Macro-economic Impact Study for Biobased Malaysia

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LEI report 2012-042
May 2012
Project code 2271000200
LEI, part of Wageningen UR, The Hague

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Macro-economic Impact Study for Biobased Malaysia
Van Meijl, H., E. Smeets, M. van Dijk and J. Powell
LEI report 2012-042
ISBN/EAN: 978-90-8615-583-5
Price € 15,25 (including 6% VAT)
56 p., fig., tab., app.

This MES is undertaken as part of the Memorandum of Understanding between AIM and BE-Basic to collaborate on the development of a biobased economy in Malaysia as signed in the presence of the Prime Minister Datuk Seri Najib Tun Razak of Malaysia at the PM's Office in Putrajaya, Malaysia in April 2011.

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This publication is available at www.lei.wur.nl/uk

LEI is ISO 9001:2008 certified.

Contents

Preface

The Government of Malaysia aims for Malaysia to become a high-income nation by 2020 and reduce greenhouse gas emissions by 40 % relative to 2005 in the same year. The large-scale introduction of renewable, biobased resources for the production of chemicals, materials, fuels and energy implies a huge opportunity and challenge for the Malaysian economy. This will require substantial investments in research & development, production plants, logistics and human capacity. And also benefits in economic and ecological terms are estimated to be large, even at today's prices for fossil alternatives. Existing sectors can also benefit, whether directly or indirectly, for instance because of a greener reputation for palm oil. New players will enter the market, and there will be threats to immobile sectors.

This Macro-economic Impact Study (MES) provides initial quantitative insights into the macro-economic effects of introducing green, palm-based alternatives for electricity, fuels, chemicals and materials industries in Malaysia until 2030 and was commissioned by Agensi Inovasi Malaysia (AIM). It complements the National Biomass Strategy 2020 (NBS) also commissioned by Agensi Inovasi Malaysia (2011), which provides a scenario analysis in which the economic and other potentials of various applications of palm biomass to 2020 are evaluated. This MES is undertaken as part of the Memorandum of Understanding between AIM and BE-Basic to collaborate on the development of a biobased economy in Malaysia as signed in the presence of the Prime Minister Datuk Seri Najib Tun Razak of Malaysia at the PM's Office in Putrajaya, Malaysia in April 2011.

This report is the result of an extensive collaboration with the Malaysian government and private sector companies as well as domestic and international research institutes. It builds on multiple research papers and statistical data sets of the Malaysian Palm Oil Board (MPOB). We acknowledge the contribution of the steering committee consisting of representatives of the Malaysian government and palm oil companies, which met three times. Members of the steering committee were: Bas Melssen (AIM, Chairman), Hj Khairudin/Alan Hamzah, (Sime Darby), Mr Palaniappan/En Azman/Dr Susana (Felda), Dr Lim (MPOB), Prof. Ramlan (UTM), Prof. Ali Hassan (UPM), En. Abdul Halim Abdul Aziz/Pn. Che Wah Bt Ibrahim (EPU), and Dr Mamat (MPOA). Furthermore, we gratefully acknowledge the contributions of Prof. Peter Dixon and Prof. Maureen Rimmer (implementation of the palm-based alternative in the global economic model) from the Centre of Policy Studies (COPs) of Monash University, Melbourne, Australia, as well as those of Prof. Luuk van de Wielen and Prof. Patricia Osseweijer (TU Delft and BE-Basic).

This study shows that the revenues related to palm-based alternatives can add substantially to the Malaysian GDP. The benefits are very dependent on the exact use of the biomass, the oil price, the level of technical learning and the opportunity costs. In general biobased chemicals deliver the highest contribution to GDP per tonne. Biofuels and pellets have an intermediate contribution and the contribution of pellets is very dependent on the persistence of biofuel policies in Europe. The contribution of bioelectricity to GDP is negative. A successful development of a biobased economy influences a large part of the economy including factor markets and requires a coherent set of governmental (introduction) policies covering agricultural, energy, transport, infrastructure, education, financial, export and technology.

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Management summary

The Government of Malaysia aims for Malaysia to become a high-income nation by 2020 and wants to reduce greenhouse gas emissions by 40% relative to 2005 in the same year. This Macro-economic Impact Study (MES) provides quantitative insights into the macro-economic effects of introducing green, palm-based alternatives for electricity, fuels, chemicals and materials industries in Malaysia between now and 2030. It was commissioned by Agensi Inovasi Malaysia (AIM). It complements the National Biomass Strategy 2020 (NBS), also commissioned by Agensi Inovasi Malaysia (2011), which provides a scenario analysis evaluating the economic potential of various applications of palm biomass between now and the year 2020. This MES has been undertaken as part of the Memorandum of Understanding between AIM and BE-Basic regarding collaboration on the development of a biobased economy in Malaysia. This Memorandum was signed in the presence of the Prime Minister Datuk Seri Najib Tun Razak of Malaysia at the PM's Office in Putrajaya, Malaysia, in April 2011.

This study focuses on the gross and net contribution to Malaysia’s gross domestic product (GDP) of the use of residues and by-products of the palm industry in various applications, taking into account the influence of technological changes and oil prices. There will also be opportunity costs involved in replacing existing production systems and in shifting resources that are being used in existing sectors to the biobased economy. The uncertainties with regard to technical learning and oil prices and the opportunity costs (as well as other indirect macro-economic effects) have not been considered in the NBS. The general equilibrium model framework (MAGNET) employed in this analysis is specifically designed to iden¬tify and quantify these types of macro-economic effects and trade-offs. Crucial assumptions on the selection of biomass applications, the costs of the biomass, the total amount of biomass used and its division across various uses have been taken from the NBS study to ensure maximum consistency and complementarity between this study and the NBS study.

The NBS portfolio consists of 4 million tonnes (m t) biomass for bioethanol, 11m t for pellets, 6m t for biobased chemicals and 10m t for bio-electricity. The revenues of this portfolio add up (in our model) to about RM30 billion and represent almost 2% of the GDP in 2030, which is comparable to the findings of the NBS (2011). In general we can conclude that the production of bioethanol as biofuel, pellets for export and power generation, and biobased chemicals will have positive effects on Malaysia’s GDP; this is assuming that the oil price increases to USD125-USD150 per barrel as projected by the International Energy Agency and that the technologies of converting palm biomass into ethanol will become more efficient. The price of oil is therefore a crucial and partially uncertain factor in our analyses.

The MES takes displacement effects as well as economic bottlenecks into account, whereas the NBS could not do this quantitatively. If the oil price is USD125, the predicted net contribution to GDP per tonne of biomass is three times as high for biobased chemicals as for pellets and bioethanol. The GDP effect per m t of palm biomass is 0.013% (RM207 per m t) for ethanol, 0.038% (RM592 per m t) for biobased chemicals, and 0.012% (RM180 per m t) for pel¬lets. Pellets are also economically attractive as long as bioenergy policies in Europe are in place and assuming that the production of pellets from other sources or other substitutes does not decrease the average pellet price. Electricity from palm biomass appears not to be competitive with electricity from coal, although small-scale electricity production might be economically viable under conditions other than those investigated in this study (such as remote, non-grid-connected locations).

The net GDP growth is around 0.43% or RM6.6 billion in the year 2030 when 22m t of biomass are used for bioethanol, pellets and biobased chemicals (assuming an oil price of USD125 per barrel). The production of electricity would lead to a negative GDP effect of 0.51%, implying that the whole portfolio has a limited GDP impact. In order to compare the NBS figures with the findings of this study, it is necessary to make simplifying assumptions. A simple comparison has been carried out without taking electricity into account. If Malaysia were to invest 35m t of the available palm biomass presented in the NBS study in the current bioethanol, pellets and biobased chemicals portfolio (same ratios), this macro-economic study shows GDP growth of 0.69% (10.7 billion RM) in 2030. In general, therefore, our findings are lower than those of the NBS study because opportunity costs have been taken into account.

The MES results can therefore be used to identify factors that generate greater macro-economic benefits of using palm biomass, which has so far not been utilised. The GDP effects would be higher if: 1) Malaysia is able to develop a competitive advantage over other producers elsewhere in the world; 2) the oil price increases; 3) biomass above 35m t is collected; 4) the demand for biofuels and other biobased products in other parts of the world continues to increase; or 5) the Malaysian government addresses bottlenecks (e.g. the labour market). It is important to realise that behind this small GDP growth a relatively large transition from fossil resources-based technologies to biomass-based resources is taking place. This implies a large-scale substitution of fossil fuels with biobased alternatives in the petrol/biomass refinery, electricity and chemical industries. This in turn leads to all kind of bottlenecks, as capital has to be attracted and built up, people need to be attracted and educated, infrastructure must be built, export markets have to be developed, and technologies have to be invented and diffused within the sectors.

The relatively large differences between net GDP effects and the revenues resulting from the use of palm oil biomass are due to the opportunity costs. The opportunity costs are relatively high in the economy of Malaysia, which has very few unused resources in addition to palm waste. In other words, the collection, transportation and processing of palm bio¬mass into ethanol and other products take resources (labour, capital, other inputs) from other activities. This is especially relevant for labour, because Malaysia currently enjoys full employment already. Therefore, the emergence of a biobased economy directly and indirectly influences many other sectors within the economy and the educational, financial and innovation systems. A successful development of a biobased economy requires a coherent set of government policies covering agricultural, energy, transport, infrastructure, educational, financial, export and technology policies.

The proposed Phase 2 of this MES-study involves reviewing some key assumptions and results of the NBS study, calculating environmental impacts (e.g. GHG emissions), and adding more details to the model so that richer analyses can be conducted. The current and future cost structure of the production and various uses of biomass will be re-examined. Another important improvement is that the amount of biomass used and its composition will be linked to commodity prices endogenously (e.g. oil prices). The amount of biomass used and its distribution among the various uses could have a major impact on the macroeconomic effects. A higher level of detail, with results per economic sector, would enable inter-industry trade-offs and the implications for Malaysian employment, capital, and international trade flows to be analysed. The environmental impacts will be considered in detail, including the direct and indirect impacts on land use change.

Samenvatting

De overheid van Maleisië streeft ernaar dat Maleisië vóór 2020 een hoge-inkomensland wordt en wil in hetzelfde jaar de uitstoot van broeikasgassen met 40% verminderen ten opzichte van 2005. Deze macro-economische impactstudie (MES) biedt kwantitatieve inzichten in de macro-economische effecten van de invoering tussen nu en 2030 van groene, op palmolie gebaseerde alternatieven voor de productie van elektriciteit, brandstoffen, chemicaliën en materialen in Maleisië. De studie werd verricht in opdracht van *Agensi Inovasi Malaysia* (AIM) en ligt in het verlengde van de National Biomass Strategy 2020 (NBS), eveneens in opdracht van *Agensi Inovasi Malaysia* (2011). In dit onderzoek wordt aan de hand van een scenario-analyse het economische potentieel van diverse toepassingen van palmolie als biomassa tussen nu en 2020 beoordeeld. De MES is uitgevoerd in het kader van het Memorandum van Overeenstemming tussen AIM en BE-Basic betreffende de gezamenlijke ontwikkeling van een bio-economie in Maleisië. Dit memorandum werd in april 2011 ondertekend in de ambtswoning van de Maleisische premier Datuk Seri Najib Tun Razak in Putrajaya, Maleisië.

De MES kijkt welke bruto- en nettobijdrage aan het bruto binnenlands product (BBP) van Maleisië wordt geleverd door diverse toepassingen van residuen en bijproducten van de palmolie-industrie, rekening houdend met onzekerheden omtrent technologisch leren en olieprijzen. Ook zullen alternatieve kosten voortkomen uit het vervangen van bestaande productiesystemen en het overhevelen naar de bio-economie van hulpbronnen die momenteel worden gebruikt in bestaande sectoren. De onzekerheden met betrekking tot technologisch leren en olieprijzen en de alternatieve kosten (evenals andere indirecte macro-economische effecten) zijn in de NBS niet in ogenschouw genomen. Het algemene evenwichtsmodel (MAGNET) dat wordt gebruikt bij deze analyse is specifiek ontworpen om dit soort macro-economische effecten en trade-offs in kaart te brengen en te kwantificeren. Cruciale aannames over de selectie van biomassatoepassingen, de kosten van de biomassa, de totale hoeveelheid biomassa die wordt gebruikt en de verdeling ervan over diverse toepassingsgebieden zijn ontleend aan de NBS-studie om te zorgen voor optimale consistentie en complementariteit tussen de MES en de NBS-studie.

Het NBS-portfolio bestaat uit 4 miljoen ton (m t) biomassa voor bio-ethanol, 11 m t voor pellets, 6 m t voor biochemicaliën en 10 m t voor bio-elektriciteit. De inkomsten van dit portfolio bedragen (in ons model) bij elkaar circa RM 30 miljard en vertegenwoordigen in 2030 bijna 2% van het BBP, hetgeen overeenkomt met de bevindingen van de NBS (2011). Over het algemeen kunnen we concluderen dat de productie van bio-ethanol als biobrandstof, pellets voor export en stroomopwekking, en biochemicaliën positief zal uitwerken op het BBP van Maleisië, ervan uitgaande dat de olieprijs toeneemt tot USD 125-150 per vat, zoals het Internationaal Energie Agentschap voorspelt, en dat de technologieën om palmolie-biomassa om te zetten in ethanol efficiënter zullen worden. De olieprijs is dan ook een cruciale en deels onzekere factor in onze analyses.

De MES houdt rekening met verplaatsingseffecten en economische knelpunten, terwijl de NBS niet in staat was deze te kwantificeren. Als de olieprijs USD 125 bedraagt, is de voorspelde nettobijdrage aan het BBP per ton biomassa driemaal zo groot voor biochemicaliën als voor pellets en bio-ethanol. Het BBP-effect per m t palmoliebiomassa bedraagt 0,013% (RM 207 per m t) voor ethanol, 0,038% (RM 592 per m t) voor biochemicaliën, en 0,012% (RM 180 per m t) voor pellets. Pellets zijn economisch aantrekkelijk zolang bio-energie in Europa van overheidswege wordt gestimuleerd en ervan uitgaande dat de gemiddelde pelletprijs niet daalt door de productie van pellets uit andere bronnen of andere substituten. Elektriciteit uit palmolie-biomassa lijkt niet concurrerend te zijn met elektriciteit uit steenkool, hoewel kleinschalige elektriciteitsproductie mogelijk economisch levensvatbaar is onder andere omstandigheden dan die welke in deze studie zijn onderzocht (zoals perifere, niet op het elektriciteitsnet aangesloten locaties).

De netto BBP-groei in het jaar 2030 bedraagt circa 0,43%, ofwel RM 6,6 miljard, wanneer 22 m t biomassa wordt gebruikt voor bio-ethanol, pellets en biochemicaliën, uitgaande van een olieprijs van USD 125 per vat). De productie van elektriciteit zou leiden tot een negatief BBP-effect van 0,51%, hetgeen erop duidt dat het hele portfolio een beperkt BBP-effect heeft. Om de NBS-cijfers te vergelijken met de bevindingen van deze studie, is het zaak vereenvoudigende aannames te hanteren. Een eenvoudige vergelijking is uitgevoerd zonder rekening te houden met elektriciteit. Als Maleisië 35 m t van beschikbare palmolie-biomassa als genoemd in de NBS-studie zou investeren in het huidige portfolio van bio-ethanol, pellets en biochemicaliën (in dezelfde verhouding), becijfert deze macro-economische studie een BBP-groei van 0,69% (RM 10,7 miljard) in 2030. Over het algemeen vallen onze cijfers over de BBP-groei lager uit dan die van de NBS-studie, omdat rekening is gehouden met alternatieve kosten.

De uitkomsten van de MES kunnen worden gebruikt om in kaart te brengen hoe macro-economisch optimaler kan worden geprofiteerd van palmolie-biomassa, die tot dusver niet is benut. De BBP-effecten zouden hoger uitvallen als: 1) Maleisië in staat is een voorsprong te nemen op concurrerende producenten van biomassa elders in de wereld; 2) de olieprijs stijgt; 3) meer dan 35 m t biomassa wordt gewonnen; 4) de vraag naar biobrandstoffen en andere bioproducten in andere delen van de wereld blijft toenemen; of 5) de Maleisische regering knelpunten aanpakt (bijv. de arbeidsmarkt). Het is van belang te beseffen dat achter deze geringe BBP-groei een betrekkelijk veelomvattende overgang van fossiele hulpbronnen naar op biomassa gebaseerde hulpbronnen schuilgaat. Deze omslag gaat gepaard met een grootschalige substitutie van fossiele brandstoffen door groene alternatieven in de olie/biomassa-raffinaderijen, de elektriciteitssector en de chemische industrie. Dit leidt weer tot allerlei knelpunten, aangezien kapitaal moet worden aangetrokken en opgebouwd, mensen moeten worden aangetrokken en opgeleid, infrastructuur moet worden aangelegd, buitenlandse afzetmarkten moeten worden ontwikkeld, en technologieën moeten worden uitgevonden en verspreid binnen de sectoren.

De vrij grote verschillen tussen netto BBP-effecten en de inkomsten die gekoppeld zijn aan het gebruik van palmolie als biomassa komen voort uit de alternatieve kosten. De alternatieve kosten zijn vrij hoog in de Maleisische economie, die behalve palmafval niet veel onbenutte hulpbronnen heeft. Met andere woorden: door de winning, het transport en de verwerking van palmolie-biomassa tot ethanol en andere producten worden hulpbronnen (arbeid, kapitaal, andere inputs) onttrokken aan andere activiteiten. Dit is met name van belang voor de factor arbeid, omdat in Maleisië nu reeds sprake is van volledige werkgelegenheid. De opkomst van een bio-economie heeft dan ook een directe en indirecte invloed op tal van andere economische sectoren en op het onderwijsstelsel, het financiële systeem en de innovatiesector. Een succesvolle ontwikkeling van een bio-economie vereist een samenhangend overheidsbeleid op het gebied van landbouw, energie, transport, infrastructuur, onderwijs, financiën, export en technologie.

In de beoogde Fase 2 van deze MES-studie zullen een aantal cruciale aannames en uitkomsten van de NBS-studie worden herzien, waarbij milieueffecten (bijv. broeikasgasemissies) opnieuw worden berekend en het model verder wordt verfijnd, zodat rijkere analyses kunnen worden uitgevoerd. De huidige en toekomstige kostenstructuur voor de productie en diverse toepassingen van biomassa zullen opnieuw tegen het licht worden gehouden. Nog een belangrijke verbetering is dat de hoeveelheid gebruikte biomassa en de samenstelling ervan endogeen worden gekoppeld aan grondstoffenprijzen (bijv. de olieprijs). De hoeveelheid gebruikte biomassa en de verdeling ervan over de diverse toepassingen kan van invloed zijn op de macro-economische effecten. Een hoger detailniveau, met resultaten per economische sector, zou trade-offs tussen industrieën en een analyse van de gevolgen voor de Maleisische arbeids- en kapitaalmarkt en internationale handelsstromen mogelijk maken. De milieueffecten, inclusief de directe en indirecte effecten op landgebruik, zullen nauwkeurig in kaart worden gebracht.

1 Introduction

The Government of Malaysia wants Malaysia to become a high-income nation by 2020 (Pemandu, 2010) and reduce greenhouse gas emissions by 40% relative to 2005 in the same year (MNRE, 2010). This requires a sustained GDP growth of 6% per annum between now and 2020. Palm oil production plays an important role in the Malaysian economy and can be expected to play an even greater role in the future (Pemandu, 2010). The production of African oil palm *(Elaeis guineensis)* as plantation crop in Malaysia has increased rapidly during the past decades. The area covered by palm plantations has increased from 1m ha in 1980, 2m ha in 1990, 3.4m ha in 2000, to 5.4m ha in 2010 (MPOB, 2011). The production of crude palm oil has increased from 2.6 to 17.0m t over the same years. The production of palm oil is expected to further increase over the coming decades, although at a much slower rate (Pemandu, 2010). The increase in production has to come from an increased yield per acre as area get more and more constrained. This requires innovation, attention for soil quality and a better use of palm biomass.

The residues and by-products of the palm oil production chain are currently barely used. Palm biomass can be used for a variety of applications, such as electricity generation and for the production of wood products, but also for the production of second generation biofuels and biobased chemicals. Various studies indicate that a biobased economy, i.e. the use of palm oil biomass for various applications, offers opportunities for Malaysia to reach the ambitions for GDP growth and greenhouse gas emissions reduction targets (Koh and Hoi, 2003; the National Biomass Strategy , 2011; Pemandu, 2010; Shuit et al., 2010; Tye et al., 2011).

The primary oil palm sector is the most important agricultural product (2.7% of GDP) and contributes more than 50% of agricultural value added. Value added is the difference between the total sales revenue of an industry and the total cost of components, materials, and services purchased from other firms within a reporting period (usually one year). It is the industry's contribution to the GDP. The (palm) oil and fats sector (1.3% of GDP) contributes 44% to value added of total food processing industry. The palm oil complex contributes therefore directly 4% to Malaysian value added. The indirect effects are approximately 1.5% to 3% to Malaysian value added and the total direct and indirect effects are approximately 6% to 7% to Malaysian value added. The residues and by-products might be used in the electricity sector (1.8% of value added), wood products

(0.9% of value added), chemical sector (5.6% of value added), bio-refinery sector (0.9% of value added) and substitute for crude (mineral) oil and natural gas (14%) of value added. It is expected that the crude oil production in Malaysia will not keep up with demand due to increasing demand and depleting oil reserves and that Malaysia will become a net importer of crude oil in the future.

Table 1.1 **Relative importance of sectors that may be influenced by Biobased innovation in the Malaysian economy as per 2005**

	(billion MYR)	%	(billion MYR)	%
Oil palm	20	1.6	14	2.7
Other agriculture	20	1.6	12	2.4
Forestry and logging	8	0.7	6	1.2
Crude oil and natural gas	86	6.9	71	14.0
Oil and fats	51	4.1	6	1.3
Other processed food	31	2.5	8	1.6
Wood products	14	1.1	5	0.9
Petroleum refinery	64	5.1	5	0.9
Chemicals (incl. rubber and plastics)	88	7.0	29	5.6
Electricity	24	1.9	9	1.8
Total economy	1,251	100.0	509	100.0

Source: 120-sector IO table for Malaysia, published by DOS (Department of Statistics) (2005).

However, the macro-economic impacts of a biobased economy in Malaysia are still partially unknown and uncertain. The advanced applications require large investments in research and development, production plants, logistics and human capacity. Existing sectors may potentially benefit, directly or indirectly, from the emergence of a green, biobased economy, although there will also be threads for immobile sectors. There will also be opportunity costs involved in replacing existing production systems and in shifting resources that are being used in existing sectors to the biobased economy. The general equilibrium model framework employed in this analysis is designed to identify and quantify these types of economic trade-offs.

This study was commissioned by *Agensi Inovasi Malaysia* (AIM, formerly UNIK) to provide quantitative insights into the macro-economic and ecological effects of replacing fossil resources by green, biobased alternatives for Malaysia from now to 2030. This MES is undertaken as part of the Memorandum of Understanding between AIM and BE-Basic to collaborate on the development of a biobased economy in Malaysia as signed in the presence of the Prime Minister Datuk Seri Najib Tun Razak of Malaysia at the PM's Office in Putrajaya, Malaysia in April 2011. It complements the National Biomass Strategy (NBS) also commissioned by *Agensi Inovasi Malaysia* (2011), which provides a scenario analysis in which the economic and other potentials of various applications of palm biomass to 2020 are evaluated. The results of the National Biomass Strategy report are used as input into our computable general equilibrium model MAGNET to ensure consistency and complementarity of these two studies. In particular, we use the NBS assumptions about the availability of biomass for the production of bioethanol, biobased chemicals, wood pellets and bio-energy.

Two developments are critical to making biomass a profitable venture. The first is the efficiency of technologies to collect palm biomass in a sustainable manner, and convert it into final products relative to fossil resources-based technologies. The second is the (development) price of fossil-based substitutes. The difference between the costs of production of the biobased product and the fossil-based substitute is an important determinant of the economic viability. These developments are (obviously) partially uncertain. To emphasise these uncertainties, as well as other risks and trade-offs involved in producing these four biomass products, we calculate a series of possible effects on Malaysia's GDP of using biomass substitutes based on a range of technological and fossil fuel price scenarios.

This report describes Phase 1 of the overall study which focuses on the macro-economic impact of the Malaysian biobased economy. It analyses the contribution to GDP of the use of palm biomass in various uses given uncertainties with regard to technological learning and oil prices. This phase does not cover potential environmental and sectoral-economic effects which will be the topic of phase 2 of the study. Phase 2 will also include more detailed analyses, including the impact of optimising logistics of palm biomass and of optimising the use of various types of biomass for different applications in terms of potential, costs, GHG emissions, efficiency and macro-economic impacts. Moreover, phase 2 will consist of a more extensive evaluation of the macro-economic impacts, including additional macro-economic parameters (e.g. trade balance effects, employment effects), at the sector level, whereby also the impact of carbon credits or a green premium and the impact of increased demand for biobased products from abroad will be investigated. In that context it is possible to study the environmental impacts in detail, including the direct and indirect impacts on land use change.

Report structure
The report gives a brief overview of availability of biomass in Malaysia and the assumptions underlying the National Biomass Strategy (2011) in Section 2. Section 3 provides information on the methodology used, i.e. the structure and assumptions of the CGE model called MAGNET. Section 4 presents a detailed description of the cost structures of four key biomass-based products that are analysed. Section 5 presents the main results. Three tables illustrate the impact on GDP for each product under different assumptions about the efficiency of the biobased technology and the level of fossil resource prices. The report ends with brief conclusions.

2 Oil palm biomass projections and scenarios

This study is complementary to the National Biomass Strategy (2011), in which a bottom-up analysis is carried out of the potentials and costs of the use of residues and by-products of the palm industry for various applications. The resulting scenario analysis evaluates the economic and other potentials of various applications of palm biomass to 2020 (National Biomass Strategy, 2011; see Section 2.3). In this study, the MAGNET computable general equilibrium model is used to estimate the *indirect* effects, especially the opportunity costs. The values provided by the NBS for the selection of biomass applications (Section 2.1), including the costs of the biomass (Section 2.2) and the potential of each application (Section 2.3), are used as input into MAGNET to ensure consistency and complementarity of these two studies.

2.1 Biomass applications

Four main types of biobased products are considered in the National Biomass Strategy and in this study, which are further described in Section 4.[1]

1. Bioelectricity.
2. Pellets, primarily as an export product especially for European demand.
3. Bioethanol, representing a wider biofuels portfolio.
4. Biochemicals.

2.2 Availability of palm oil biomass

The focus of this study is on the use of residues and by-products of the palm industry, which account for an amount equal to almost five times the weight of oil

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[1] A fifth application is considered in the McKinsey National Biomass Strategy (NBS) study, which is wood products, but which is excluded from phase 1 of this macro-economic study, given lack of data and resource constraints.

produced (Van Dam, 2010). The National Biomass Strategy defines the total available palm oil biomass as the sum of the dry weight of five types of residue:[1]

- *Trunks (oil palm trunks or OPT)* are obtained during the replanting to replace the old oil palm trees.
- *Fronds (oil palm fronds or OPF)* are available during the year when the palms are pruned during the harvesting of the fresh fruit bunches and during pruning.
- *Empty fruit bunches (EFB)* are a major by-product of oil palm production. It is the woody fibrous residue that remains after the fruits are removed from the bunch and the oil is extracted.
- *Palm pressed fibres (PPF)* is the mesocarp fibrous material in the press cake. This mixture is passed through a screen to remove the fibre.
- *Palm kernel shells (PKS)* are also a residue from the press. In larger mills, the palm nuts are collected and cracked in centrifugal crackers to separate the kernel from the shell. The shells are collected to serve as fuel for internal use in the palm oil mill boilers. Smaller mills might dry and sell the unprocessed nuts to other companies who process them into palm kernel oil.

Figure 2.1 shows the theoretical availability of palm oil biomass in Malaysia for 2010, 2015 and 2020, taken from the National Biomass Strategy (2011). Projections for 2015 and 2020 reflect a middle scenario based on assumptions about area planted from the Malaysian Palm Oil Board (MPOB) and historical fresh fruit bunch (FFB) yields. The upper parts of the bars depict the additional production of palm oil biomass under the assumptions of the Economic Transformation Programme (Pemandu, 2010).

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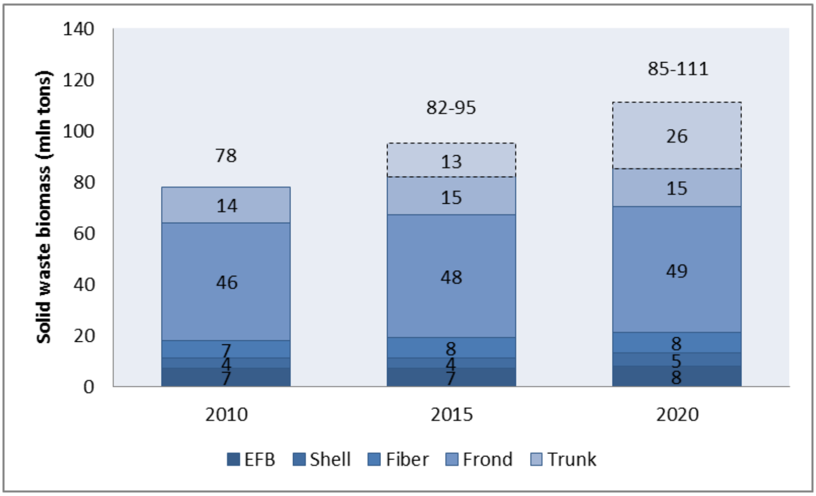
[1] McKinsey NBS excludes palm oil mill effluent (POME) and palm kernel cake.

Figure 2.1 **Oil palm biomass availability**

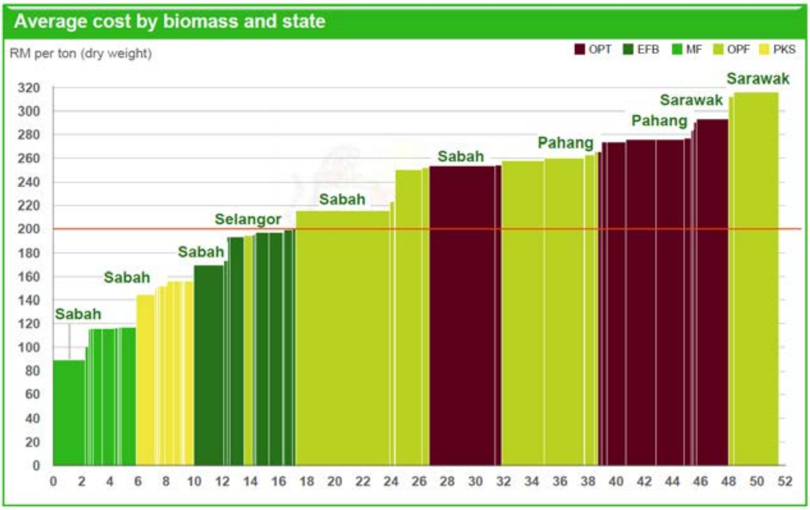


Source: the National Biomass Strategy (2011).

The National Biomass Strategy also includes a cost-supply curve for palm biomass for the year 2010 (see Figure 2.2 below). The cost-supply curve shows how much biomass is available at what cost in 2010. The cost-supply curve consists of different cost-supply curves for various types of palm biomass. It is thereby assumed that the only about one-third of the biomass is left on the field to protect the soil against soil nutrient and carbon depletion as well as erosion. For practical reasons, no distinction is made between the various types of oil palm biomass in this study (see further Section 4).

Note also that the supply curve is very flat and that at slightly higher prices of alternatives, it is profitable to collect much more biomass. For instance, 25m t of biomass can be collected at a cost price of below MYR250 per tonne and almost 50m t of biomass can be mobilised at a cost of MYR300 per tonne or less.

Figure 2.2 **Cost-supply curve for palm biomass (2010)**

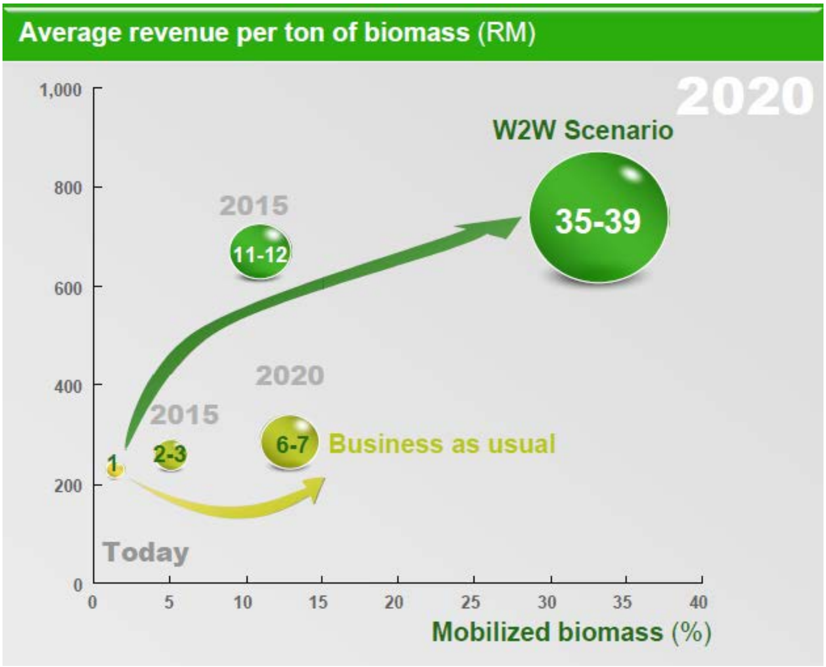


Source: The National Biomass Strategy (2011).

2.3 Palm oil biomass scenarios

The National Biomass Strategy study includes an analysis in which a Business As Usual (BAU) scenario is compared with the Waste to Wealth (W2W) scenario in which biomass or a share of biomass is transformed into a number of high revenue products (Figure 2.3). In the BAU scenario, the share of mobilised biomass gradually increases from 1% today to 5% in 2015 and to almost 15% in 2020 (about 12m t of biomass). It is predominantly used for the production of wood products and bio-energy and is mainly driven by the Renewable Energy Act (2011) and demand for pellets from abroad. To fully capitalise on the biomass opportunity, an additional 20m t of biomass compared with a business-as-usual scenario could be deployed towards higher value downstream activities such as pellets, biofuels and biobased chemicals. The revenue of the 35m t of biomass is approximately MYR200 per tonne on average (see Figure 2.2). In the W2W scenario, approximately 35m t of biomass are mobilised for the production of wood products, bioelectricity, biobased chemicals, ethanol and pellets in 2020. The current contribution to GNI is MYR1bn. In the BAU scenario, this number might become MYR6-7bn in 2020 and in the W2W scenario; this number might become as high as MYR35-39bn.

Figure 2.3 **The National Biomass Strategy Waste to Wealth Scenario**



Size of circles gives GNI impact in billions.
Source: National Biomass Strategy (2011).

Table 2.1 provides an overview of the use of biomass in 2020 according to the W2W scenario. The W2W scenario is proposed on the basis of expected qualitative trends in the medium term for chemicals and fuels demand in the region and worldwide. The largest share of biomass is used for the production of pellets, followed by bio-energy. Biobased chemicals, bio-fuels and wood products demand a relatively small share of biomass. According to the W2W study, a total of 35.0m t (including wood products) and 31.5m t (excluding wood products) is used in 2020. In this study, the same values (excluding wood products) are used for 2030, on request of the reference group (Table 2.1). The corresponding price of biomass per tonne in the National Biomass Strategy study is MYR200 per dry tonne or USD56 per dry tonne (see Figure 2.2).

Table 2.1 **Biomass use per product in the W2W scenario (2020)**

Product	Biomass used (m t)	Share (%)
Biobased chemicals	6.3	18
Bioethanol	4.2	12
Pellets	11.2	32
Wood products	3.5	10
Bioelectricity	9.8	28
Total	35.0	100

Source: the National Biomass Strategy (2011).

3 Model and data

To study the impact of an emerging biobased economy based on palm oil biomass in Malaysia, an extended version of the MAGNET model is used, combined with the GTAP database as well as a specific data set for the palm oil sector and related biomass.

3.1 The GTAP database

The analysis is based on version 7 of the GTAP database. The GTAP database contains detailed bilateral trade, transport and protection data characterising economic linkages among regions, linked together with individual country input-output databases, which account for intersectoral linkages. All input-output tables and demand tables distinguish between imported and domestically produced products and between before and after tax values. For international trade, total imported demand for products is allocated to countries. All monetary values of the data are in million USD and the base year for version 7 is 2004.

The database covers 113 regions/countries and distinguishes 57 sectors in each of the regions. Hence, for each of the 113 regions, the database includes input-output tables with 57 sectors that depict the backward and forward linkages amongst activities. For the purpose of this study, the database has been extended with several new sectors to reflect the palm oil biomass chain in the model (see below).

For computability, countries and sectors are aggregated into larger regions and sectors, respectively. In total 14 regions and 23 sectors are distinguished. The sectoral aggregation includes the new sectors: palm oil plantation and palm oil production as well as several primary sectors (e.g. cereals and oil seeds), processed products (e.g. sugar and vegetable oils), industry and resources (e.g. wood products, coal, oil, petroleum products, chemicals and electricity) and services. The regional aggregation includes Malaysia and important neighbouring ASEAN countries, including Indonesia, Singapore, China, India, Japan and Korea and the Rest of Asia plus important regions such as North American Free Trade Area (NAFTA), the European Union and Africa.

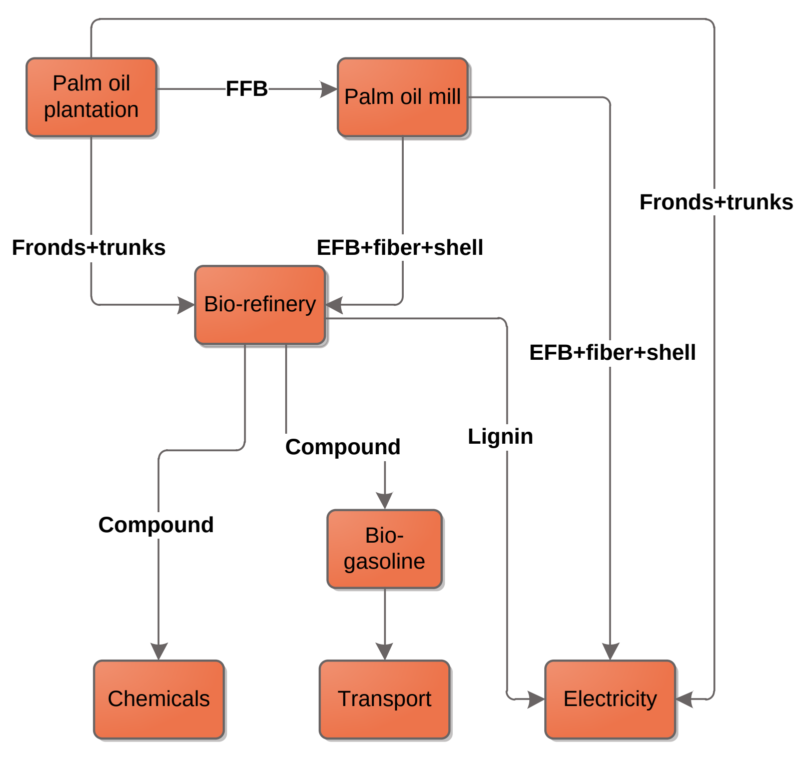
3.2 The MAGNET model

MAGNET i.e. Modular Applied GeNeral Equilibrium Tool, (until 2010 referred to as LEITAP), is a global computable general equilibrium model that covers the whole economy and is able to analyse the effect of changes in technological change, oil prices, national and international trade and agricultural policies on international trade, production, consumption, prices and use of production factors (see Meijl et al., 2006, Eickhout et al., 2009, Banse et al., 2008). The model is based on GTAP (Hertel and Tsigas, 1997) developed at Purdue University, United States, but has been extended with several modules to improve the modelling of the agricultural sector and land use (e.g. various imperfectly substitutable types of land, the land use allocation structure, land supply function, substitution between various animal feed components, Meijl et al., 2006, Eickhout et al., 2009), biofuel policy (e.g. capital-energy substitution, fossil fuel - biofuel substitution, Banse et al., 2008, Banse et al., 2011), and for this study with palm biomass technologies.

Figure 3.1 provides a schematic overview of the simplified biobased economy model for using oil palm biomass in Malaysia for the energy, fuels and chemicals sectors.

In this study we introduce new biobased technologies to produce bio-energy, pellets, bioethanol and biobased chemicals. These biomass-based technologies are an alternative to fossil resources-based technologies. The methodology used in this study is to distinguish between three technologies for producing 1 unit of output. In the case of ethanol, the unit of output is 1 litre of gasoline equivalent in the Malaysian petroleum products industry in 2030. Technology 1 is the baseline technology that is the vector of inputs required per unit of output in the baseline run based on fossil resources such as oil and coal. Technology 2 depicts the newly developed biobased technology to produce the same unit of output. Technology 3 is based on a combination of technology 1 and technology 2. The weighting factor between technology 1 and 2 will be determined by the amount of fossil-based input that can be replaced by the biobased alternative and this is dependent on the amount of biomass provided by the Biomass Strategy (the National Biomass Strategy, 2011) and the efficiency of biomass conversion. The latter will be described in Section 4. In the simulations, technology 1 will be replaced by technology 3. The GTAP model is a multi-regional, static, applied general equilibrium model based on neoclassical microeconomic theory. The standard model is characterised by an input-output structure (based on input-output tables of nations and groups of nations) that explicitly links industries in a value added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. Other assumptions include the application of a representative producer for each sector of a country or region that maximises profits by choosing outputs and inputs of labour, capital, natural resources, land and intermediate goods. Each sector produces one type of output and perfect competition is assumed in all sectors within a country. Supply of labour, capital, and natural services is exogenous and these production factors are always fully employed.

Figure 3.1 **Conceptual framework for biomass flows**



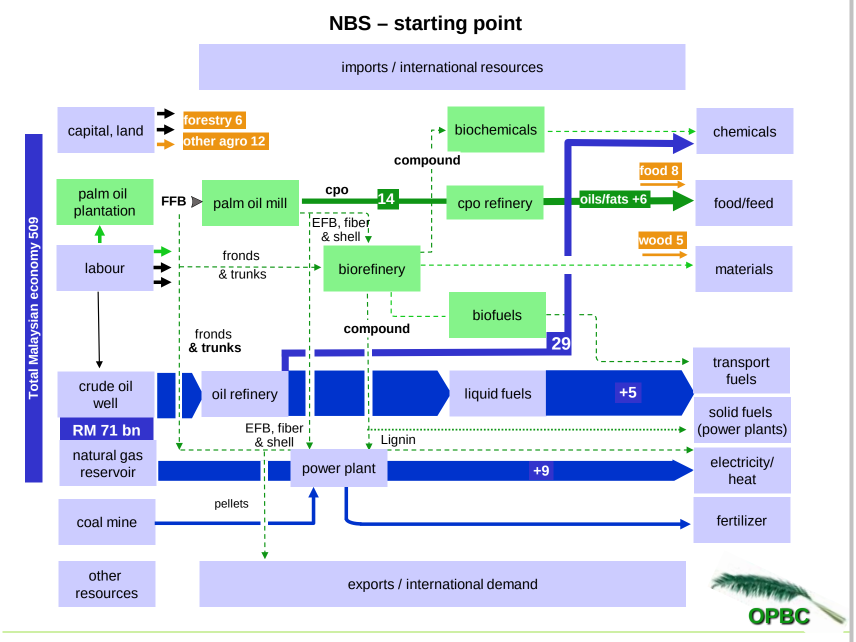
MAGNET is flexible in its time periods, but the minimum length of a period is one year. All value changes are decomposed into quantity and price changes. Important outputs are the percentage changes in prices and quantities of land use, employment, capital use, productivity, production, trade, intermediate input use and consumption.

The model is mainly used to simulate long-term scenarios and analysing policy options within these scenarios. By coupling MAGNET with biophysical models such as an integrated assessment model (IMAGE: Integrated Model to Assess the Global Environment) and a spatially explicit land-use change model (CLUE-s: Conversion of Land Use and its Effects model) results about greenhouse gases or land use may be generated (Verburg et al., 2008). The model has been used to analyse the macro-economic impact of the Dutch biobased economy (Platform Groene Grondstoffen, 2008) and the effects of EU agricultural (Nowicki et al., 2006, 2009a, 2009b), biofuel (Banse et al., 2008) and land-use (Eickhout et al., 2007) policies. It has been used for long-term modelling in the OECD Environmental Outlook (2008, 2011-forthcoming) and the 'The Economics of Ecosystems and Biodiversity' study (TEEB, 2010).

To run the scenarios, the database is updated in five consecutive time steps: 2007-10, 2010-15, 2015-20, 2020-25 and 2025-30. In the first stage, exogenous GDP targets are met and given the exogenous estimates on factor endowments - skilled and unskilled labour, capital and natural resources - and population. The procedure implies that an additional country-level technological change is endogenously determined within the model. In the final stage, this technological change is, in turn, exogenous in the remaining simulation experiments. The sectoral total factor productivities (TFP) are a linear function of country level technological change. Following Kets and Lejour (2003), we assumed different technological development by sector and common trends for relative sectoral TFP growth. They assume that all inputs achieve the same level of technical progress within a sector; i.e., Hicks-neutral technical change.

Figure 3.2 gives a schematic representation of the palm-based BBE model in a simplified Malaysian macro-economic model (not all sectors shown). The MAGNET model also ensures a proper embedment in the overall Malaysian economy (including fossil substitutes) and the regional (ASEAN) and global economy (including exports and imports).

Figure 3.2 **Conceptual framework for biomass related economy**



4 Description of biomass applications, technologies and cost data

In this section, the new various biomass applications and technologies are described, including the data that are inserted into the MAGNET model.

4.1 Biomass costs and supply

The costs of harvesting, collecting and transporting palm biomass to a processing facility are crucial factors for determining the economic performance of the biomass applications. In this study, results from the National Biomass Strategy investigating quantitatively and qualitatively oil palm biomass availability, logistics and processing towards energy, fuels and chemicals, carried out in 2011, are used. The National Biomass Strategy compiled a cost-supply curve that shows how much biomass is available at what cost in 2010. The cost-supply curve consists of different cost-supply curves for various types of palm biomass. For practical reasons, no distinction is made between the various types of palm biomass in this study.

The following cost categories are included in the calculations of the cost supply curve:

- *The additional costs of fertilisers*
  At this moment, empty fruit bunches and fronds are mulched and left on the plantation where they function as soil improver and fertiliser. The opportunity costs of using these types of palm biomass for other applications are included, i.e. the costs of the use and application of fertilisers to compensate for the loss of the soil improver and fertiliser effects of using palm biomass.
- *The price of oil palm kernels and fibres*
  Kernels and fibres are currently the only types of palm biomass that are used. So, in the case of kernels and fibres, the opportunity costs are the actual prices.
- *The costs of harvesting and collecting of the biomass*
  Oil palm fronds and trunks are available at the plantations; empty fruit bunches, palm kernel shells and fibres are available at the palm mills, so there is no need to harvest and collect these residues.

- *The costs of chipping and drying the biomass*
  Before transportation, the biomass is chipped and dried, which facilitates the transportation of the palm biomass.
- *The costs of transporting the biomass*
  The costs of transportation include the costs of transporting the biomass to the closest central gather point where the biomass is further processed. In this phase of the study, no detailed evaluation is carried out of the logistics of palm biomass supply of various applications.

In this study, an average of MYR200 (at 2010 price level) or USD56 (at 2007 price level) per dry tonne of palm biomass is assumed for all applications. At this price level, about 31.5m t of palm biomass is available in 2020 for bioenergy, pellets, bioethanol and biobased chemical production, which is about one-third of the theoretical potential of palm biomass. The availability of biomass could be higher in 2030, for example if the plantation area increases further between 2020 and 2030, but in this study a conservative 31.5m t of biomass availability is assumed. No distinction is made between the costs of various types of biomass, although this could have a large impact. For example, fibres are relatively cheap (MYR <120 per dry tonne for a supply of 6m t in 2010) and are especially suitable for electricity generation, because of the high lignin content and low moisture content. Fibres are, however, not suitable for the production of ethanol, because of the high lignin content which reduces the efficiency and increases the costs of the process. These and other aspects have not been considered now, but will be in phase 2 of this project. Based on the data provided by National Biomass Strategy and our own calculations, the following cost structure of collecting, chipping, drying and transporting biomass is included in our analyses (Table 4.1).

Table 4.1 **The costs of the palm biomass (in USD per dry tonne)**

Cost item - general	Cost item - specified	USD/dt
Substitution - fertiliser	Substitution - fertiliser	17.2
Substitution - fertiliser application	Labour	1.8
Substitution - fertiliser application	Capex and other opex	0.2
Harvesting and collection	Labour	5.8
Harvesting and collection	Capex and other opex	0.6
Pre-processing - chipping	Labour	6.7
Pre-processing - chipping	Capex and other opex	10.0
Transportation	Transportation	13.8
Total		56.2

Sources: National Biomass Strategy (2011) and own calculations.

4.2 Bio-electricity

The production of electricity from palm biomass is the application considered in this study that is expected to be readily implemented in the very near future. In 2011 Malaysia adopted a Feed-in Tariff system for the production of electricity from biomass using small-scale systems (<30 MW). The goal of this system is to increase the installed capacity from 40 MW in 2010 to 800 MW in 2020 (PoM, 2011).

In this study, no detailed evaluation was carried out of the economic performance of the production of electricity from palm biomass compared with conventional systems. Instead, the Feed-in Tariff is taken as a proxy for the additional costs of electricity from palm biomass compared with conventional electricity production systems in Malaysia, which are based on natural gas and coal.

The Feed-in Tariff is MYR0.31, 0.29 and 0.27 (at 2010 level) per kWh for <10MW, >10-<20MW and >20-<30MW systems, respectively. A bonus of MYR0.02, 0.01 and 0.01 (at 2010 price level) per kWh is given in case gasification of solid biomass technology is used, steam-based electricity generation is applied and in case locally manufactured gasification technologies are applied. The Feed-in Tariff is guaranteed for the next 16 years, but an annual decrease of -0.5% is applied. In our analyses, the average of the three basic Feed-in Tariffs (excluding bonuses) is used, which is USD9.5 per kWhe. This is well above the costs of electricity made from coal (USD0.05-0.064 per kWhe) and from gas (USD0.044 per kWhe; at 2004 energy prices) (values are at 2007 price level; RaoE, 2004).

The total level of subsidies needed to support the production of electricity is around 1 GUSD, assuming a 17 GJ (lower heating value) per dry tonne and a 34% efficiency of electricity production. This number is based on a total biomass use of 9.8m t.

The actual difference in production costs of electricity from palm biomass versus conventional sources is potentially higher, because small-scale systems are typically more capital intensive than large-scale power plants. On the other hand, small-scale and local production of electricity may reduce the costs of transporting electricity or may prove to be the only realistic option in remote areas.[1]

4.3 Bioethanol

The production of ethanol from ligno-cellulosic biomass is a relatively complex technology that is currently in the research and development and pilot phases and is not yet technically mature or economically feasible. It is expected that the production of ethanol from lignocellulose will become economically viable within the next couple of years (IEA, 2010). The price of biomass and the suitability of the biomass for the production of ethanol is thereby an important factor which is investigated in this section.

Data about the costs of the conversion of ethanol from lignocellulose biomass are taken from a study carried out by the US National Renewable Energy Laboratory (NREL, 2011). This study is one of the most recent studies and also one of the most detailed and thorough analyses available. Another crucial advantage is that intermediate results are given about the costs of the production of sugar. The costs of sugar are used as input when calculating the economic performance of biochemicals (see the section below).

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[1] These issues will be further discussed in phase 2 of this project, whereby also other technologies will be considered, such as the production of heat and power via gasification and co-combustion with coal. Another potentially important issue is the optimisation of palm fruit biomass use. Shells and fibres are more suitable for electricity generation than empty fruit bunches and fronds because of the lower moisture content. Also, revenues from using the ash from combustion of palm biomass will be considered in phase 2. Some studies indicate that ash from palm biomass combustion is not very suitable as fertiliser, but ash can be used as a suitable supplementary cementing material for producing a number of construction materials (Tay et al., 1995).

In the NREL report the biomass (corn stover) is converted into ethanol by dilute-acid pre-treatment, enzymatic saccharification, and co-fermentation. Also the costs of feed handling, product recovery, wastewater treatment, lignin combustion, and utilities are included. The combustion of lignin generates sufficient electricity and heat for the production of ethanol. The surplus electricity is sold to the electricity grid. The cost data presented in the NREL study that are used in this study are based on technologies available for 2012 and assuming 'nth-plant' project costs and financing. An nth plant is a plant with technologies that are currently employed in existing facilities. The NREL data are adjusted for the costs of the feedstock. All other cost elements are assumed constant. A total of 4.2m t of biomass is assumed in this study (Table 2.1). The cost structure of the production of ethanol is shown in Table 4.2.

Table 4.2 **The costs of the production of ethanol from palm biomass based on current technology (in USD at 2007 price level per litre of gasoline equivalent)**

Inputs	**USD/lge**
Feedstock and handling	0.318
Sulfuric acid	0.011
Ammonia	0.028
Glucose (enzyme production)	0.084
Other raw materials	0.056
Waste disposal	0.011
Net electricity	-0.047
Fixed costs	0.076
Capital depreciation	0.096
Average income tax	0.054
Average return on investment	0.247
Total a)	0.933

a) Costs per category do not add up to the total due to rounding.
Sources: NREL (2011) and own calculations.

The results show that ethanol can be produced at a cost of USD0.93 (at 2007 price level) per litre gasoline equivalent (lge) based on the use of current technologies. A decrease of the production costs of 25% is assumed for future technologies, following the projections of the International Energy Agency (IEA, 2010). The costs of the production of gasoline is calculated at USD0.716 per lge. The cost consist of which USD0.073 per lge capital costs and USD0.643

per lge feedstock and energy costs at an oil price of USD110 (at 2007 price level) per barrel (IEA, 2010). According to these data, ethanol becomes competitive at a price of 100 and USD135 per barrel, assuming future and current technologies for producing the ethanol from palm biomass respectively.

The costs of ethanol from palm biomass calculated in this study are very similar to the cost levels projected by the International Energy Agency, although the ranges found in the literature remain large. Estimates of production costs range between 25-175 USD0.25-1.75 (at 2007 price level) per litre of gasoline equivalent. However, in many cases, economic variance between techno-economic studies can be explained by normalising for a few important inputs.[1]

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[1] There are several ways in which the results can be updated and refined in phase 2. An important aspect that has been ignored so far is that not all types of palm biomass are equally suitable for the production of ethanol. Empty fruit bunches and palm fronds are especially suitable for the production of ethanol because of their relatively high cellulose and hemi-cellulose content compared with other types of palm biomass. If this factor would have been taken into account, then the costs of ethanol would decrease by 10-25%, assuming no change in the costs of biomass. However, the costs of the supply of biomass would also change since each type of palm biomass has a different cost supply curve. Empty fruit bunches and palm fronds are also the most expensive types of palm biomass, except for palm trunks. Another potentially important aspect is that the lignin content of empty fruit bunches and palm fronds is also higher compared with the biomass considered the NREL report (corn stover) based on which the revenues from co-production of electricity (corn stover). A higher lignin content increases the revenues from the co-production of electricity. On the other hand, lignin can also reduce the efficiency and increase the costs of the pre-treatment process in which the lignin is removed from the biomass to increase the enzymatic digestibility (Bakker et al., 2010). In phase 2 also other aspects will be investigated further. For example, other production pathways are potentially also promising in terms of economic performance and GHG emission reduction. According to the IEA biomass-to-liquids (diesel) and hydrogen are potentially cheaper, dependent on the speed of technology developments. The IEA also estimated the impact of the oil price on the costs of ethanol production; an increase of the oil price from USD60 to 120 per barrel increases the costs by 15%. The IEA assumes an oil price to biomass price elasticity of 20%, i.e. a 25% increase in the oil price increases the price of biomass by 20% of 25% or 5%. Also the impact of oil prices on the costs of energy needed for ethanol production are calculated, which is in contrast to the NREL study in which an energy neutral technology is assumed. These and other aspects will be investigated further in phase 2.

4.4 Pellets

The costs of pellet production are estimated using data about the costs of pellet production in the United States (Mani et al., 2006). First, the data are corrected for the lower costs of labour in Malaysia compared with the US, of which the costs are assumed to be half those of the US. Second, a large-scale pellet plant is assumed with a capacity of 120 kton per year. Another crucial cost category is cost of drying the biomass. The moisture content of the different types of palm biomass is higher compared with the moisture content of pellets, which is 10%. In the original data source, the costs of drying are relatively low, namely about USD5.5 (at 2007 price level) per tonne of pellets. These costs are based on the costs of drying wet sawdust (from 40% to 10% moisture content) using dry sawdust as fuel at a cost of circa USD11 (at 2007 price level) per tonne. For Malaysia, the same costs of drying the biomass are assumed. Existing pellets plants often use natural gas to dry the biomass, but this is prohibitively expensive and would increase the costs by about USD15 (at 2007 price level) per tonne. Various options are potentially feasible to limit the costs of drying the biomass. Residues from agriculture, forestry or from the wood processing industry can be used. Other options are the use of heat from the combustion of palm residues in existing palm oil mills or from the combustion of lignin from ethanol production. Also, surplus heat from other industries, e.g. the petrochemical industry might be used. The costs of pellet production assumed in this study are shown in Table 4.3.

The costs of pellet production are calculated to be USD73 (at 2007 price level) per tonne of pellets, excluding transportation. At this moment the production and use of pellets in Malaysia is virtually zero. However, there are many regions in the world in which the production and use of pellets is increasing rapidly and it is expected that this will continue during the coming decades (Sikkema et al., 2010; CMT, 2011). Asia and Europe are expected to have a shortage of pellets (defined as the demand minus supply) of -2.2m t and -1.4m t in 2015 (CMT, 2011). Potentially interesting export markets are the EU27, China and Japan. In this study the focus is on the potential of Malaysia to export pellets to Europe, which is the largest global pellet-consuming region. The total amount of palm biomass used for the production of pellets is set at 11.2m t. For comparison, the total pellet production capacity in Europe in 2008 was 8m t (Sikkema et al., 2011).

Table 4.3 **The costs of the production of pellets from palm biomass (in USD at 2007 price level per tonne of pellets)**

Input	USD/t
Feedstock	56.0
Drying energy	5.5
Drying other costs	1.7
Hammer mill	0.7
Pellet mill	2.3
Pellet cooler	0.2
Screening	0.1
Packing	1.4
Pellet storage	0.1
Miscellaneous equipment	0.5
Personnel cost	4.5
Land use and buildings	0.2
Total	73.2

Sources: Mani et al. (2006) and own calculations.

The costs are compared with the price of pellets in Europe and the price of pellets in various pellet-producing regions. Europe, the United States and Canada are the most important pellet producing regions in the world. Pellet prices in the United States and in Canada increased from USD90 to USD130 per tonne in 2010 due to tight feedstock supplies (Sikkema et al., 2011; all USD in this section are USD of 2007). In this study, a value of USD125 per tonne is assumed, which is also in line with the results of the National Biomass Strategy.

Pellet prices in Europe are higher, but when comparing European prices with the costs of pellet production in Malaysia the costs of transportation should also be considered. The costs of shipping pellets from North America to Europe range considerably over the period 2007-2010, but the median shipping costs were around USD40 per tonne (Sikkema et al., 2011). The costs of palm biomass pellets delivered in Europe would then be around USD115 per tonne, assuming the same costs of transportation for pellets from Canada and the US to Europe as for Malaysia to Europe. The price of pellets for large-scale power production in the Netherlands and the United Kingdom and for district heating and combined heat and power production in Scandinavia ranged between USD125 and USD165 per tonne in 2007-2010. Current pellet prices are around USD150 per tonne (APX-ENDEX, 2011). This means that the production of pellets is economically attractive also when the costs of transportation are included.

An important caveat thereby is that the prices of pellets in Europe and the prices of pellet transportation fluctuated drastically. Freight costs fluctuated due to global economic developments. But more important is the impact of energy and climatic change policies in Europe, which are responsible for the increase in pellet demand and high prices in 2010. In other words, the current pellet markets trends and pellet prices depend heavily on the energy and climatic change policies in Europe. For example, subsidies in the Netherlands for green electricity are equal to USD140 per tonne of pellets; subsidies in Sweden are around USD180 per tonne (Sikkema et al., 2011). Also important are the price of carbon credits/CO_2 emission rights, which in 2007-2008 were equivalent to USD30 per tonne of pellets (Sikkema et al., 2011).

The extent to which these policies will remain in place or will be expanded is unknown. This also makes the profitability of the pellet chains very uncertain. Based on the high subsidy level in especially Sweden and the Netherlands, which are the largest markets in Europe, it can be expected that even limited reduction in the policies will have a large impact on the prices of pellets in Europe and thus also on the profitability of pellet production in Malaysia. Subsidies for green electricity from woody biomass will be gradually abandoned in the Netherlands in the coming years. Without subsidies, pellets will not be able to compete with conventional energy electricity systems. For example, at USD125 per tonne of pellets, the cost of electricity generation (excluding capital and operation and maintenance) are almost twice the costs of electricity made from coal.[1]

4.5 Biobased chemicals

In this study the production costs of biobased chemicals from palm biomass are estimated using data from two sources. First, the costs of producing sugar are derived from a study of the US National Renewable Energy Laboratory (NREL, 2011). This source is also used to calculate the production costs of ethanol and

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[1] In the proposed Phase 2 of this project, a more elaborate evaluation will be carried out of the economic viability of pellet production from Malaysia, taking into account the impact of EU policies. Specific attention will be paid to the costs of drying, as already discussed above. Also, the types of palm biomass that are used for pellet production will be considered. Palm fronds and empty fruit bunches are not very suitable for the production of pellets, due to the higher costs and higher moisture content compared with palm kernel shells and fibres. Other crucial factors are the costs of transportation of the palm biomass to the pellet plant and the intercontinental transportation of biomass. Further, also the amount of pellets that realistically can be exported to Europe needs to be further investigated.

the same assumptions are also used here. The costs of sugar are calculated to be USD276 and USD207 (at 2007 price level) per tonne for present and future conversion technologies. Sugar can be used as feedstock for the production of bulk chemicals. The costs of the production of biobased chemicals are taken from the BREW project (Patel et al., 2006). The BREW project is the only study that was readily available and in which detailed data are given about the costs of producing chemicals from biomass and from fossil oil. Data are available for 17 bulk biobased chemicals for current and future technologies and also for conventional chemicals. The most promising biobased chemicals are selected. For each the most efficient current and future technologies are assumed. The production of conventional chemicals is assumed to be an established technology and the efficiency is assumed to be constant. The contribution of non-renewable energy to the total costs is estimated, based on the price of oil and on the non-renewable energy use per tonne of chemicals. In the case of bio-chemical also the contribution of sugar to the total costs is estimated. This allows a comparison of the costs of producing biobased chemicals and conventional chemicals based on a sugar from lignocellulosic resources (Table 4.4).

Results are generated for a basket of 6 biobased chemicals which seems the most interesting in terms of economic competitiveness and potential. These are ethanol, PDO, PHA, PTT, PLA and ethylene, whereby a ratio of 1 : 1 : 1: 1: 2: 3 is assumed. In total 6.3m t of palm biomass is assumed to be converted into biobased chemicals. A similar dataset is derived for petro-chemicals.

The results show that the production of biobased chemicals using current technologies is economically competitive at an oil price of about USD90 (at 2007 price level) per barrel. Future technologies will reduce the costs of the production of sugar and the costs of converting sugar into chemicals. Based on future technologies the equilibrium oil price is around USD50 (at 2007 price level) per barrel.[1]

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[1] In phase 2 of this project the calculations presented above will be improved in various ways. The analyses will be further refined and updated with data from other studies, as far as data are available. The costs of energy are an important element in the data presented above, but in the calculations above the price of crude oil per unit of energy is used as a crude approximation for the costs of energy, while in reality also other types of energy will be included. And future technological developments in the conventional chemicals industry have also been ignored, but these are potentially interesting. If possible, also specialty chemicals will be included, which are potentially more economically viable compared with bulk chemicals. Also the costs of converting biomass into lignin (e.g. for electric¬ity, proteins (for food and feed) and ethanol/sugar) will be evaluated. The performance of such integrated biorefinery systems is potentially better compared with the mono-product systems

Table 4.4 **Costs of the production of chemicals from palm biomass and of the production of conventional chemicals (in USD at 2007 price level per tonne of chemicals) for various oil prices and technologies**

Biochemicals current technology					
Oil price (USD at 2007 price level per bbl)	50	75	100	125	150
Feedstock	766	766	766	766	766
Conversion costs non-energy	924	924	924	924	924
Conversion costs energy	164	246	329	411	493
Total	1,855	1,937	2,019	2,101	2,183
Biochemicals future technology					
Oil price (USD at 2007 price level per bbl)	50	75	100	125	150
Feedstock	520	520	520	520	520
Conversion costs non-energy	819	819	819	819	819
Conversion costs energy	72	108	144	180	216
Total	1,411	1,447	1,483	1,519	1,555
Conventional chemicals					
Oil price (USD at 2007 price level per bbl)	50	75	100	125	150
Conversion costs non-energy	834	834	834	834	834
Feedstock* and conversion costs energy	590	885	1,180	1,475	1,770
Total	1,424	1,719	2,014	2,309	2,604

* Feedstock costs are the costs of sugar made from palm biomass.

Sources: NREL (2011), Patel et al. (2006) and own calculations.

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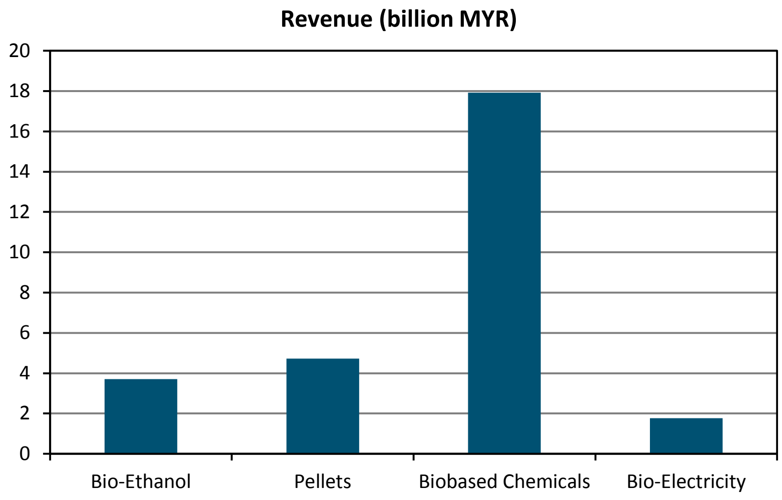
considered in this study. The costs of the production of biochemicals from palm biomass can be further reduced by optimisation of the use of palm biomass. The use of empty fruit bunches and palm fronds, which have a relatively high cellulose and hemi-cellulose content, would decrease the costs by 5%, assuming a constant price of palm biomass of USD56 per dry tonne. However, also the costs of the supply of biomass would change, since each type of palm biomass has a different cost supply curve. In particular, transportation of empty fruit bunches and palm fronds make these types of biomass among the most expensive types of palm biomass.

5 Results

The starting point of our analysis is that palm biomass can be used as a substitute for fossil energy input in a number of production processes. Specifically, we examine four cases, namely, the production of bioethanol, biobased chemicals, pellets, and bio-electricity. Whether it is *economical* to use palm biomass as a substitute is largely determined by the efficiency of the biomass based technology and the price of the fossil energy input for which it is substituting.

Figure 5.1 **Revenue related to National Biomass Strategy Portfolio (2030)**



The revenues generated with the biobased technologies are depicted in Figure 5.1. The revenues are generated by 4m t of biomass for ethanol, 11m t for pellets, 6m t for chemicals and 10m t for electricity. These revenues add up to about MYR30bn and represent almost 2% of GDP in 2030 assuming the GDP projections of the Economic Transformation Programme of Malaysia (Pemandu, 2010) and the baseline projections of the United States Department of Agriculture (USDA, 2011). The GDP effect is comparable to the findings of the NBS (2011). Almost two-thirds of these revenues are generated in the biobased chemicals sector. In the case of chemicals, we have to take into account that biomass in the chemical sectors are only a small part of total inputs and therefore total costs. Compared with the other uses, many other inputs (e.g. labour, capital) have to be added to create the relatively high value added.

Further, we examine the complete economic picture including both the revenues and costs of employing palm biomass products. The potential revenues of adding millions of tonnes of biomass into the production system are relatively easy to calculate, however, the message on the cost side of the equation is more subtle. When economists refer to costs, they mean opportunity costs, in other words the costs of the second best use of a resource. For instance, the production of palm biomass products requires the use of inputs such as capital and labour. If those resources are considered idle, in other words, if they are not used productively elsewhere in an economy, and then their opportunity costs are near zero. However, to the degree that they are used elsewhere, using them to convert palm biomass products into fossil fuels substitutes requires that capital, labour and other inputs be pulled away from wherever they are currently used, implying that less of those other goods can be produced. This displacement effect could not be quantified in the NBS, yet is significant. In this study we assume that the production of bioethanol, biobased chemicals and bioelectricity substitutes for the use of fossil oil for gasoline and chemicals production, while for electricity and pellets the substitute is the production of electricity from coal or natural gas. The most important determinant of the macroeconomic benefits of the production of bioethanol, biobased chemicals and bioelectricity is the difference between the costs of the biobased products and the price of the fossil resource-based substitute. In short, an important cost of producing palm-based biomass products is a reduction in the production of other goods in Malaysia as their inputs will be used to produce biobased products and/or the input costs increase as demand for inputs increases. Equilibrium models are designed precisely to model trade-offs such as the opportunity costs. By modelling an entire economy, the *net* benefits of a transition from a fossil resources-based economy to a biobased economy can be determined. In this study no additional policies are assumed to address bottlenecks such as shortage of labour in an economy such as Malaysia with full employment currently.

An important question for policy makers is which application of palm biomass should be stimulated to achieve the highest macro-economic impacts. This study calculated the GDP effects per unit of palm biomass for four applications. The GDP impact depends on the rate of technological development and the price of the fossil resources-based substitute. The sensitivity of the results of these four applications with regard to technological development and oil prices is discussed in Section 5.1 to Section 5.4. As default for this summary section we assume that future technologies for the production of bioethanol and biobased chemicals will become more efficient and that the oil price will increase to USD125 per barrel, which is roughly the level projected by the International Energy Agency for 2030. We also assume a pellet production cost of USD72 and a price of USD125 per tonne of pellets. The GDP effect perm t palm biomass is 0.013% (MYR207 perm t) for bioethanol, 0.038% (MYR592 perm t) for biobased chemicals and 0.012% (MYR180 per m t) for pellets. Pellets have the lowest GDP effect per unit of biomass and run the risk that the high EU price will decrease when substitutes emerge. Bioethanol and especially biobased chemicals are the most favourable option to increase the GDP. Biobased chemicals yield more than three times the GDP effect per volume of palm biomass compared with pellets. Electricity is excluded from the summary table (Table 5.1), because under any reasonable assumptions about the price of coal or natural gas a bioelectricity project will be expensive in terms of GDP loss.

Table 5.1 **Summary table: GDP effect per million tonnes**

	GDP effect (%)	Biomass mass (m t)	GDP effect/biomass volume (%/m t)
Bioethanol	0.056	4.2	0.013
Biochemicals	0.240	6.3	0.038
Pellets	0.130	11.2	0.012

The results show that the total net GDP growth effect is relatively limited for most applications due to the above displacement and constraining factors, without taken further and flanking measures. The total GDP growth is around 0.43% or MYR6.6bn in 2030 using 22m t of biomass. This figure is calculated assuming that future technologies will be used for the production of bioethanol and biobased chemicals, assuming an oil price of USD125 per barrel (which is the level projected by the International Energy Agency for 2030) and assuming a pellet production cost of USD72 and a price of USD125 per tonne of pellets. The production of electricity, which is not included in the 0.43%, would lead to a negative GDP effect of 0.51%, assuming a cost equivalent to the feed-in tariff. The total net GDP impact of the four palm biomass applications together, would then be virtually zero, under the conditions described above.

The relatively large differences between net GDP effects in Table 5.1 and the revenues in Figure 2.3 are the opportunity costs which are not zero in an economy that does not have a lot of unused resources next to palm waste. In other words, the collection, transportation and processing of palm biomass into ethanol and other products takes resources (labour, capital, other inputs) from other activities as we assume that for example there is full employment in Malaysia already. In particular, the labour availability has substantial implications for flanking policy measures and technology development such as exploring technological opportunities for mechanisation of collection and pre-processing of biomass.

In the next sections, we discuss in more detail the four applications of biomass and the sensitivity of the results with regard to technological change and the level of the oil price. Four tables are provided showing the effects on Malaysia's gross domestic product of using biomass inputs in place of fossil fuel inputs. There are several points to notice about the tables. The first is that the results should be read as alternative scenarios, in other words, each table models the results of using palm biomass exclusively as an input in the production of ethanol, chemicals, pellets or electricity. This was done in order to accentuate the contributions of biomass to specific uses. Future scenarios could quite easily be modelled to calculate the economic effects of combinations of biomass products. The second point to note is that, following the National Biomass Strategy report, the tables are made for different amounts of biomass input. Specifically, ethanol and chemical production are modelled using 4.2 and 6.3m t respectively of biomass, pellet production is taken to use 11.2m t, and electricity generation is estimated to use 9.8m t (Table 2.1). This has to be taken into account if one compares the GDP impacts of different biobased options.

The numbers in the main body of each of the tables represent percentage of GDP in 2030 (estimated GDP value is USD409bn or MYR1.554bn in 2030). For instance, the number -0.26 in Table 5.2 represents a 0.31% reduction in the GDP of Malaysia. The colour key for all of the tables is the same, those GDP results equal to or greater than 0.05 are marked green, those equal to or less than -0.05 are red, and those numbers between -0.05 and 0.05 are yellow.

There is a common way to read all of the tables. The column along the y-axis should be thought of as the technological development of a fossil fuel substitute. Higher values mean that the cost of using the biomass product as a substitute is higher, as a technology improves the price of using it as a substitute falls. For instance, in Table 5.2, the cost of producing ethanol from biomass materials is modelled as costing USD135 (current technology) and USD100 (future technology) per unit of substitute (y-axis). To be more specific, the cost of producing bioethanol is currently competitive with oil costing USD135 and it is expected to be competitive at USD100 per unit in the future.

A range of prices for a barrel of oil in USD at 2007 price level is arranged across the x-axis. A good method to read the table is to pick a row and then read across columns. For example, in Table 5.2, if a technology is used that produces bioethanol at a cost of USD135 while the price of oil is USD135; there is clearly no economic advantage to substituting bioethanol for oil. However, if the price of a barrel of oil increases to USD150, then we calculate that the Malaysian economy will realise an increase in their GDP of 0.03% when no alternative measures are taken. It is important to note that there may be reasonable, non-economic, reasons to support policies which are calculated to lead to a reduction in GDP; our analysis focuses on the economic and technical questions concerning the use of palm biomass. Finally, the tables represent a calculation of the state of the Malaysian economy in real terms in 2030. In other words, the simulations take as a base case the expected economic state of Malaysia in 2030 and present results for a range of fossil fuel prices and for current and future technologies.

5.1 Ethanol

The ethanol simulation models the use of 4.2m t of biomass to produce bioethanol as a substitute for gasoline produced by petroleum. The amount of biomass available for the production of ethanol and each of the other biomass products is taken from the Biomass Roadmap (the National Biomass Strategy report). Currently, ethanol is calculated to be competitive with oil priced at about USD135 per barrel, however, by 2030 it is anticipated that technological improvements will make bioethanol competitive with oil at around USD100 per barrel (see Section 4.3). Therefore, the Table 5.2 shows that a consumer of gasoline in 2030 will be indifferent to gasoline produced with bioethanol (at a price of about USD135 assuming current conversion technologies) and the same amount produced from oil. However, if the price of oil decreases to USD50 the GDP decreases with -0.26% and if the price of oil increases to USD150, then there will be an increase in Malaysia's GDP of 0.03%. If the technology to make ethanol from palm biomass improves to the point the ethanol is competitive at an oil price of USD100 per barrel, then GDP increases could increase to 0.11% if the oil price reaches USD150 per barrel.

Table 5.2 **Percentage effect on Malaysian GDP in 2030 of 4.2m t of biomass ethanol project**

	Price of oil in USD (at 2007 price level) per barrel						
	50	**70**	**80**	**100**	**110**	**135**	**150**
Current technology (135)	-0.26	-0.18	-0.14	-0.08	-0.06	0.00	0.03
Future technology (100)	-0.16	-0.08	-0.05	0.00	0.02	0.08	0.11

Learning effects in lignocellulose biomass conversion technologies will most likely be similar to those found in other segments of the biobased economy and agro-food-energy processing field. The best-documented case is the learning effect in (1st generation) ethanol production from sugar cane in Brazil. Here the combination of increased market competitiveness in combination with sustained support of the government for science and technology development has led to a significant reduction in ethanol cost price. Contributions to cost price reduction stemmed from all portions of the suga- cane value chain (field, harvest, processing) as analysed by Van der Wal and co-authors (2008).

Higher GDP impacts are possible when the empty fruit bunches and palm fronds are used, which have a higher ethanol yield. In that case an equilibrium oil price of USD80 per barrel seems feasible and a GDP effect of 0.15% if the oil price increases to USD150 per barrel. In general we can conclude that the production of ethanol will be positive from a GDP point of view from Malaysia assuming that the oil price increases to as projected by the International Energy Agency in the Current and Policies scenario (USD150 per barrel in 2035) or New Policies scenario (USD120 per barrel) and if the technologies of converting palm biomass into ethanol will become more efficient (IEA, 2011). In case of very strict climatic change policies (in the case of a 450 ppm CO_2 Scenario) the demand for oil decreases and the oil price increases to circa USD99 per barrel (IEA, 2011).

5.2 Pellets

In contrast to the ethanol case described above, pellets produced from palm residuals are assumed to be exported to Europe due to the renewable energy directive in the European Union. The production costs are USD73 per tonne compared with a current pellet market price of USD125 per tonne. The largest reported increase in GDP, 0.20%, comes from the use of palm biomass for the production of pellets by a pellet price of USD150 per tonne and a production price of USD73 per (dry) tonne. However, this profitability in the pellet case for a great deal depends on the recent bioenergy policies in Europe, especially in Sweden and the Netherlands. If these policies are revoked or new pellet producers and other substitutes enter the market, then the price of pellets is expected to decrease rapidly and associated prices and rents will fall (see also Section 4). The current costs of producing pellets are calculated to be around USD73 per tonne (excluding transport) and USD115 per tonne (including transport). This is well below the price of coal per unit of energy. It might therefore be expected that the current pellet price comes under pressure as EU electricity companies will look for cheaper alternatives.

Table 5.3 Percentage effect on Malaysian GDP in 2030 of 11.2m t of biomass pellets project

	Price of pellets in USD (at 2007 price level) per tonne			
	73	**90**	**125**	**150**
Current = future technology (73)	0.00	0.06	0.13	0.20

5.3 Chemicals

The question addressed in the case of using palm-based biomass for the production of oil substitutes is similar to the bioethanol case. The question at hand is what costs are incurred in transforming residues and by-products from the palm oil plantations and palm oil processing industry into a substitute that can be used for a similar amount of oil-based inputs. The real costs of a series of possible technologies for producing chemicals using biobased inputs is calculated and compared with a range of possible real oil prices in 2030. Our calculations show that current technologies are competitive at USD90. Given a current price of a barrel of oil of USD70, this means that the current technology is not competitive. Improvements in technology are expected to make biobased chemicals competitive at an oil price of USD50 per barrel. In that case, biobased chemicals will increase the GDP by circa 0.25-0.28%, assuming the oil price increases to the USD120-150 per barrel in 2035 as projected by the International Energy Agency (IEA, 2011).

Table 5.4 **Percentage effect on Malaysian GDP in 2030 of 6.3m t of biomass chemicals project**

	Price of oil in USD (at 2007 price level) per barrel					
	50	**70**	**90**	**110**	**135**	**150**
Current technology (90)	-0.18	-0.07	0.01	0.08	0.15	0.17
Future technology (50)	0.03	0.11	0.17	0.21	0.26	0.28

5.4 Electricity

The use of biomass strictly as a substitute for coal (or natural gas) to produce electricity is not economically attractive in case of a well-established grid. The most striking feature of the results is that all of the scenarios lead to a relatively large reduction in Malaysia's GDP. There would have to be strong, non-economic reasons or the absence of a grid infrastructure, to pursue the path of electricity production using palm biomass. This MES does not investigate the additional costs and macro-economic impacts of establishing a grid in remote parts of Malaysia, for which also non-economic issues such as impacting pristine forest play a key role.

We consider a bioelectricity project which uses 9.8m t of biomass in 2030 (National Biomass Strategy, 2011), which is about 3% of Malaysian requirements in 2030. A negative GDP effect of 0.51% is calculated of replacing conventional electricity by bioelectricity. This figure is based on the assumption that the full feed-in tariff is needed to make bioelectricity economically attractive. In case these costs are lower, e.g. because the costs of producing electricity from coal or gas would increase due to an increase in the price of coal or gas, then the costs of electricity would decrease accordingly. The costs of conventional electricity are much lower, namely about USD0.05-0.064 (at 2007 price level) per kWhe for electricity from coal; USD0.044 (at 2007 price level) per kWhe for electricity from gas; at 2004 energy prices. Coal prices are expected to increase from USD99 per tonne to USD110-118 in 2035 in the case of the Current and New Policies scenarios; in case of strict climatic change policies (the 450 Scenario) the coal price decreases to USD68 per tonne (IEA, 2011). So it seems that under any reasonable assumptions about the price development of coal or natural gas, a bioelectricity project will be expensive in terms of GDP loss to the Malaysian economy when compared with conventional electricity.

6 Conclusions

Our analyses concentrate on the two most important determinants of the profitability of using biomass products as substitutes for fossil fuel inputs, namely, the technological improvements related to the conversion of palm biomass to a point at which it can act as a substitute, and the price of competing fossil resources-based substitutes. The tables in Section 5 are constructed around that simple idea.

In general, we can conclude that the production of bioethanol, pellets and biobased chemicals will be positive from a GDP point of view for Malaysia, assuming that the oil price increases to USD125 - USD150 per barrel as projected by the International Energy Agency and if the technologies of converting palm biomass into ethanol will become more efficient. The price of oil is thereby a crucial and partially uncertain factor which price is an important factor in our analyses. According to the International Energy Agency (2011), the cost of producing oil will increase as oil companies are forced to turn to more difficult and costly sources to replace lost capacity and to meet rising demand. The average oil price is expected to increase, approaching USD120 (at 2010 price level) per barrel in 2035. However, if between 2011 and 2015, investments in oil production are limited in comparison to what is needed according to the New Policies Scenario, a near-term rise in the oil price to USD150 (at 2010 price level) per barrel is feasible over that period. Under these conditions the production of both bioethanol and biobased chemicals are expected to become economically viable, assuming that future improvements in conversion technologies are realised. However, predicting the oil price is very difficult. Also during the high oil prices in the 70s it was predicted that oil prices would be high for a long time and would increase. However, oil prices turned very low for a long period until recently.

At an oil price of USD125, the contribution to GDP per tonne of biomass is three times as high for biobased chemicals as for pellets and bioethanol. The net GDP effect per million tonnes of palm biomass is 0.013% (or MYR207 per million tonnes) for bioethanol, 0.038% (MYR592 per million tonnes) for biobased chemicals and 0.012% (MYR180 per million tonnes) for pellets. Pellets are also economically attractive as long as bioenergy policies in Europe will be in place and assuming that the production of pellets from other sources or other substitutes does not decrease the average pellet price. Electricity from palm biomass is probably not competitive with electricity from coal, although small-scale production might be economically viable under conditions that have not been investigated in this study.

The NBS portfolio consists of by 4m t of biomass for bioethanol, 11m t for pellets, 6m t for biobased chemicals and 10m t for bio-electricity. These revenues of this portfolio add up to about MYR30bn and represent almost 2% of GDP in 2030 which is comparable to the findings of the NBS (2011). This study shows that the net GDP growth is around 0.43% or MYR6.6bn in 2030 using 22m t of biomass for bioethanol, pellets and biobased chemicals (assuming an oil price of USD125 per barrel). The production of electricity would leads to a negative GDP effect of 0.51% implying that the whole portfolio has a limited GDP impact.

We need simplifying assumptions to compare the NBS figures with the findings of this study. We have made a simple comparison without taking electricity into account. If Malaysia would invest 35m t of the NBS study in the current bioethanol, pellets and biobased chemicals portfolio (same ratios) this study leads to 0.68% (MYR10.7bn) of GDP growth in 2030. Therefore in general our findings are lower than the NBS study, simply because opportunity costs are taken into account, which the NBS does not.

In our analyses, the opportunity costs are accounted for by using the MAGNET CGE model. The most important GDP effect is the decrease or increase in the costs of production when conventional inputs are replaced by biobased alternatives. The GDP effects would be higher in case:

1. Malaysia is able to develop a competitive advantage over other producers elsewhere in the world;
2. The oil price is higher; or
3. More biomass than 35m t is collected;
4. The demand for biofuels and other biobased products in other parts of the world continues to increase; or
5. The government addresses bottlenecks such as constraints at the labour or capital markets.

It is important to realise that behind these relatively small GDP growth figures, a relatively large transition from fossil resources-based technologies to biomass-based resources takes place. This implies a large-scale substitution of fossil fuels by biobased alternatives in the petrol/biomass refinery, electricity and chemical industries leading to all kind of 'bottlenecks' as capital has to be attracted and built up, people have to be attracted and educated, infrastructure has to be built, export markets have to be developed and technologies have to be invented and diffused within the sectors. The relatively large differences between net GDP effects and the revenues connected to the use of palm oil biomass are the opportunity costs which are not zero in an economy that does not have many unused resources in addition to palm waste. In other words, the collection, transportation and processing of palm biomass into ethanol and other products take resources (labour, capital, other inputs) from other activities as we assume that for example there is full employment in Malaysia already. Therefore, the emergence of a biobased economy influences directly and indirectly many other sectors within the economy, the education, financial and innovation system. A successful development of a biobased economy requires a coherent set of governmental policies covering agricultural, energy, transport, infrastructure, education, financial, export and technology policies.

An additional issue that has not been included so far in the evaluation is the availability of domestic fossil resources such as crude oil and natural gas, which are believed to cease after 20 and 40 years respectively. This could lead to all sorts of extremely drastic economic and non-economic (energy and resource security) effects since the oil and gas sector in Malaysia comprises approximately MYR71bn (or 14%) of the Malaysian GDP of MYR509bn and the fast growing Malaysian energy demand.

The analysis presented represents a first step, an overview of the important possibilities and constraints faced by users of palm biomass. There are recognised shortcomings in our analyses. First, as stated on numerous occasions throughout this text, we concentrate on the *economic* aspects of using palm biomass; there are certainly non-economic reasons that do and should play a role in the decision to use palm biomass. Some of these aspects also have implications for the economics, such as the price of carbon credits, which has been excluded from our current analyses. Second, there are uncertainties inherent in any study which hopes to calculate events which may occur twenty years in the future. We tried to partially encompass this issue by including a range of technological developments and fossil fuel prices, but many more uncertain factors are relevant that have not been explicitly addressed in our analyses, but will be in phase 2.

The next step will review some key assumptions and results of the NBS study and add more details to the model so that richer analyses can be conducted. The current and future cost structure of the production and various uses of biomass will be revisited. An example is the cost structure of collecting biomass such as the high cost of replacing fertilisers in the NBS study, which might be much lower with integrated recycling. Another key assumption in this study is that the total amount of biomass used and its distribution across various uses was based on the NBS study and assumed exogenous independent of commodity prices (oil, coal) and economic development. Given the flatter part of the biomass supply curve, the amount of biomass used in the Malaysian economy and the corresponding price for biomass does not necessarily follow an externally imposed scenario (as in the current study).

The amount of biomass used and its distribution among the various uses will have a major impact on the macro-economic effects. New sectoral details in the modelling will allow us to better analyse the precise implications for the Malaysian economy of the intensive use of palm biomass. We will be able to show inter-industry trade-offs and the implications for Malaysian employment, capital and international trade flows. Phase 2 will also include more detailed analyses, including the impact of optimising logistics of palm biomass and of optimising the use of various types of biomass for different applications in terms of potential, costs, GHG emissions, efficiency and macro-economic impacts. Moreover, phase 2 will consist of a more extensive evaluation of the macro-economic impacts, including additional macro-economic parameters (e.g. trade balance effects, employment effects), at sectoral level, whereby also the impact of carbon credits or a green premium and the impact of increased demand from biobased products from abroad will be investigated. In addition, the environmental impacts will be considered in detail, including the direct and indirect impacts on land-use change.

Literature and websites

Banse M., H. van Meijl, A. Tabeau and G. Woltjer, 'Will EU biofuel policies Aafect global agricultural markets?' In: *European Review of Agricultural Economics* 35 (2008) 2, pp. 17-141.

Banse, M., H. van Meijl, A. Tabeau, G. Woltjer, F. Hellmann and P.H. Verburg, 'Impact of EU biofuel policies on world agricultural production and land use.' In: *Biomass & Bioenergy* 35 (2011) 6, pp. 2385-2390.

CMT, 2011. *Pellets are coming to Asia - A strategic position paper*. Pöyry Management Consulting for Centre for Management Technology (CMT), 4 pp.

Eickhout, B., H. van Meijl, A. Tabeau and T. van Rheenen, 'Economic and ecological consequences of four European land use scenarios.' In: *Land Use Policy* 24 (2007), pp. 562-575.

Eickhout, B. and H. van Meijl, 'A multi-scale, multi-model approach for analysing the future dynamics of European land use.' In: *The Annals of Regional Science* 42 (2008) pp. 57-7.

Eickhout, B., H. van Meijl, A. Tabeau and E. Stehfest, 'The impact of environmental and climate constraints on global food supply.' In: *Economic Analysis of Land Use in Global Climate Change Policy*, edited by T. Hertel, S. Rose and R. Tol, Routledge, USA, 2009.

Hertel, T.W. and M.E. Tsigas, Structure of the Standard GTAP Model, Chapter 2. In: T.W. Hertel (editor), *Global Trade Analysis: Modeling and Applications*. Cambridge University Press, 1997.

IEA, *World Energy Outlook 2011*. International Energy Agency, Paris, France, 2011.

Kets, W. and A.M. Lejour, *Sectoral TFP developments in the OECD*. CPB Memorandum 58, The Hague, 2003.

Koh, M.P. and K. Hoi, 'Sustainable biomass production for energy in Malaysia.' In: *Biomass and Bioenergy* 25 (2003) 5, pp. 517-529.

National Biomass Strategy, *Biomass Roadmap / Waste to Wealth*. Study commissioned by Agensi Inovasi Malaysia, AIM, 2011.

Meijl, H. van, T. van Rheenen, A. Tabeau and B. Eickhout, *The impact of different policy environments*. 2006

MPOB, *Economics and statistics*. Malaysia Palm Oil Board. 2010. Accessible online via: http://mpob.gov.my/

MNRE, *National policy on climatic change*. Ministry of National Resources and Environment Malaysia, 32 pages, 2010.

Nowicki, P., V. Goba, A. Knierim, H. van Meijl, M. Banse, B. Delbaere, J. Helming, P. Hunke, K. Jansson, T. Jansson, L. Jones-Walters, V. Mikos, C. Sattler, N. Schlaefke, I. Terluin and D. Verhoog, *Scenar 2020-II - update of analysis of prospects in the scenar 2020*. Study - Contract No. 30-CE-0200286/00-21. European Commission, Directorate-General Agriculture and Rural Development, Brussels, 2009a. http://ec.europa.eu/agriculture/analysis/external/scenar2020ii/index_en.htm.

Nowicki, P., K. Hart, H. van Meijl, D. Baldock, M. Banse, J. Bartley, K. van Bommel, J. Helming, K. Jansson, T. Jansson, I. Terluin, K.H. van der Veen, D. Verhoog, P. Verburg and G. Woltjer, *Study on the impact of modulation.* Contract No. 30-CE-0200286/00-21. European Commission, Directorate-General Agriculture and Rural Development, Brussels, 2009b. http://ec.europa.eu/agriculture/rica/pdf/hc0401_impact_modulation.pdf.

Nowicki, P., H. van Meijl, A. Knierim, M. Banse, J. Helming, O. Margraf, B. Matzdorf. R. Mnatsakanian, M. Reutter, I. Terluin, K. Overmars, D. Verhoog, C. Weeger, H. Westhoek, *Scenar 2020 - Scenario study on agriculture and the rural world*. Contract No. 30 - CE - 0040087/00-08. European Commission, Directorate-General Agriculture and Rural Development, Brussels, 2006. http://ec.europa.eu/agriculture/publi/reports/scenar2020/index_en.htm

NREL, *Process design and economics for biochemical conversion of lingo-cellulosic biomass to ethanol dilute-acid retreatment and enzymatic hydrolysis of corn stover.* National Renewable Energy Laboratory (NREL), Golden, Colorado and Harris Group Inc., Seattle, Washington and Atlanta, Georgia, 2011.

Patel, M., M. Crank, V. Dornburg, B. Hermann, L. Roes, B. Hüsing, L. Overbeek, F. Terragni and E. Recchia, 2006. *The BREW project: medium- and long-term opportunities and risks of the biotechnological production of bulk chemicals from renewable resources.* Economic Transformation Programme - A roadmap for Malaysia, Performance Management & Delivery Unit (Pemandu), 2010.

Pemandu, *Economic transformation program, performance management and delivery unit* (Pemandu). Malaysia, 2010.

Platform Groene Grondstoffen, *Bio-based economy in Nederland: Macro-economische verkenning van grootschalige introductie van groene grondstoffen in de Nederlandse energievoorziening.* 2009.

PoM, *Renewable Energy Act 2010*. Parliament of Malaysia. 2011.

RaoE, *The cost of generating electricity*. Royal Academy of Engineering, London, United Kingdom, 2004.

Shuit, S.H., K.T. Tan et al., 'Oil palm biomass as a sustainable energy source: A Malaysian case study.' In: *Energy* 34 (2009) 9, pp. 1225-1235.

Sikkema, R., M. Steiner et al., 'The European wood pellet markets: current status and prospects for 2020.' In: *Biofuels, Bioproducts and Biorefining* 5 (2010), pp. 250-278.

Tay, J.H. and K.Y. Show, 'Utilization of ashes from oil-palm wastes as a cement replacement material.' In: *Water Science and Technology* 34 (1996) 11, pp. 185-192.

Tye, Y.Y., K.T. Lee, W.N.W. Abdullah and C.P. Leh, 'Second-generation bio-ethanol as a sustainable energy source in Malaysia transportation sector: Status, potential and future prospects.' In: *Renewable and Sustainable Energy Reviews* 15 (2011) 9, pp. 4521-4536.

USDA, *International Macroeconomic Data Set*. United States Department of Agriculture (USDA), 2011. Accessible online via: http://www.ers.usda.gov/Data/Macroeconomics/#BaselineMacroTables

Van Dam, J.E.G., *Options for sustainability improvement and biomass use in Malaysia*. Rapport 1080. Agrotechnology and Food Innovations, part of Wageningen UR, 2010.

Verburg, P.H., B. Eickhout and H. van Meijl 'A multi-scale, multi-model approach for analyzing the future dynamics of European land use (2008).' In: *Annals of Regional Science*, 42(1): 57-77

Wall Bake, J. van der, M. Junginger et al., 'Explaining the experience curve: Cost reductions of Brazilian ethanol from sugarcane.' In: *Biomass and Bioenergy* 33 (2009) 4: pp. 644-658.

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