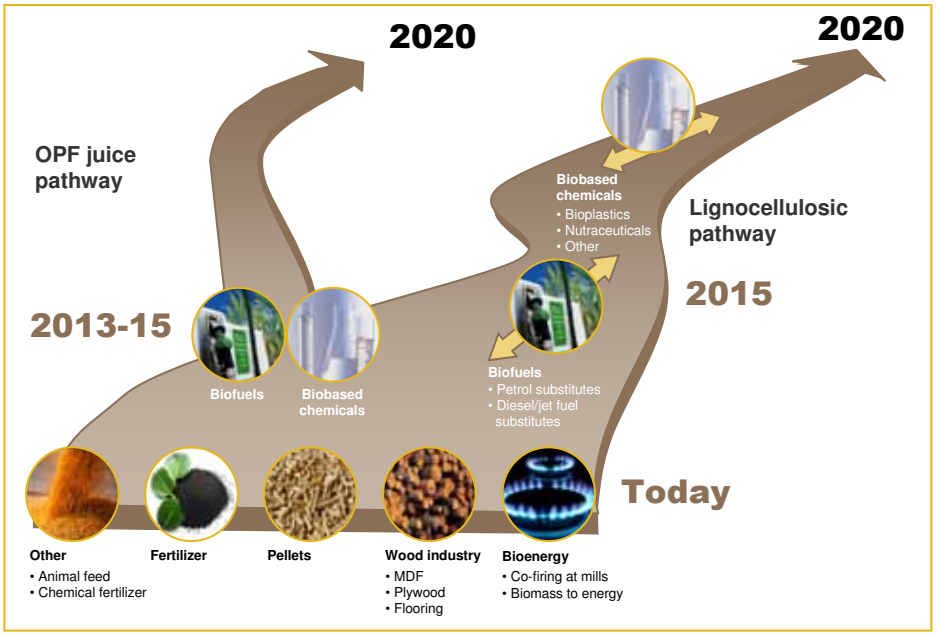
Downstream technologies of today

The downstream technologies to produce wood products, bioenergy and pellets are already well known and available on a large commercial scale across the world and the first installations are being built on the ground in Malaysia.

Today, oil palm biomass is already used as input in the wood industry to produce products such as plywood and medium-density fibre boards (MDF). Large scale pellet plants with more than 750,000 tonnes annual capacity already exist in countries such as Brazil and Sweden, and that technology can be applied in Malaysia.

The transformation of biomass to energy already takes place in Malaysia, but on a smaller scale than that practiced in Europe. With the new renewable energy feed-in tariff system, biomass-to-energy plants of a similar scale to Europe will have to be constructed in Malaysia (see *Malaysia's renewable energy target*).

EXHIBIT 1
Timeline of technological availability



Downstream technologies of tomorrow

First generation biofuels and biobased chemicals – using food crops such as sugarcane, cassava or corn as feedstock – are already produced at commercial scale today, at plants such as the 400,000-tonne ethanol plant in Thailand based on cassava feedstock, or similar plants in Brazil based on sugarcane feedstock. In contrast to these existing technologies that use food biomass as inputs, emerging second-generation technologies are exploring the use of non-food, *lignocellulosic biomass* (e.g., forest and agricultural residues). The term lignocellulosic biomass refers to the main building blocks of plant matter: lignin, cellulose and hemicellulose.

Second generation technologies to convert lignocellulosic biomass to biofuels are still in development, with first pilot and demonstration plants in operation today, though not in Malaysia. Technological uncertainty remains around the step of breaking down the biomass into individual sugars that can subsequently be fermented in a manner similar to existing first generation approaches. Despite this uncertainty, biofuel from lignocellulosic biomass is expected to be commercially viable between 2013 and 2015.

Although a steep learning curve is expected in the first years of commercialisation, second generation ethanol may initially not be competitive with first-generation ethanol from sugar cane, and thus is unlikely to compete in the export market. Therefore, second generation biofuels will require domestic policy support such as a blending mandate to be successful in the mid-term.

On the other hand, the production of biobased chemicals from lignocellulosic biomass faces additional hurdles. Biobased chemicals derived from ethanol can

be produced on a commercial scale once the process of converting lignocellulosic biomass to ethanol has been optimised at scale and the exact composition of the input is known. The production of other (non-ethanol) biobased chemicals from lignocellulosic biomass is slightly more difficult, but small scale pilots are being built today, for example a 1,000-tonne succinic acid plant in China's Jiangsu Province. Production is expected to reach commercial scale between 2015 and 2020.

An alternative route to derive biofuels and biobased chemicals from oil palm biomass is to squeeze sugar juice from the basal part of the oil palm frond. Similar to sugar cane, the juice can then serve as feedstock for production of first generation biofuels and biobased chemicals, and thus many of those products could be produced today. However, the juice of the oil palm frond contains less than 10 percent of the carbohydrates present. The remaining sugars are the building blocks of the insoluble, cellulosic material of the frond. Hence, from 1 tonne of wet weight oil palm fronds 400 kg of sugars can be recovered by breaking down the cellulosic components, compared to only 40 kg of sugars from the oil palm frond juice alone. The use of sugar juice is unlikely to be the most economically viable in the long term, but it could provide a stepping stone for the industry until the lignocellulosic route becomes technically feasible.

Business as usual

In a business as usual scenario, by 2020 Malaysia's palm oil industry would provide 12 million tonnes of biomass p.a. for use in wood products and bioenergy.

Currently, oil palm biomass makes up a small percentage of the input to the wood industry. This is expected to grow steadily to about 1 million tonnes p.a. in 2015; with industry growth and a higher share of oil palm biomass as input instead of rubber wood the volume is expected to reach almost 3 million tonnes of biomass p.a. by 2020.

In 2015, more than 3.5 million tonnes of biomass and in 2020, close to 9 million tonnes of biomass will be used for biomass to energy production so that the country can meet its renewable energy target (see *Malaysia's renewable energy target*).

In all, the use of oil palm biomass in the wood and bioenergy industries by 2020 could contribute RM 2.8 billion and RM 2.4 billion to GNI respectively (Exhibit 2). The growth of bioenergy alone will create about 1,400 and 3,900 direct and indirect jobs respectively and require additional private investment of RM 8–10 billion.

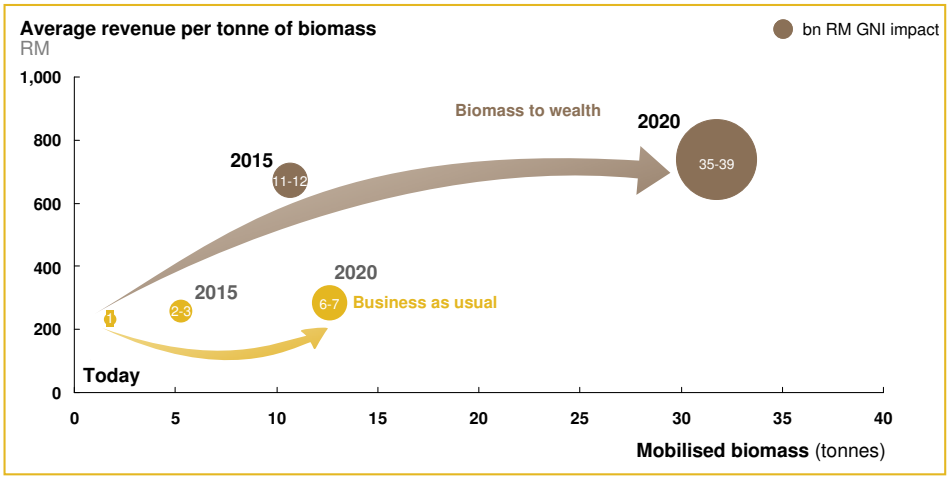
Additional value creation: Biomass to wealth

To fully capitalise on the biomass opportunity, an additional 20 million tonnes of biomass compared to a business as usual scenario could be deployed towards higher-value downstream activities such as pellets, biofuels and biobased chemicals.

Pellets

Converting biomass to pellets will allow plantation owners in Malaysia to immediately capitalise on available biomass. Pellets produced in Malaysia can be shipped to Europe as well as Japan or Korea to be burned for energy. There is an

EXHIBIT 2
National Biomass Strategy 2020 would deliver incremental GNI of approximately RM 30 bn



existing market demand for pellets from European energy utility companies that need to meet European renewable energy targets. Similarly, Japan is sourcing biomass for co-firing to ensure sufficient energy supply given its reduction in nuclear energy capacity. The current European market is about 10 million tonnes of pellets p.a., which at current growth rates could be as much as 90 million tonnes p.a. by 2020. European utilities value assurance of supply and longer term contracts (i.e., 12–18 months), and Malaysian pellet companies that can meet these needs may be able to command a higher price.

A 100,000-tonne p.a. pellet plant can be constructed for RM 30–40 million within a year with just minor customisation of existing technologies. The capital investment is expected to have a payback period of 3–5 years depending on the changes in pellet prices. A plant of this size will allow plantation owners to immediately capitalise on biomass not currently used for other purposes and kick-start the mobilisation of biomass. Mobilising 10 million tonnes of biomass for pellets by 2020 could create about RM 9–10 billion in GNI and about 5,500 and 6,800 direct and indirect jobs respectively. The cumulative private sector investment required is RM 3–4 billion.

In addition to the contribution to GNI and the creation of new jobs, pelletization creates flexibility by allowing the industry to divert biomass to higher value opportunities such as biobased chemicals. This becomes especially relevant if biobased chemicals materialize earlier and/or global demand for biofuels and biobased chemicals grows faster than expected. Similarly, if total biomass supply five years from today was lower than anticipated, the available biomass should be used for the highest value end-use available and thus redirected towards biobased chemicals.

Biofuels

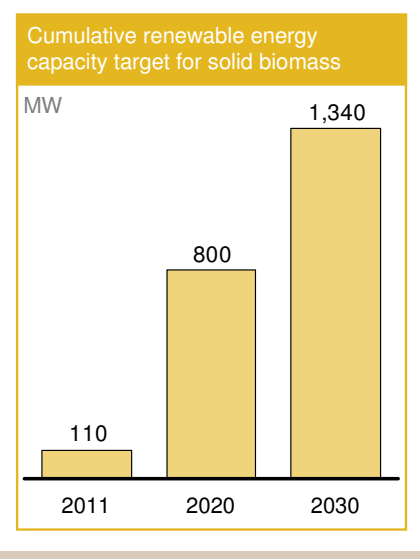
Once second-generation biofuels (e.g. bioethanol, biobutanol etc.) become technically feasible on a commercial scale, they present a potential opportunity for Malaysia, but will initially likely not be competitive with first-generation biofuels (e.g., Brazilian sugarcane) in the export markets. Introducing a mandate for

Malaysia's renewable energy target

The Renewable Energy Policy and Action Plan sets a target of 4,000 megawatts of installed renewable energy capacity for 2030, raising the total installed capacity to 17 percent from less than 1 percent today. This target covers five individual types of renewable energy: biogas, biomass, municipal solid waste, small hydro and solar photovoltaic (PV).

The target for biogas alone is 410 MW installed capacity by 2030, which can only be achieved by the conversion of almost all mills to use biogas, as suggested by EPP 5 of the Palm Oil NKEA. This can be achieved by capturing the biogas produced by the POME at the palm oil mills. To generate energy, a facility to capture the biogas must be constructed at a cost of RM 4–5 million and the existing boilers in the mills converted to use biogas as input at a cost of about RM 0.5 million. Importantly, this will supply the mills with sufficient power and steam to run their processing facilities, and allow those mills connected to the power grid to supply some power to the grid.

The target for biomass is to reach 1,340 MW by 2030. This can be achieved by a combination of installing small power plants in the vicinity of grid connected mills, or larger, more efficient power plants closer to industrial clusters. The interim target of 800 MW in 2020 will require 6–9 million tonnes of biomass for this purpose, depending on the efficiency of the plants constructed.



bioethanol blending of 10 percent in Malaysia would generate a domestic demand for 1 million tonnes of bioethanol p.a. (see Capturing the RM 30 billion opportunity for details).

Significant investment from the private sector will be required to build five to ten bioethanol plants across Peninsular and East Malaysia. The capital cost to construct a mid-sized bioethanol plant with an annual capacity of 100,000 tonnes is about RM 450 million.

To meet demand for 1 million tonnes of bioethanol p.a. would require about 4 million tonnes of biomass to be mobilised and could result in a GNI increase of RM 7–9 billion and 1,700 and 9,400 direct and indirect jobs respectively. The cumulative investment required is RM 5–7 billion.

However, given its reliance on a national blending mandate the biofuels opportunity requires further study and assessment.

Biobased chemicals

Biobased chemicals represent the largest potential for Malaysia. Currently, the global market for all chemicals amounts to more than RM 7 trillion. Of this, lignocellulosic biomass can supply about 0.6 percent, equivalent to a global market size of RM 48 billion, which is expected to grow to as much as RM 110–175 billion by 2020.

By taking a diverse portfolio approach Malaysia can produce as much as 1.6 million tonnes of biobased chemicals, with a market value of RM 7–9 billion. This would cover a broad range of chemicals from ethanol based chemistry like polyethylene and ethylene oxide, to amino acids like glutamic acid and serine, to other chemicals like polylactic acid and acetone. What will become the most attractive chemicals to focus on is difficult to judge at this time, as is the most attractive way of deriving them (see *The brave unknown*).

To fulfil the production of 1.6 million tonnes of biobased chemicals would require 10–20 biobased chemical plants and a total investment of RM 10–15 billion by the private sector as well as the mobilisation of about 5.5 million tonnes of biomass. The products would largely be manufactured for export, but there is an opportunity to build an even larger downstream industry around this, leading to more wealth being generated in Malaysia. Seizing the biobased chemicals opportunity could lead to an increase in GNI of RM 14–15 billion and the creation of 2,500 and 13,400 direct and indirect jobs respectively.

Summary

In total, the opportunity for pellets, biofuels and biobased chemicals represents a possible GNI increase of RM 30–34 billion and the creation of 10,000 and 30,000 direct and indirect jobs respectively compared to business as usual (Exhibit 2). For this opportunity to be realised, an additional 20 million tonnes of biomass must be mobilised than that required in the business as usual scenario that includes only the wood industry and bioenergy. The realisation of this opportunity for Malaysia will also require active private sector participation and investment amounting to RM 20–26 billion.

The Brave Unknown

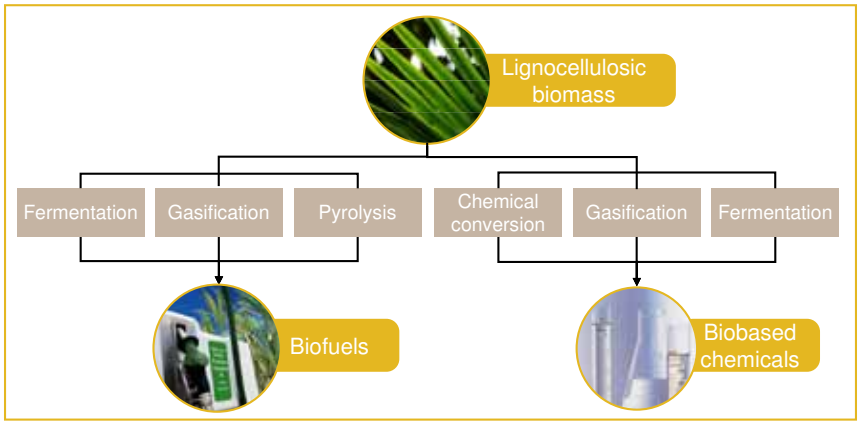
Three main biomass conversion technology platforms are being explored today: thermal, biological and chemical.

Thermal conversion: Biomass is first broken down into syngas using heat and low oxygen concentrations. Subsequently, a range of thermo-chemical processes can be applied to generate fuels or chemicals.

Biological conversion: Biomass is treated by chemicals and enzymes to produce sugars, which are then fermented into the desired fuels or chemicals.

Chemical conversion: Biomass and sugars are treated using chemicals only in a variety of methods to produce fuels or chemicals.

Pilot scale plants employing each of these technologies have been completed for both biofuels and biobased chemicals. At this stage of development it is impossible to predict a winning technology platform and it is likely that several technologies will emerge depending on what specific end products are desired. Thus no specific technology is expected to become vastly dominant across the biobased chemical industry.



Initiatives until 2020

Many initiatives will have to begin before future technologies become commercially attractive. Mills will have to switch from burning biomass to using biogas. Plantation cooperatives will begin mobilising biomass for pellet plants and other end uses. Different conversion technologies need to be tested, starting with pilot plants and leading up to commercial scale plants, and before 2015, an industry around second generation biofuel will be developed.

Given the higher risk and return of future technologies, private sector participants might chose to jointly develop and scale up future downstream end uses. However, it is important to Malaysia's success in developing new higher value industries that these building blocks for future scenarios are laid today.

Costing the mobilisation of biomass to create more value from oil palm

Malaysia's palm oil plantations are spread out across both Peninsular and East Malaysia, with the states of Sabah and Sarawak containing the largest proportion of planted area. The total acreage under cultivation grew from 3.38 million hectares in 2000 to 4.85 million hectares in 2010.

Potential upstream volume by 2020

In 2010, Malaysia's palm oil industry produced almost 80 million dry tonnes of solid biomass p.a. This volume is projected to increase to 85–110 million dry tonnes by 2020. Similarly, POME volumes are expected to increase from 60 million tonnes today to 70–110 million tonnes by 2020.

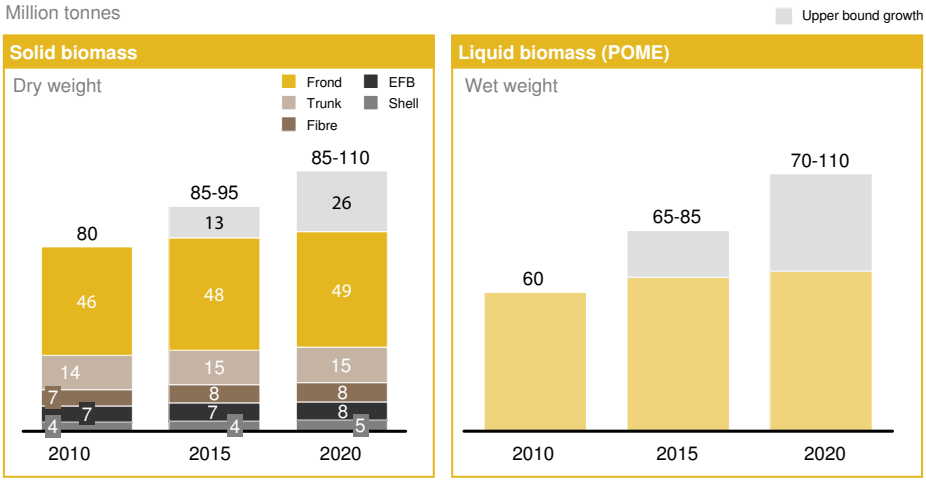
Historically, an increase in planted area for oil palm was the main driver of biomass volume growth. Going forward, the forecasted growth will be influenced by a combination of plantation expansion and FFB yield improvement. Improvements in yield of FFB for palm oil production are possible with continuous improvements in plantation management, crop material and replanting of mature plantations.

Most of the solid biomass is found in the plantations, as fronds and trunks account for about 75 percent of the biomass volume as illustrated in Exhibit 3. The remaining 25 percent is generated in the mills during the extraction of palm oil.

Cost of mobilising upstream volume

For Malaysia to fully capture the downstream potential of oil palm biomass, it is necessary to free up part of the biomass from its current uses and establish a collection system for fronds and trunks, which presently remain in the plantations. It is critical that the oil palm biomass be mobilised at a cost that is competitive with global substitutes and other agricultural residues such as sugar cane leaves, corn stover or wheat straw. The cost of these residues typically ranges between RM 130 to RM 180 per dry tonne at mill gate. As such, it is important to understand the volume of oil palm biomass that can be mobilised at an average cost of less than RM 150 per tonne at mill gate. For the purpose of assessing the economic feasibility of mobilisation, four kinds of cost were considered for making biomass available for downstream uses: substitution cost, harvesting and collection cost, pre-processing cost and transportation cost.

EXHIBIT 3
By 2020, solid biomass will increase to 85-110 million tonnes, POME to 70-110 million tonnes



Forecast assumptions:
Yield growth: lower bound: historical growth rate of CAGR of 0.1%; upper bound: ETP projections of 26 tonne FFB/ha in 2020
Increase in planted area: lower bound: MPOB - increase of 1.1 million ha over 2005 figures; upper bound: ETP upper limit of 28% area increase over 2010. Figure excludes seasonality

SOURCE: ETP; MPOB; "Exploring land use changes and the role of palm oil production in Indonesia and Malaysia" 2010. B. Wicket

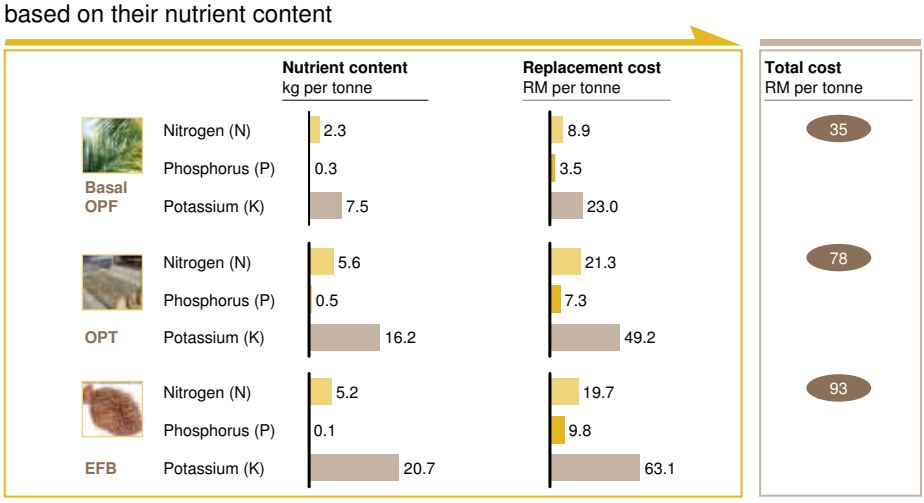
Substitution cost

Today, an estimated three quarters of the solid biomass is used for nutrient replacement and mulching purposes in plantations. To this end, fronds and trunks are retained in the plantations, and a large share of the EFBs is returned from the mills to the plantations. In the mills, mesocarp fibre, palm kernel shells and some EFBs are utilised for steam and power generation. In addition, some of the biomass is used for niche downstream applications, such as in the wood industry and as animal feed.

The cost of replacing some of the biomass with synthetic fertiliser is a combination of the price of synthetic fertiliser with equivalent nutrient content and the cost to apply that synthetic fertiliser in the plantation. Exhibit 4 outlines the differences in nutrient content between oil palm fronds (OPF), oil palm trunks (OPT) and EFBs, and the respective fertiliser replacement cost. Of note is that only the frond's basal portion will be collected for downstream uses in biofuels and biobased chemicals, while the frond's leaflets which contain most of the nutrients are left in the plantation (See *The nutrient content of fronds*). Across all biomass types, 80 percent of nutrients would remain in the plantations in the 2020 biomass to wealth scenario. Still additional long-term research studies are needed to assess any potential impact on CPO yield and soil health.

Besides being used for steam and power generation at the mills, mesocarp fibre and palm kernel shells are also being sold today, e.g., for non-mill power generation or to the cement industry. Thus the cost of substitution is the current market price, which in 2010 was RM 40 per tonne for mesocarp fibre and RM 130 per tonne for palm kernel shells.

EXHIBIT 4
Fertilizer replacement costs were estimated for OPF, OPT and EFB based on their nutrient content



SOURCE: Quantification of oil palm biomass and nutrient value in a mature plantation. Khalid et al.

Harvesting and collection cost

Today FFBs are harvested and collected in the plantations and subsequently transported to the mills for production of crude palm oil. As a result, EFBs, palm kernel shells and mesocarp fibre already accumulate at the mills and are thus readily available to be transported to aggregation hubs or downstream processing facilities. For fronds and trunks, on the other hand, a new harvesting and collection system will need to be established.

Oil palm fronds can be obtained during plantation replanting, pruning of the oil palm tree and harvesting of FFBs, with the latter accounting for the greatest share of volume. Today, the cut fronds are left as top soil replacement and natural fertiliser. Different collection methods could be adopted to collect the fronds ranging from simple manual collection with a wheelbarrow, to collection with a buffalo cart or motorised cart, to advanced mechanisation. The choice of collection method for a specific plantation depends on the terrain (e.g., elevation, spacing of trees), labour constraints and economies of scale. Depending on the collection method, cost estimates range from RM 16–67 per dry tonne.

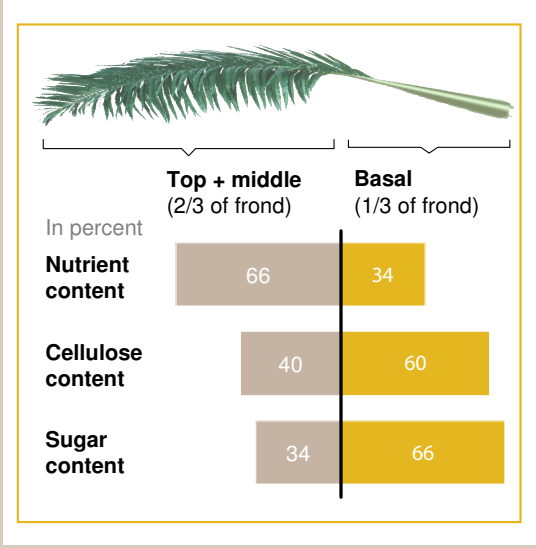
Oil palm trunks become available at the end of a plantation's life cycle every 25–30 years. Today, most of the trunks remain in the plantation as fertiliser. Trunks are either felled and chipped to allow for quicker return of nutrients to the soil, or are killed with poison and left standing to decompose naturally in the field. A small percentage of trunks is currently used for niche uses in the wood industry, for example, flooring, plywood, fibre board and furniture.

Over the next 10 years, approximately 240 million tonnes of trunks will become available during replanting. However, this supply will be unevenly distributed across Malaysia's states as well as over time due to different maturities of the plantations. These geographic and timing constraints pose severe challenges on the collection model as well as on potential uses, as many of the downstream industries would be dependent on a consistent and regular supply of biomass over time. Based on

The nutrient content of fronds

The oil palm frond is approximately 2–3 metres long and weighs about 10 kg (wet weight). It consists of the petiole (the stem) and many long leaflets on either side of the stem. The top two thirds of the frond contain most of the nutrients, while the basal (lower) third is rich in cellulosic materials and sugars, which are needed in the production of biofuels and biobased chemicals.

The collection of only the basal portion of the fronds for downstream uses has two key advantages: two thirds of the desirable content for production of biofuels and biobased chemicals (contained in the basal portion of the frond) would be made available for downstream uses; at the same time two thirds of the nutrients (contained in the remaining two thirds of the frond) would remain in the plantations as fertiliser.



today's fees paid to contractors to remove trunks from plantations, the cost of harvesting and collection is estimated at RM 47 per dry tonne.

Pre-processing cost
Different biomass types can undergo different forms of pre-processing in order to reduce the moisture content, reduce the weight or volume to be transported and/or in preparation for a specific end use. For instance, trunks and fronds can be chipped, dried and/or pelletised, while EFBs and mesocarp fibre can be shredded, dried and/or compacted. Palm kernel shells already have very low moisture content and thus can be used or transported without further pre-processing. Depending on the type of biomass and the extent of pre-processing required, cost estimates range from RM 17–550 per tonne for mesocarp fibres, fronds, trunks and EFBs. With drying accounting for a large proportion of pre-processing cost it is likely that both plantations and downstream industries will explore scenarios that do not require biomass to be dried.

Transportation cost
Most of the crude palm oil is currently transported from the mills to port-based bulking and refinery installations, where it is either further refined or exported internationally by ship. A similar structure is envisaged for the biomass supply chain in order to aggregate sufficiently large biomass volumes in hubs where further processing can take place.

EFBs, palm kernel shells and mesocarp fibre accumulate at the mills and can be transported directly from the mills to these hubs. Fronds and trunks on the other hand first need to be collected in the plantations. They could either be transported first from the plantation to the mill and subsequently to a hub or directly from the plantation to a hub. The exact transport mode would depend on the transport distance, the possible savings in transport cost from pre-processing and the final end use.

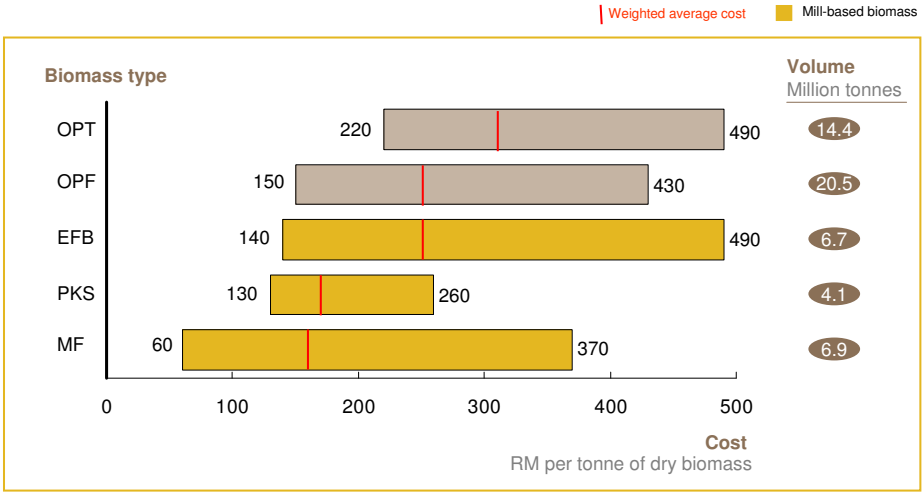
Current cost estimates, based on the density of the product and the distance transported, range from about RM 0.2 to 10.0 per kilometre per tonne. However, these estimates are based on road transport by truck, and actual transport cost could be lower in regions where transport by train and/or barge is feasible.

Summary of costs
Mill-based biomass, i.e., mesocarp fibre, palm kernel shells and EFBs, accounts for most of the biomass that can be sourced at the lowest cost (Exhibit 5).

As illustrated in Exhibit 6, 25 million dry tonnes of biomass could be aggregated today at the principle port-based bulking installations for less than RM 250 per tonne. This is equivalent to a cost of approximately RM 150 per tonne at mill gate, which is required to be competitive with global substitutes. About 44 percent of this volume would be available in Peninsular Malaysia and 56 percent in East Malaysia, the bulk of which would come from Sabah.

EXHIBIT 5

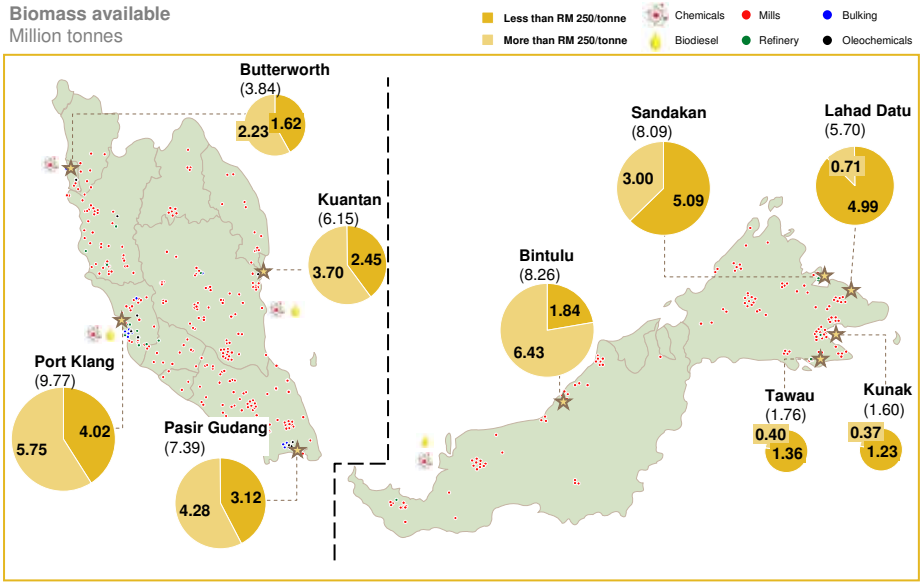
Mill-based biomass accounts for most of the 'cheap' biomass



SOURCE:, M. Islam et al.; K. Haron et al.; H. Kalid et al;. Lazaro A. et al.; ICIS; MARDI; MPOB; Field visit; Interviews

EXHIBIT 6

25 million tonnes of biomass can be mobilised at competitive cost



SOURCE:, M. Islam et al.; K. Haron et al.; H. Kalid et al;. Lazaro A. et al.; ICIS; MARDI; MPOB; Field visit; Interviews

Capturing the RM 30 billion opportunity

To realise this opportunity, Malaysia must move decisively and ensure that the right structures, regulatory framework and incentive package are put in place. This will be achieved through firstly supporting the formation of cooperatives of plantation owners and providing transparency of the potential opportunities and need for a portfolio approach. Secondly, the establishment of new EPPs and the expansion of the scope of a few existing EPPs under the umbrella of the Palm Oil NKEA can catalyse private sector investments. Lastly, the Government can adopt new policies to reduce private sector risk.

- **Cooperative structures to help aggregation of biomass** – The creation of cooperatives of plantation owners will help alleviate the risk of vertical market failure between the owners of biomass and the downstream users, such as biobased chemical refineries or pellet plants. This applies especially to the smaller plantations; however it is also potentially relevant to reduce the risk for the larger ones.

  The structure of a cooperative would enable scale and reduce the risk that would be taken by individual plantation owners. Ideally cooperatives would take ownership stakes in downstream industries, therefore giving the owners of biomass an incentive to sell their biomass at an economically viable cost. Cooperatives can and should have different investment strategies, e.g., one might be regionally focused on producing very cost-competitive pellets, while another might take a complete portfolio perspective by supplying to all possible end uses. Plantation owners will be able to choose between different portfolios depending on their investment preference.

- **Transparency of potential opportunities and adopting a portfolio approach** – The Government will play a role to ensure transparency of potential downstream uses, starting with the National Biomass Strategy 2020. There will be a natural tendency for companies to focus on lower-risk opportunities; however it will be critical that a number of the larger companies and cooperatives adopt a longer-term view to extract higher value from the biomass from opportunities in biofuels and/or biobased chemicals.

Two new EPPs within the Palm Oil NKEA are to be established to support the development of a pelletisation industry for export or domestic use and to create a Public-Private Partnership consortium to accelerate the development of new technologies for conversion of lignocellulosic biomass into biofuels, biobased chemicals and/or intermediate products.

- **Pelletisation Capacity EPP** – The production and export of biomass pellets to markets with steeply growing demand, mostly in Europe but potentially also Japan and Korea, can generate RM 9–10 billion GNI impact and provide about 12,000 new jobs in Malaysia.

  Pelletisation technology is already economically viable allowing plantation owners to generate value from their biomass immediately, encouraging in turn the immediate mobilisation of biomass.

  A medium sized pellet plant of 100,000 tonnes capacity p.a. requires an investment of RM 30–40 million and has a payback period of 3–5 years. Because of the low capital costs, the biomass need not stay locked into this use and can be channelled to higher value uses once the technology and infrastructure is in place.

- **Oil Palm Biomass Centre (OPBC) EPP** – The creation of a consortium of upstream and downstream companies to accelerate the development of lignocellulosic conversion technologies will benefit all companies in the industry. The ultimate objective of the OPBC would be to accelerate time-to-commercialisation of the biobased chemicals opportunity. Thus the OPBC will focus on developing technology, accelerating implementation and producing intellectual property for further commercialisation of technologies for conversion of lignocellulosic biomass into higher value-added uses such as biofuels and biobased chemicals.

Beyond these two new EPPs, two existing EPPs within the Palm Oil NKEA will require changes or renewed emphasis to support the National Biomass Strategy 2020.

- **EPP 5 Developing Biogas at Palm Oil Mills** – Acceleration of EPP 5 to encourage mill-level conversion of biogas to energy, not only for grid-connected mills but for all mills across the nation. As per EPP 5, grid-connected mills will be able to sell excess energy into the grid. However non grid-connected mills will also benefit as significant amounts of biomass will be freed up for higher value-added activities.

- **EPP 6 Developing Oleo Derivatives** – To expand the scope of EPP 6 to include biobased chemicals derived from lignocellulosic biomass. This expansion in scope will help reduce the risk for private sector investment in this area and support the setup of pilot plants and scale-ups.

Lastly, the Government will play an important role in accelerating this opportunity.

- **Government policy** – Beyond the structural changes proposed and the introduction of new and expanded EPPs, there are specific policies that the Government can introduce to encourage acceleration of this opportunity. These will be defined in detail over the next 3 months. During this time a 'lab' will be convened i.e. a dedicated cross-agency team with private sector involvement will be formed to identify and develop new EPPs, refine the proposed EPPs as well as develop the required policy recommendations.

Conclusion

The National Biomass Strategy 2020 could translate into an incremental RM 30 billion in GNI and an additional 66,000 new jobs by 2020. Achieving this aspiration will require disciplined implementation across numerous dimensions including the:

- Formation of cooperatives of plantation owners
- Transparency of the potential opportunities and need for a portfolio approach
- Creation of two new EPPs to catalyse action
- Expansion in scope of two existing Palm Oil NKEA EPPs
- Definition of Government policies that reduce private sector risk

The largest contributor to the increase in GNI would be biobased chemicals with RM 14–15 billion GNI potential and up to 16,000 new jobs. However realising this potential will require longer-term investment by the private sector, support for companies developing conversion technologies to accelerate time to maturity and equity joint ventures between plantations and downstream companies as well as likely risk mitigation support from the Government. This opportunity has a horizon of 2015–2020.

The next largest opportunity is pelletisation, with RM 9–10 billion GNI potential and about 12,000 new jobs. There is a ready market and the economics are attractive. thus requiring only modest Government support in the form of a new EPP.

Biofuels could be an attractive stepping stone to accelerate the mobilisation of biomass, the conversion of lignocellulosic biomass into sugars and the development of a biobased chemical industry, However it is largely dependent on a domestic blending mandate. This requires further study, however if adopted, it has the potential to create RM 7–9 billion in GNI impact and more than 11,000 new jobs. In addition, the mobilisation of an additional 20 million tonnes of biomass has the potential to generate significant related benefit, including 27,000 additional jobs.

To ensure this opportunity is realised, the Government is taking decisive and concerted action across ministries and agencies as well as engaging extensively with the private sector to catalyse investment. Agensi Innovasi Malaysia will be tasked to coordinate the execution of the two new oil palm biomass EPPs as well as develop additional biomass EPPs. It will operate within the existing Palm Oil NKEA and report progress into the Palm Oil NKEA Steering Committee chaired by Tan Sri Bernard Dompok and Dato' Sri Idris Jala, Ministers for KPPK and Pemandu respectively.

Annually, the Government will review the National Biomass Strategy 2020 and commission an independent audit of progress. The Government of Malaysia is fully committed to making new wealth creation from biomass a reality for the nation.

Appendix A

List of acronyms

CPO	crude palm oil
EFB	empty fruit bunch
EPP	Entry Point Project
ETP	Economic Transformation Programme
FFB	fresh fruit bunch
GNI	gross national income
MDF	medium-density fibre (for boards)
MF	mesocarp fibre
NKEA	National Key Economic Area
OPBC	Oil Palm Biomass Centre
OPT	oil palm trunk
PV	photovoltaic
PKO	palm kernel oil
PKS	palm kernel shells
POME	palm oil mill effluent