Highlights

- EFB can be used as a feedstock for the production of multiple products.
- Optimization model demonstrates the significant economic benefits of EFB utilization
- Optimization model could be an useful decision-making tool for policy makers to improve the EFB utilization

OPTIMIZATION OF OIL PALM EMPTY FRUIT BUNCHES VALUE CHAIN IN PENINSULAR MALAYSIA

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ABSTRACT

Empty fruit bunches (EFB) are valuable palm oil mill waste that could be used to produce multiple products in the form of energy, chemicals, and materials. Therefore, efficient utilization of these biomass resources is essential to optimize the profitability of the industry while addressing environmental issues. In this study, a decision-support tool is developed to perform economic and environmental analyses of the future expansion of the palm oil industry. The sequential steps in the modeling and optimization of the EFB value chain are discussed. This study consists of four processing stages: converting EFB into intermediates and products, transportation networks, direct sale of products, and further processing of products. The proposed tool includes a mathematical model that considers biomass, production, transportation, and emission treatment costs from transportation and production activities. The model is solved with the Advanced Interactive Multidimensional Modeling System to determine the maximum profit and analyze biodiesel production. Peninsular Malaysia is selected as a case study. Results reveal the significant economic benefits of EFB utilization. The most profitable cases of EFB utilization are Case A, C, and D, which have the same 47% profit margin. The maximum profit of the selected utilization pathways in Case A is USD 151,822,904 per year based on different ownerships of all EFB processed, which is 79% lower than the result of a previous study that ignores the capacity limitations of the respective processing facilities. The environment–food–energy–water nexus is also elaborated in this study. The conclusions are obtained based on the limitation, availability, and parameters or data used in this study.

Keywords: Optimization, empty fruit bunch, biomass value chain, nexus

1.0 INTRODUCTION

Malaysia's palm oil industry is growing rapidly and has contributed a huge volume of oil palm wastes, which can be good alternative sources of renewable energy and bioproducts. These wastes include palm fronds, palm trunks, empty fruit bunches (EFB), mesocarp fibers, palm kernel shells, and palm oil mill effluent (POME) (Hazman et al., 2018). However, Malaysia's palm oil industry has elicited increasing concern because oil palm plantations with their high volume of waste generation are negatively related to environmental pollution issues. A survey conducted by Umar et al. (2018) showed that only 23% of oil palm biomass is used in a palm oil mill as fuel for the boiler, and the remaining 75% is abandoned on site. Continued increase of this waste is expected to lead to serious environmental impacts (Dalton et al., 2017). Therefore, sustainable management of the palm oil industry is required to combat these problems (Faridah et al., 2018).

Oil palm biomass utilization involves two main processes, namely, thermochemical and biochemical. Thermochemical processes, such as combustion, gasification, pyrolysis, liquefaction, and transesterification, involve heat and chemicals in production. Thermochemical processes have higher efficiencies, shorter reaction times, and can break down more organic compounds than biochemical processes. Biochemical conversion processes primarily include digestion and fermentation using microorganisms and catalysts (Zhang et al., 2010). These process options are another way to achieve sustainability in the future where value-added products can be generated via biorefinery (Ali et al., 2015). EFB is lignocellulosic biomass that has a potential to be used as a renewable feedstock for heat and power generation and bioproducts (Ahmad et al., 2016; Kwapinski et al., 2010). In the past, EFB was used as fuel in boilers to generate steam for power generation only. However, the use of EFB was restricted by the government because of its emission issue (Rosli et al., 2017). At present, EFB is used as mulch and fertilizer in plantations. Although usage as mulch and fertilizer could reduce EFB waste, large amounts of unutilized EFB remain (Chang, 2014; Koguleshun et al., 2015). This unutilized EFB waste can be converted into bioenergy, such as biochar, biofuel, and biogas, and value-added products, such as pellets, materials, and fertilizers, via different types of conversion technologies (Abdullah et al., 2015; Sudiyani et al., 2013).

The development of a value chain is important to ensure efficient and sustainable EFB utilization (Tapia et al., 2019; Zandi Atashbar et al., 2018). A value chain can be described as activities of conversion, transportation, and storage from raw materials to high-value products and energy generation (Jarvis and Samsatli, 2018). The main challenge in the biomass value chain is the uncertainties in biomass supply, demand, prices, costs, technology, policies, and environmental impacts. Considering all of these uncertainties is challenging. Uncertainty can be defined as a decision-making situation with imperfect information that can change over time (Bairamzadeh et al., 2018; Chemmangattuvalappil et al., 2017). Process system engineering or the value chain optimization model approach can be a useful tool to include these uncertainties in decision-making.

Shukery et al. (2016) suggested the most efficient way to utilize oil palm biomass while maximizing the economic performance. They used Johor with various oil palm biomass as their case study. However, they provided limited details on the technologies involved. Kasivisvanathan et al. (2016) used a fuzzy optimization method to address the process synthesis problem caused by demand uncertainty in palm oil-based biorefinery. The model was designed to achieve trade-off between maximum flexibility and minimum total cost of the plant. However, the study did not consider any environmental impact. Theo et al. (2017) adopted a fuzzy optimization method to optimize oil palm biomass and the POME utilization pathway and used the bioCNG distribution network for a palm oil mill cluster while giving priority to economic performance. The model considered the Federal Land Development Authority (FELDA) palm oil mill cluster in Pahang that includes seven typical palm oil mills with anaerobic digestion units. However, their

study was limited to palm oil mills in the same cluster and did not consider the possibility of integrating different clusters. Although the environmental impact was not considered in the two models, these models are useful for the planning and feasibility study of biomass utilization in Malaysian palm oil mills. In another study on producing and distributing biomethane generated from POME, Hoo et al. (2017) used a BeWhere model to optimize the amount of biomethane injected into a natural gas grid in peninsular Malaysia. The case study aimed to minimize costs by identifying the locations, capacity, and technology of biogas refinery plants. Wu et al. (2017) also investigated and optimized power and heat generation from biomass in the palm oil industry by using a simulated model in ECLIPSE software. Both studies showed the capability of biomass to produce sufficient electricity and heat, but it was limited to combined heat and power (CHP) plants.

Memari et al. (2018) utilized a mixed – integer linear programming model to optimize the proposed regional oil palm biomass-to-bioenergy supply chain planning model based on actual palm oil mills, refineries, and oleochemicals in the northern part of Borneo Island, Malaysia. EFB was used as a source to generate heat and power for powering CHP plants. The optimum level of EFB transported from mills to CHP plants was determined to minimize the total logistics costs and carbon emissions. Such a method is straightforward, simple, and can be easily used to understand the basis of a regional bioenergy supply chain. How et al. (2018) utilized the p-graph approach and sustainability index in a case study of 62 palm oil mills and other biomass plants in Perak and Selangor to identify the bottlenecks of technological pathways and biomass selection. Their approach can effectively identify the bottlenecks of value chains but is not sensitive to economic fluctuations and regulatory risks.

A recent study on sustainable biomass value chain concepts was conducted by Ling et al. (2019). Bioelectricity production of oil palm biomass was synthesized and analyzed. The locations of palm oil mills and processing facilities in Selangor were clearly indicated in the study. A detailed economic evaluation and the optimum location of pretreatments and power plants were provided. However, this study only considered palm oil mills in small regions and did not reveal multiple pathways of bioenergy production. Tapia and Samsatli (2019) used a fuzzy analytic hierarchy process approach for multi-objective optimization of oil palm value chains in Peninsular Malaysia. Balance was obtained among economic feasibility, climate change, and water pollution impact. This study presented palm oil production and bioenergy products in every state in Peninsular Malaysia but did not provide detailed information on palm oil mills and technologies. According to this overview, most models include multiple biomass feedstock, many use multiple technologies, and several generate multiple output products; however, none has focused on the quantitative availability of biomass and processing facilities in the region. Furthermore, the locations of biomass supply and technologies were not clearly indicated.

In the present study, we explore all possible processing routes of utilizing EFB in Peninsular Malaysia as a feedstock to produce energy and high-value-added products. An optimal EFB supply chain for multiproduct production of energy, chemicals, and materials was previously investigated by Abdulrazik et al. (2017). This preliminary study is an extension of work of Abdulrazik et al. but with the inclusion of the geographic information system locations of feedstock collection points (palm oil mills) and processing facilities in Peninsular Malaysia, and analysis on bio-diesel production and environment–food–energy–water (EFEW) nexus that include the CO_2 emissions produced from transportation and processing facilities. Peninsular Malaysia is selected as the pilot study because it has a land area of 131,598 km^2, and 76% of the total population of Malaysia resides here (Sabo et al., 2016). Therefore, the demand for bioproducts and economic activities are high in this area. Currently, Peninsular Malaysia accounts for 54% of the total number of palm oil mills in Malaysia (Hamzah et al., 2019). Palm oil mills are vastly distributed around Peninsular Malaysia, especially in Johor, Pahang, and Perak, thereby making this region suitable for use in this study to investigate the status of the palm oil sector. East Malaysia accounts for half of the total amount of generated EFB. Its unique geographical location, which is ~640 km away and separated by the South China Sea, suggests that cross-boundary biomass transportation is very

unlikely. Hence, East Malaysia is not within the scope of this study. This study aims to develop a value chain model that integrates EFB availability, facility locations, processing technologies and capacities, bioproducts, and power production with the cost as well as analysis on bio-diesel production and EFEW nexus along with the CO_2 emissions of production and transportation. Optimal pathways are identified based on predefined objective functions.

2.0 EFB VALUE CHAIN MODEL DEVELOPMENT

The development of the EFB value chain model is based on the sequential steps shown in Figure 2.1. EFB is used as biomass feedstock to produce various intermediate and final bioproducts via different processing routes. Several of the routes can accommodate more than one intermediate product to produce similar final products. The developed structure is shown in Figure 2.2. In this superstructure, the squares represent the processing facilities, and the ovals represent the products located within a facility. The solid lines show the processing sequences, and the dashed lines show the products to be sold directly. Products from the facility without further processing are to be sold directly. The indices and descriptions of each facility are listed in Table 2.1 and are used in the model formulation. The numbering of the processing represents the number of existing facilities.

Four processing stages, namely, preprocessing facilities (*h*), main processing facilities (*j*), further processing facilities 1 (*l*), and further processing facilities 2 (*n*), are used. The preprocessing facilities (*h*) consist of dry long fiber (DLF) production, pelletization mill, torrified pelletization, aerobic digestion, extraction plant, alkaline activation (activated carbon) plant, and briquetting plant. The preprocessed feedstock (*i*) consists of DLF, biocompost, activated carbon, cellulose, hemicellulose, lignin, briquette, pellet, and torrified pellet. Biocompost and activated carbon are treated as final products of the preprocessing facilities.

The main processing facilities (*j*) consist of biocomposite production, carboxymethyl cellulose (CMC) production, acid and enzymatic hydrolysis, resin production, boiler combustion, gasification, and fast and slow pyrolysis. The intermediate products (*k*) produced from the main processing facilities *(j*) are biocomposite, CMC, glucose, xylose, bio-resin, high-pressure (HP) steam, biosyngas, bio-oil, and biochar. Biocomposite, CMC, bioresin, and biochar are the final products of the main processing facilities.

Further processing facilities 1 (*l*) consist of steam reforming, separation, xylitol production, fermentation, anaerobic digestion, power production, methanol production, bio-oil upgrading, and FTL production. Intermediate products 2 (*m*) consist of biohydrogen, biomethanol, xylitol, biogas, electricity, medium-pressure (MP) steam, low-pressure (LP) steam, biogasoline, biodiesel, and bioethanol. At this stage, the majority of the products, such as xylitol, bioethanol, biogas, electricity, MP steam, LP steam, biogasoline, and biodiesel, do not undergo further processing. Other products are further processed in further processing 2 (*n*) or the final stage, which consists of ammonia production, bioethylene production and formaldehyde production. The final products (*o*) are ammonia, bioethylene, and formaldehyde. The index (*p*) is not shown in Figure 2.2 but is used in the mathematical model. This index (*p*) indicates the sum of all products.

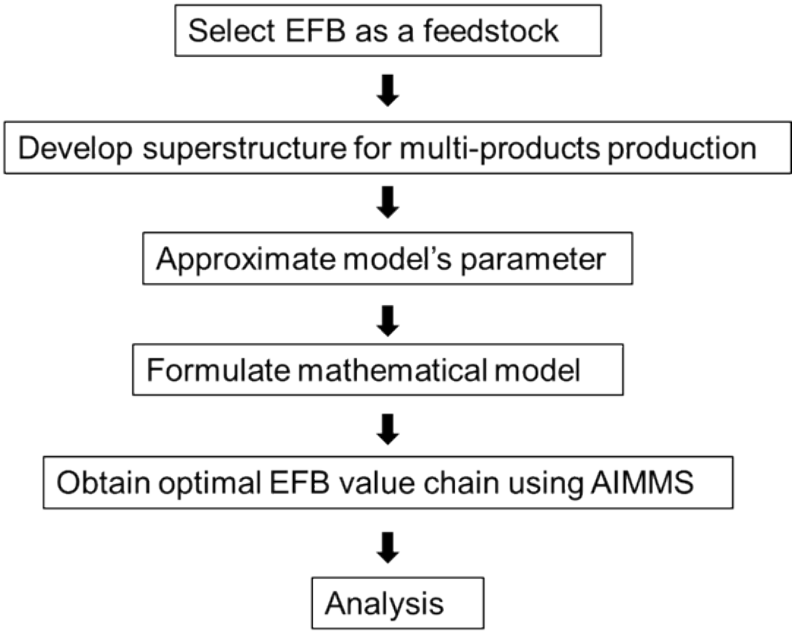


Figure 2.1 Sequential steps to optimize EFB value chain

Table 2.1 List of indices and descriptions for model formulations

Indices	Description	Contents
g	Biomass source storage	EFB collection (146 palm oil mills)
h	Preprocessing facilities	Dry long fiber (DLF) Production1, DLF Production2, DLF Production3, DLF Production4, DLF Production5, DLF Production6, DLF Production7, Pelletization Mill1, Pelletization Mill2, Pelletization Mill3, Pelletization Mill4, Pelletization Mill5, Pelletization Mill6, Pelletization Mill7, Pelletization Mill8, Torrefied Pelletization1, Torrefied Pelletization2, Torrefied Pelletization3, Torrefied Pelletization4, Torrefied Pelletization5, Torrefied Pelletization6, Torrefied Pelletization7, Aerobic Digestion1, Aerobic Digestion2, Aerobic Digestion3, Extraction Plant, Alkaline Activation (Activated Carbon) Plant, Briquetting Plant1, Briquetting Plant2
i	Preprocessed feedstock	DLF, biocompost, activated carbon, cellulose, hemicellulose, lignin, briquette, pellet, and torrefied pellet
j	Main processing facilities	Resin Production, Boiler Combustion1, Boiler Combustion2, Boiler Combustion3, Boiler Combustion4, Boiler Combustion5, Boiler Combustion6, Boiler Combustion7, Boiler Combustion8, CMC Production, Gasification 1, Gasification 2, Gasification 3, Biocomposite Production, Fast Pyrolysis, Slow Pyrolysis, Acid Hydrolysis, Enzymatic Hydrolysis
k	Intermediate product 1	Biocomposite, CMC, glucose, xylose, bioresin, HP steam, biosyngas, bio-oil, and biochar
l	Further processing 1 facilities	Power Production1, Power Production2, Power Production3, Power Production4, Power Production5, Power Production6, Power Production7, Power Production8, FTL production Anaerobic Digestion Plant, Fermentation Plant, Bio-oil upgrading, Steam reforming, Separation Plant, Methanol Production, Xylitol Production

m	Intermediate product 2	Biohydrogen, biomethanol, xylitol, biogas, electricity, MP steam, LP steam, biogasoline, biodiesel, and bioethanol
n	Further processing 2 facilities	Ammonia production, formaldehyde production, bioethylene production
o	Final products	Ammonia, formaldehyde, and bioethylene
p	Sum of all products	PEFB DLF, biocompost, activated carbon, cellulose, hemicellulose, lignin, PEFB briquette, PEFB pellet, PEFB torrefied pellet, biocomposite, CMC, glucose, xylose, bioresin, HP steam, biosyngas, bio-oil, biochar, biohydrogen, biomethanol, xylitol, biogas, electricity, MP steam, LP steam, biogasoline, biodiesel, bioethanol, ammonia, formaldehyde, and bioethylene

(Abdulrazik et al., 2017)

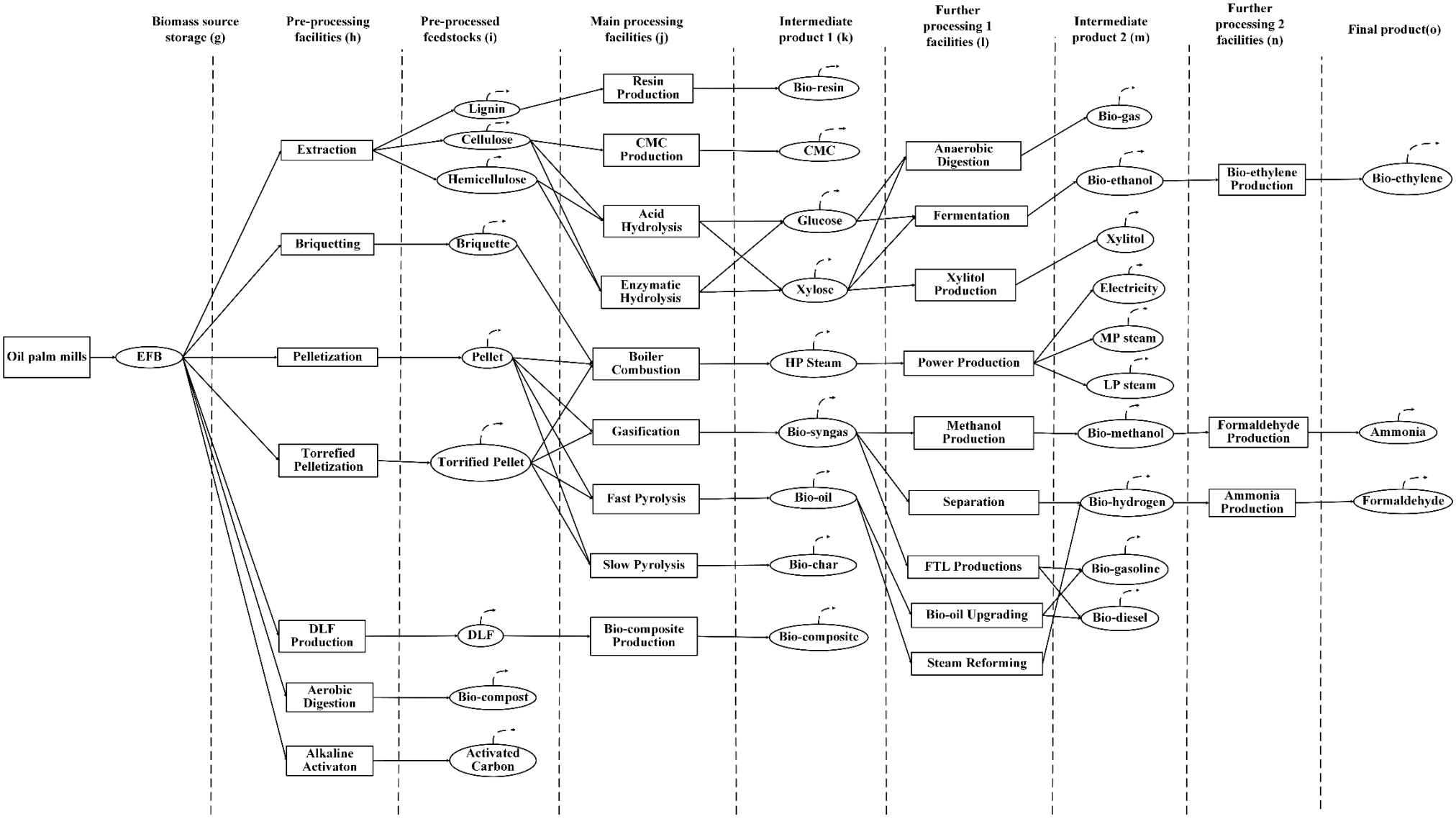


Figure 2.2 A superstructure of value chain for multi-products productions from EFB (Abdulrazik et al., 2017)

In this study, 146 out of 246 palm oil mills in Peninsular Malaysia are regarded as the EFB supply. The amount of EFB is ~23% of the amount of EFB processed according to the estimation of Trisakti et al. (2018). Figure 2.3 shows the locations of palm oil mills and processing facilities (preprocessing, main processing, further processing 1, and further processing 2) in Peninsular Malaysia. The operation status of these processing facilities is either fully operational, nearly operational, or at demonstration level. Table A.20 shows the owners of the processing facilities and their processing capacities. Processing facilities that can produce the desired products from other biomass or chemical feedstock are assumed to be able to process EFB and its derivatives due to the limited existing processing facilities that use EFB and its derivatives as feedstock. Most of the preprocessing facilities for EFB are fully operational, except for the extraction and alkaline activation plants that are still under research. The same situation applies to resin production, acid hydrolysis, enzymatic hydrolysis, gasification, fast pyrolysis, slow pyrolysis, anaerobic digestion, fermentation, xylitol production, bioethylene production, separation, methanol production, FTL production, steam reforming, bio-oil upgrading, ammonia production, and formaldehyde production. The CMC production facility is nearly operational and located at Pahang. The location of boiler combustion is similar to that of power production sites. Palm oil mills are scattered throughout Peninsular Malaysia in almost all states, except for Perlis (the northernmost region of the peninsula). The distance between any two facilities is calculated using the coordinates of the two locations.

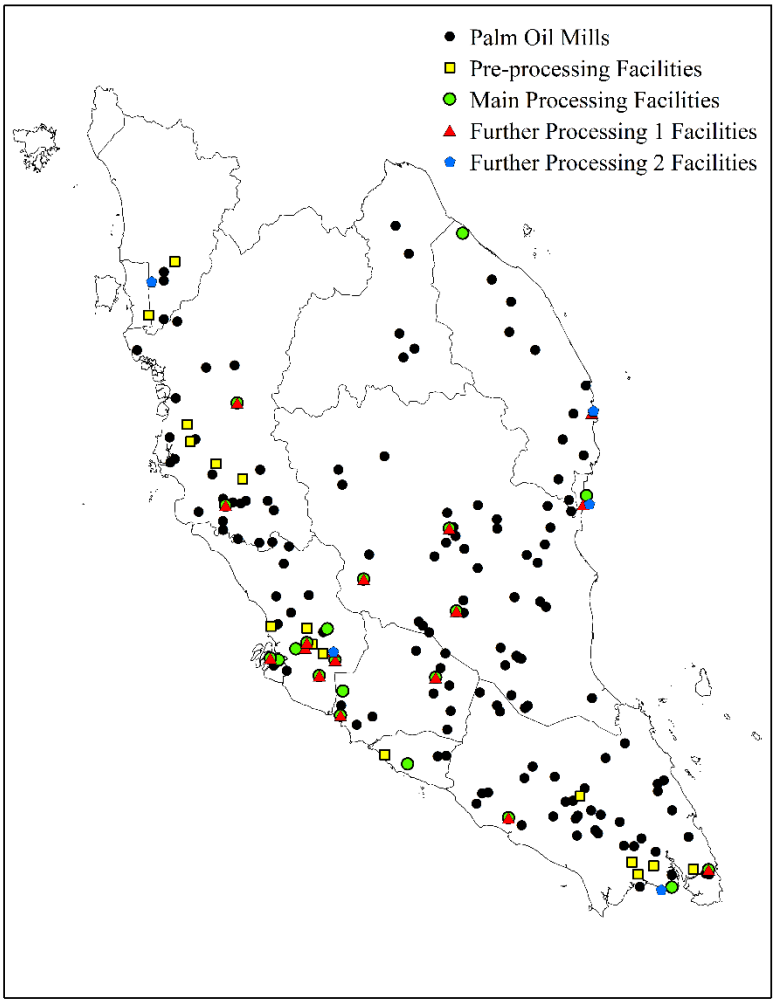


Figure 2.3 Location of palm oil mills and processing facilities in Peninsular Malaysia

Mathematical models are developed to illustrate the economic values of each process and product. The model formulations used in this study and their parameters are shown below. The descriptions of the terms used are listed in Table 2.4.

Maximize Profit=Maximize (Sales of Products − Biomass cost − Transportation cost − Production cost − Emission treatment cost from transportation − Emission treatment cost from production) (1)

The objective function of the optimized model expressed in Equation (1) is to maximize the overall profit by subtracting all associated costs from the revenues. In searching for the optimal solution, the model evaluates each processing pathway and identifies the pathway that contributes to the minimum cost and high product sales.

$$\text{Sales of product} = \sum_{p=1}^{P} \text{QS}_\text{p} \times \text{Selling price} \quad (2)$$

The selling price is used to determine the revenue of the products, as shown in Equation (2). The product selling prices are listed in Table A.1 in the Appendix. The sum of all sold products, QS_p, is multiplied with their selling price to obtain the total product sales.

$$Biomass\ cost = \sum_{g}^{G} FTB_{g,h} \times \text{EFB Cost} \quad (3)$$

The EFB biomass unit cost is assumed to be USD 6 per ton in this model and is multiplied with the biomass transported, $FTB_{g,h}$, to determine the total biomass cost, as shown in Equation (3).

$$Transportation\ cost = \left(\sum_{g}^{G}\sum_{h}^{H} FTB_{g,h} \times \text{TFB}_{\text{g,h}}\right) + \left(\sum_{h}^{H}\sum_{i}^{I}\sum_{j}^{J} FTI_{h,i,j} \times \text{TFI}_{\text{h,i,j}}\right) + \left(\sum_{j}^{J}\sum_{k}^{K}\sum_{l}^{L} FTK_{j,k,l} \times \text{TFK}_{\text{j,k,l}}\right) + \left(\sum_{j}^{J}\sum_{m}^{M}\sum_{n}^{N} FTM_{l,m,n} \times \text{TFM}_{\text{l,m,n}}\right) \quad (4)$$

The transportation cost in Equation (4) is expressed in USD per ton, and the mass flow rate is multiplied with the transportation cost factor to determine the transportation cost. $FTB_{g,h}$ is the amount of biomass in ton per year transported from the resource location (g) to preprocessing facilities (h). $\text{TFB}_{\text{g,h}}$ is the transportation cost factor for the biomass transported in USD per ton. $FTI_{h,i,j}$ is the amount of preprocessed feedstock (i) transported from preprocessing facilities (h) to the main processing facilities (j), in ton per year. $\text{TFI}_{\text{h,i,j}}$ is the transportation cost factor for preprocessed feedstock transported in USD per ton. $FTK_{j,k,l}$ is the amount of intermediate products 1 (k) transported from main processing facilities (j) to further processing 1 facilities (l), in ton per year. $\text{TFK}_{\text{j,k,l}}$ is the transportation cost factor for intermediate product 1 transported in USD per ton. $FTM_{l,m,n}$ is the amount of intermediate products 2 transported (m) from further processing 1 facilities (l) to further processing 2 facilities (n) in ton per year. $\text{TFM}_{\text{l,m,n}}$ is the transportation cost factor for intermediate product 2 transported in USD per ton. The transportation cost factor is calculated as follows:

$$\text{TFB}_{\text{g,h}} = C_1 + C_2 * L \qquad \forall_{\text{g,h}} \quad (5)$$

$$\text{TFI}_{\text{h,i,j}} = C_1 + C_2 * L \qquad \forall_{\text{h,i,j}} \quad (6)$$

$$\text{TFK}_{\text{j,k,l}} = C_1 + C_2 * L \qquad \forall_{\text{j,k,l}} \quad (7)$$

$$\text{TFM}_{\text{l,m,n}} = C_1 + C_2 * L \qquad \forall_{\text{l,m,n}} \quad (8)$$

Where

C_1 = fixed cost constant
C_2 = variable cost constant
L = distance (km)

Table 2.2 Transportation model constants of different modes for biomass

Mode	C1	C2	Reference
Truck	6.84	0.1641	(Oo et al., 2012)
Train	20.52	0.0333	(Oo et al., 2012)
Pipeline	0.116	0.089	(Marufuzzaman et al., 2015)

The transportation cost factors calculated in Equations (5) to (8) use the method proposed by Abdulrazik et al. (2017), who previously referred to Oo et al. (2012), Mckinnon (2007) and Marufuzzaman et al. (2015). The transportation costs consist of two constants, namely, fixed cost (C1) and variable cost (C2). Abdul Razik (2016) reported that the fixed cost constant includes the capital cost, and the variable cost constant includes the operating cost. Transportation cost constants C_1 and C_2 are listed in Table 2.2.

$$Emission\ treatment\ cost\ transportation = \left[\left(\sum_g^G\sum_h^H ETB_{g,h}\right) + \left(\sum_h^H\sum_i^I\sum_j^J ETI_{h,i,j}\right) + \left(\sum_j^J\sum_k^K\sum_l^L ETK_{j,k,l}\right) + \left(\sum_l^L\sum_m^M\sum_n^N ETM_{l,m,n}\right)\right] \times \text{Emission treatment cost per ton } CO_2\text{eq} \quad (9)$$

The total cost of emission treatment in transportation is obtained by multiplying the amount of emission from transportation with cost of emission treatment. The cost of emission treatment in transportation is fixed at USD 40 per ton of CO_2 (Abdulrazik et al., 2017). $ETB_{g,h}$ is the amount of emission from biomass transported from resource locations (g) to preprocessing facilities (h) in ton CO_2eq per year. $ETI_{h,i,j}$ is the amount of emission of preprocessed feedstock (i) transported from preprocessing facilities (h) to the main processing facilities (j) in ton CO_2eq per year. $ETK_{j,k,l}$ is the amount of emission of intermediate products 1 (k) transported from main processing facilities (j) to further processing 1 facilities (l) in ton CO_2eq per year. $ETM_{l,m,n}$ is the amount of emission of intermediate products 2 (m) transported from further processing 1 facilities (l) to further processing 2 facilities (n) in ton CO_2eq per year.

$$ETB_{g,h} = FTB_{g,h} \times \text{ETFB}_{\text{g,h}} \qquad \forall_{\text{g,h}} \qquad (10)$$

$$ETI_{h,i,j} = FTI_{h,i,j} \times \text{ETFI}_{\text{h,i,j}} \qquad \forall_{\text{h,i,j}} \qquad (11)$$

$$ETK_{j,k,l} = FTK_{j,k,l} \times \text{ETFK}_{\text{j,k,l}} \qquad \forall_{\text{j,k,l}} \qquad (12)$$

$$ETM_{l,m,n} = FTM_{l,m,n} \times \text{ETFM}_{\text{l,m,n}} \qquad \forall_{\text{l,m,n}} \qquad (13)$$

Table 2.3 Emission factors

Mode	ton CO_2eq b/km
Truck	6.2×10^{-5}
Train	2.2×10^{-5}

(McKinnon, 2007)

The amount of emission from transportation shown in Equations (10) to (13) is obtained by multiplying the mass flow rate of biomass and products transported with the transportation CO_2 emission factors. $ETFB_{g,h}$ is the transportation CO_2 emission factor of biomass transported from resource locations (*g*) to preprocessing facilities (*h*) in ton CO_2eq per year. $ETFI_{h,i,j}$ is the transportation CO_2 emission factors of preprocessed feedstock (*i*) transported from preprocessing facilities (*h*) to the main processing facilities (*j*) in ton CO_2eq per year . $ETFK_{j,k,l}$ is the transportation CO_2 emission factors of intermediate products 1 (*k*) transported from the main processing facilities (*j*) to further processing 1 facilities (*l*) in ton CO_2eq per year. $ETFM_{l,m,n}$ is the transportation CO_2 emission factors of intermediate products 2 (*m*) transported from further processing 1 facilities (*l*) to further processing 2 facilities (*n*) in ton CO_2eq per year. The transportation CO_2 emission factors are calculated by multiplying the distance traveled between facilities with the emission factors indicated in Table 2.3. In this study, the transportation modes of solid and liquid products are defined on the basis of transportation distance as follows: trucks for distances up to 100 km and trains for distances exceeding 100 km. Pipeline transportation is selected only for gaseous products. Zero CO_2 emission is generated for pipeline transportation and for the processing facilities in the same location. The results for transportation cost factor and transportation CO_2 emissions are tabulated in Tables A.3 to A.13 in the Appendix.

$$Production\ cost = \left(\sum_h^H \sum_i^I FPI_{h,i} \times \mathrm{PFI_{h,i}}\right) + \left(\sum_i^I \sum_j^J \sum_k^K FPK_{i,j,k} \times \mathrm{PFK_{i,j,k}}\right) + \left(\sum_k^K \sum_l^L \sum_m^M FPM_{k,l,m} \times \mathrm{PFM_{k,l,m}}\right) + \left(\sum_m^M \sum_n^N \sum_o^O FPO_{m,n,o} \times \mathrm{PFO_{m,n,o}}\right) \quad (14)$$

The production cost in Equation (14) is the cost to produce a unit capacity of the product. Abdul Razik (2016) reported that the production cost comprises capital and operating costs for the equipment. The production cost factor is multiplied with the mass flow rate to determine the production cost. $FPI_{h,i}$ is the amount of preprocessed feedstock (*i*) through preprocessing facilities (*h*) in ton per year. $PFI_{h,i}$ is the production cost factor of preprocessed feedstock (*i*) in USD per ton. $FPK_{i,j,k}$ is the amount of intermediate products 1 (*k*) produced from preprocessed feedstock (*i*) through the main processing facilities (*j*) in ton per year. $PFK_{i,j,k}$ is the production cost factor of intermediate products 1 (*k*) in USD per ton. $FPM_{k,l,m}$ is the amount of intermediate products 2 (*m*) produced from intermediate products 1 (*k*) through further processing 1 facilities (*l*) in ton or MWh per year. $PFM_{k,l,m}$ is the production cost factor of intermediate products 2 (*m*) in USD per ton or per MWh. $FPO_{m,n,o}$ is the amount of final products (*o*) produced from intermediate products 2 (*m*) through further processing 2 facilities (*n*) in ton per year. $PFO_{m,n,o}$ is the production cost factor of final products (*o*) in USD per ton.

$$Emission\ treatment\ cost\ production = \left[\left(\sum_h^H \sum_i^I EPI_{h,i}\right) + \left(\sum_i^I \sum_j^J \sum_k^K EPK_{i,j,k}\right) + \left(\sum_k^K \sum_l^L \sum_m^M EPM_{k,l.m}\right) + \left(\sum_m^M \sum_n^N \sum_o^O EPO_{m,n,o}\right)\right] \times \text{Emission treatment cost per ton } CO_2\text{eq} \quad (15)$$

The total cost of emission treatment production in Equation (15) is obtained by multiplying the amount of emission from transportation with the cost for emission treatment. Similarly, the cost for emission treatment for production is fixed at USD 40 per ton of CO_2 (Abdulrazik et al., 2017). $EPH_{h,i}$ is the amount of emission of preprocessed feedstock (*i*) produced at preprocessing facilities (*h*) in ton CO_2eq per year. $EPJ_{i,j,k}$ is the amount of emission of intermediate products 1 (*k*) produced at main processing facilities (*j*) in ton CO_2eq per year. $EPL_{k,l.m}$ is the amount of emission of intermediate products 2 (*m*) produced at further processing 1 facilities (*l*) in ton CO_2 equivalent per year. $EPN_{m,n,o}$ is the amount of emission of final products (*o*) produced at further processing 2 facilities (*n*) in ton CO_2eq per year.

$$EPI_{g,h} = FPI_{h,i} \times \mathrm{EPFI_{h,i}} \quad \forall_{h,i} \quad (16)$$

$$EPK_{i,j,k} = FPK_{i,j,k} \times \mathrm{EPFK_{i,j,k}} \quad \forall_{i,j,k} \quad (17)$$

$$EPM_{k,l,m} = FPM_{k,l,m} \times \mathrm{EPFM_{k,l,m}} \quad \forall_{k,l,m} \quad (18)$$

$$EPO_{m,n,o} = FPO_{m,n,o} \times \mathrm{EPFO_{m,n,o}} \quad \forall_{m,n,o} \quad (19)$$

The amount of emissions from production shown in Equations (16) to (19) is obtained by multiplying the mass flow rate of biomass and products produced with the production CO_2 emission factors. $\mathrm{EPFI_{h,i}}$ is the production CO_2 emission factors of preprocessed feedstock (i) produced at preprocessing facilities (h) in ton CO_2eq per year. $\mathrm{EPFK_{i,j,k}}$ is the production CO_2 emission factors of intermediate products 1 (k) produced at main processing facilities (j) in ton CO_2eq per year. $\mathrm{EPFM_{k,l,m}}$ is the production CO_2 emission factors of intermediate products 2 (m) produced at further processing 1 facilities (l) in ton CO_2eq per year. $\mathrm{EPFO_{m,n,o}}$ is the production CO_2 emission factors of final products (o) produced at further processing 2 facilities (n) ton CO_2eq per year. The production cost and production CO_2 emission factors are presented in Tables A.14 to A.17 in the Appendix.

$$\sum_g^G FTB_{g,h} \leq \text{Biomass Availability} \quad \forall_g \quad (20)$$

$$Product\ or\ Biomass\ Transport \leq \text{Processing Facilities Capacities} \quad \forall_p \quad (21)$$

$$\text{Five percent of World Demand} \geq QP_p \geq \text{Product Demand} \quad \forall_p \quad (22)$$

Constraints are added to the model, as indicated in Equations (20) to (22), to find the optimal profit based on the parameters used. The constraints are set based on several criteria to establish the boundaries of the models. The total amount of EFB transported from the respective locations must not exceed the total availability of EFB in the palm oil mills. Furthermore, the amount of EFB and products transported to the processing facilities should not exceed the capacity of the processing facilities. The production amount of each product, QP_p, must be in the range of minimum product demand and maximum 5% of the world demand. These requirements should be met to fulfil customer demands. The required parameters are shown in Tables A.18 to A.20 in the Appendix.

The mass balance equations are presented by Equations (23) to (24). The conversion factors (CONV) are defined as the ratio of the outlet mass flow rate to the inlet mass flow rate of each processing facility, and they are used to estimate the amount of products produced from each processing facility. Electricity generation (in MWh) is estimated solely from the mass of inlet steam with a conversion factor of 0.3 MWh/ton of steam.

$$\sum_g^G FTB_{g,h} \times \mathrm{CONVI_{h,i}} = FPI_{h,i} \quad \forall_{h,i} \quad (23)$$

As shown in Equation (23), the summation amount of biomass transported ($FTB_{g,h}$) is multiplied with the conversion factor of preprocessed feedstock ($\mathrm{CONVI_{h,i}}$) to obtain the amount of preprocessed feedstock (i) produced ($FPI_{h,i}$).

$$\sum_h^H FPI_{h,i} = FSI_{h,i} + \sum_j^J FTI_{h,i,j} \qquad \forall_{h,i} \qquad (24)$$

Equation (24) shows that the summation amount of preprocessed feedstock (i) produced ($FPI_{h,i}$) is the addition of the summation amount of preprocessed feedstock (i) transported for further processing ($FTI_{h,i,j}$) and the portions to be sold ($FSI_{h,i}$).

$$\sum_h^H FTI_{h,i,j} \times \mathrm{CONVK_{i,j,k}} = FPK_{i,j,k} \qquad \forall_{i,j,k} \qquad (25)$$

As shown in Equation (25), the summation amount of preprocessed feedstock (i) transported ($FTI_{h,i,j}$) is multiplied with the conversion factor of intermediate products 1 ($\mathrm{CONVK_{i,j,k}}$) to obtain the amount of intermediate products 1 (k) produced ($FPK_{i,j,k}$).

$$\sum_i^I FPK_{i,j,k} = FSK_{j,k} + \sum_l^L FTK_{j,k,l} \qquad \forall_{j,k} \qquad (26)$$

Equation (26) shows the summation of the amount of intermediate products 1 (k) transported ($FTK_{j,k,l}$) for further processing and the portions to be sold ($FSK_{j,k}$) are equal to the amount of intermediate products 1 (k) produced ($FPK_{i,j,k}$).

$$\sum_j^J FTK_{j,k,l} \times \mathrm{CONVM_{k,l.m}} = FPM_{k,l,m} \qquad \forall_{k,l,m} \qquad (27)$$

As shown in Equation (27), the amount of intermediate products 1 (k) transported ($FTK_{j,k,l}$) is multiplied with the conversion factor of intermediate products 2 ($\mathrm{CONVM_{k,l.m}}$) to obtain the amount of intermediate products 2 (m) produced ($FPM_{k,l,m}$).

$$\sum_k^K FPM_{k,l,m} = FSM_{l,m} + \sum_n^N FTM_{l,m,n} \qquad \forall_{l,m} \qquad (28)$$

Equation (28) shows the summation of the amount of intermediate products 2 (m) transported ($FTM_{l,m,n}$) for further processing and the portions to be sold ($FSM_{l,m}$) are equal to the amount of intermediate products 2 (m) produced ($FPM_{k,l,m}$).

$$\sum_l^L FTM_{l,m,n} \times \mathrm{CONVO_{m,n,o}} = FPO_{m,n,o} \qquad \forall_{m,n,o} \qquad (29)$$

As shown in Equation (29), the amount of intermediate products 2 (m) transported ($FTM_{l,m,n}$) is multiplied with the conversion factor of final products ($\mathrm{CONVO_{m,n,o}}$) to obtain the amount of final products (o) produced, ($FPO_{m,n,o}$).

$$\sum_m^M FPO_{m,n,o} = FSO_{n,o} \qquad \forall_{n,o} \qquad (30)$$

Equation (30) shows that the amount of final products (o) produced ($FPO_{m,n,o}$), is equal to the amount of final products (o) to be sold directly ($FSO_{n,o}$).

$$\sum_h^H FSI_{h,i} + \sum_j^J FSK_{j,k} + \sum_l^L FSM_{l,m} + \sum_n^N FSO_{n,o} = QS_p \qquad \forall_{i,k,m,o} \qquad (31)$$

Equation (31) describes the total of sold products, (QS_p). The product conversion factors required are listed in Tables A.14 to A.17 in the Appendix.

Table 2.4 Descriptions of terms used in Equations (1) to (31)

Term	Category	Description
$TFB_{g,h}$	Parameter	Transportation cost factor for biomass feedstock from *g* to *h* in USD per ton
$TFI_{h,i,j}$	Parameter	Transportation cost factor for pre-processed feedstock from *h* to *j* through *i* in USD per ton
$TFK_{j,k,l}$	Parameter	Transportation cost factor for intermediate product 1 from *j* to *l* through *k* in USD per ton
$TFM_{l,m,n}$	Parameter	Transportation cost factor for intermediate product 2 from *l* to *n* through *m* in USD per ton
$ETFB_{g,h}$	Parameter	CO_2 emission factor for EFB feedstock transported from *g* to *h*
$ETFI_{h,i,j}$	Parameter	CO_2 emission factor for pre-processed feedstock transported from *h* to *j*
$ETFK_{j,k,l}$	Parameter	CO_2 emission factor for intermediate product 1 transported from *j* to *l*
$ETFM_{l,m,n}$	Parameter	CO_2 emission factor for intermediate product 2 transported from *l* to *n*
$PFI_{h,i}$	Parameter	Production cost factor at *h* to produce *i* from *g* in USD per ton
$PFK_{i,j,k}$	Parameter	Production cost factor at *j* to produce *k* from *i* in USD per ton
$PFM_{k,l,m}$	Parameter	Production cost factor at *l* to produce *m* from *k* in USD per ton or per MWh
$PFO_{m,n,o}$	Parameter	Production cost factor at *n* to produce *o* from *m* in USD per ton
$EPFI_{h,i}$	Parameter	CO_2 emission factor at production *h*
$EPFK_{i,j,k}$	Parameter	CO_2 emission factor at production *j*
$EPFM_{k,l,m}$	Parameter	CO_2 emission factor at production *l*
$EPFO_{m,n,o}$	Parameter	CO_2 emission factor at production *n*
$CONVI_{h,i}$	Parameter	Conversion factor at *h* to produce *i*
$CONVK_{i,j,k}$	Parameter	Conversion factor at *j* to produce *k* from *i*
$CONVM_{k,l.m}$	Parameter	Conversion factor at *l* to produce *m* from *k*
$CONVO_{m,n,o}$	Parameter	Conversion factor at *n* to produce *o* from *m*
QP_p	Decision variable	Sum of products produced from each of product storage in ton or MWh per year
QS_p	Decision variable	Sum of products sold from each of product storage in ton or MWh per year
$FTB_{g,h}$	Decision variable	Amount of biomass transported to pre-processing facilities *h* in ton per year
$ETB_{g,h}$	Decision variable	Amount of emission from transportation between *g* and *h* in ton CO_2eq per year
$FPI_{h,i}$	Decision variable	Amount of preprocessed feedstock *i* produced from biomass feedstock *g* through pre-processing facilities *h* in ton per year
$EPI_{h,i}$	Decision variable	Amount of emission from production at *h* in ton CO_2eq per year
$FTI_{h,i,j}$	Decision variable	Amount of preprocessed feedstock *i* transported from preprocessing facilities *h* to main processing facilities *j* in ton per year
$ETI_{h,i,j}$	Decision variable	Amount of emission from transportation between *h* and *j* in ton CO_2eq per year
$FSI_{h,i}$	Decision variable	Amount of preprocessed feedstock *i* produced from preprocessing facilities *h* to be sold directly in ton per year
$FPK_{i,j,k}$	Decision variable	Amount of intermediate product 1 *k* produced from preprocessed feedstock *i* through main processing facilities *j* in ton per year
$EPK_{i,j,k}$	Decision variable	Amount of emission from production at *j* in ton CO_2eq per year
$FTK_{j,k,l}$	Decision variable	Amount of intermediate products 1 *k* transported from main processing facilities *j* to further processing 1 facilities *l* in ton per year

$ETK_{j,k,l}$	Decision variable	Amount of emission from transportation between *j* and *l* ton CO_2eq per year
$FSK_{j,k}$	Decision variable	Amount of intermediate products 1 *k* produced from main processing facilities *j* to be sold directly in ton per year
$FPM_{k,l,m}$	Decision variable	Amount of intermediate products 2 *m* produced from intermediate products 1 *k* through further processing 1 facilities *l* in ton or MWh per year
$EPM_{k,l.m}$	Decision variable	Amount of emission from production at *l* in ton CO_2eq per year
$FTM_{l,m,n}$	Decision variable	Amount of intermediate products 2 *m* transported from further processing 1 facilities *l* to further processing 2 facilities *n* in ton per year
$ETM_{l,m,n}$	Decision variable	Amount of emission from transportation between *l* and *n* in ton CO_2eq per year
$FSM_{l,m}$	Decision variable	Amount of intermediate products 2 *m* produced from intermediate products 1 *k* through further processing 1 facilities *l* to be sold directly in ton per year
$FPO_{m,n,o}$	Decision variable	Amount of final products *o* produced from intermediate products 2 *m* through further processing 2 facilities *n* in ton per year
$EPO_{m,n,o}$	Decision variable	Amount of emission from production at *n* in ton CO_2eq per year
$FSO_{n,o}$	Decision variable	Amount of final products *o* produced from intermediate products 2 *m* through further processing 2 facilities *n* to be sold in ton per year

2.1 Case Study

In this case study, 146 palm oil mills in Peninsular Malaysia are selected as EFB suppliers. Multiple products can be produced through processing facilities based on the availability of EFB in Peninsular Malaysia. The processing technologies in this study have their corresponding processing capacities that need to be considered. Capacity limitation is important to ensure that feedstock supply to the processing facilities does not exceed the production capacity. In Malaysia, palm oil is commonly used as feedstock for biodiesel production because Malaysia is one of the largest producers of palm oil worldwide. The price fluctuation trend of palm oil makes the production of biodiesel from palm oil infeasible. The high cost of feedstock reduces the net profit of production (Anuar and Abdullah, 2016). In this study, the production of bio-diesel from EFB is highlighted. EFB is a cheap raw material used for biodiesel production, but its low oil content makes it unsuitable for producing high yields of biodiesel when the same method is used with palm oil. EFB is utilized for biodiesel production in this study via gasification and FTL. Biosyngas is produced by gasification and further processing in FTL to generate biodiesel. Subsequent analysis of biodiesel production is conducted in this study. Four case study scenarios are generated to analyze the EFB value chain in Peninsular Malaysia and biodiesel production. The outputs of the model for each scenario, such as profit and cost, distribution and production of EFB, and products and interactions in the environment–food–energy nexus, are discussed. Each scenario is described below.

Case A: This case is the baseline scenario from the proposed EFB value chain model (Equations (1) to (31)), where the objective function is to maximize the profit in relation to the demand satisfaction of all products.

Case B: This scenario is based on the maximum production of biodiesel in relation to the demand satisfaction of all products.

Case C: The objective function of this case is to maximize the profit with a fixed amount of biodiesel as in Case B. The amount of biodiesel produced in Case B is assumed to be the maximum yield required. The demands of all products in this scenario also need to be met.

Case D: This case is the baseline scenario similar to Case A but with the addition of transesterification facilities with crude palm oil (CPO) and biomethanol as feedstock for biodiesel production. The amount of available CPO in oil palm mills assumed to be 25% from every fresh fruit bunch (FFB) processed (Taqwa and Purwanto, 2019). The process superstructure is shown in Figure 2.4. The number of transesterification and anaerobic digestion facilities in this case is 14. The facilities are assumed to be in the same location. The feedstock ratio (methanol:oil) is 6:1 (Ali and Tay, 2013). The ratio will be the deciding factor of the amount of CPO required in the process. The cost of CPO is estimated at USD $594/tonne (MPOB, 2019). Glycerol as a by-product is

also produced and treated as feedstock to anaerobic digestion for bioethanol production. The data used in this case are shown in Tables A.21 to A.29 in the Appendix.

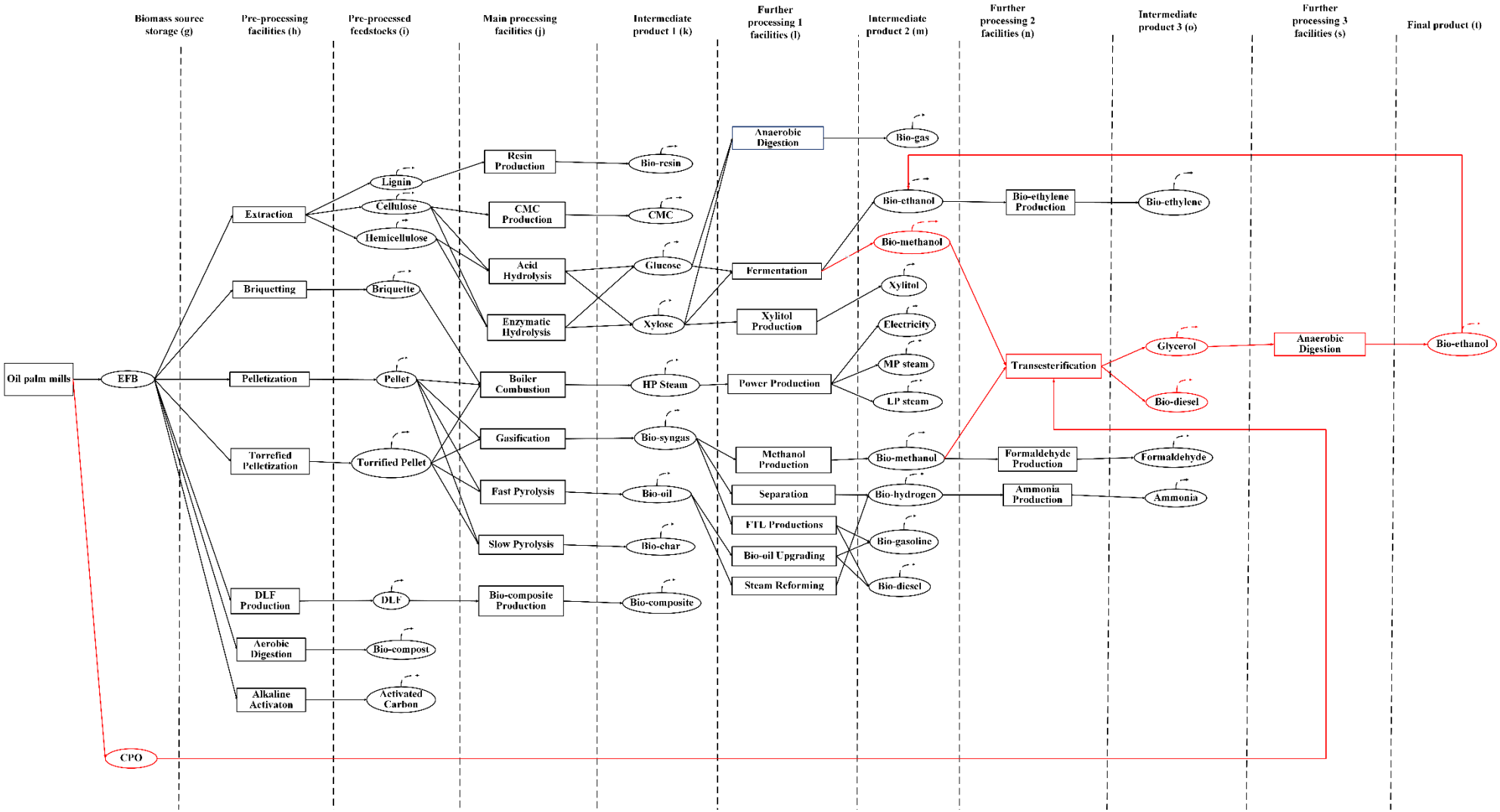


Figure 2.4 Process superstructure for Case D

3.0 RESULTS AND DISCUSSION

3.1 Profit and cost assessment

As shown in the case studies, the developed model demonstrates the significant economic benefits of EFB utilization. Among all the case studies shown in Figure 3.1, the most profitable cases of EFB utilization are A, C, and D, all of which have 47% profit margin, followed by Case B with 17% profit margin. The maximum profit of the selected utilization pathways in Case A is USD 151,822,904 per year based on the multi ownership of all EFB processed. This value is 79% lower than the results of Abdulrazik et al. (2017) because they did not consider the capacity limitations of the respective processing facilities. The drastic reduction in the profit of Case B is due to the reduction of other products to increase the biodiesel yield. This condition results in a decrement of the overall sales of the products. Cases C and D are the alternative means to recover the profit with maximum biodiesel yield. Both cases show that high profit can still be achieved with the maximum biodiesel required in Case B.

Figure 3.2 shows the total costs generated in the EFB value chains. Notably, these are the least possible costs generated from the process. The production cost is the highest cost generated. The production cost of products need to be considered because the demand of each product has to be met. The production costs of EFB in all cases and of CPO in Case D are excluded in this study, but their feedstock costs, transportation costs, and transportation emission treatment costs are considered because EFB and CPO are collected from the mills. Case D has the highest total cost of USD 174,308,697 per year. The addition of CPO as feedstock and the addition of transesterification and anaerobic digestion plant to the process with the process loop contribute to the small increment of the overall cost in Case D. The fluctuation of CPO price in Malaysia is a major issue in biodiesel production using CPO. The growth of the biodiesel industry has increased the demand for CPO as a feedstock (Anuar and Abdullah, 2016; Kushairi et al., 2018). Alternative feedstock with low costs, such as waste cooking oil, can be used to reduce the overall costs and increase the profit margin. Low-cost feedstock could be the key for sustainable biodiesel production (Farhan Mirus et al., 2019). In this study, the variation of feedstock cost exerts a small impact on the profit margin. The amount of biodiesel produced increases with the reduction of the CPO cost. A slight increment in profit margin occurs because of the overall production cost.

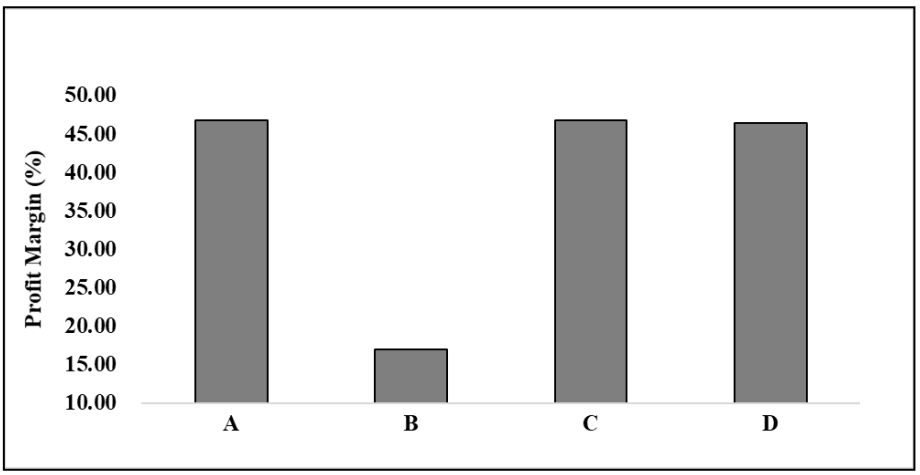


Figure 3.1 Profit margin of each case

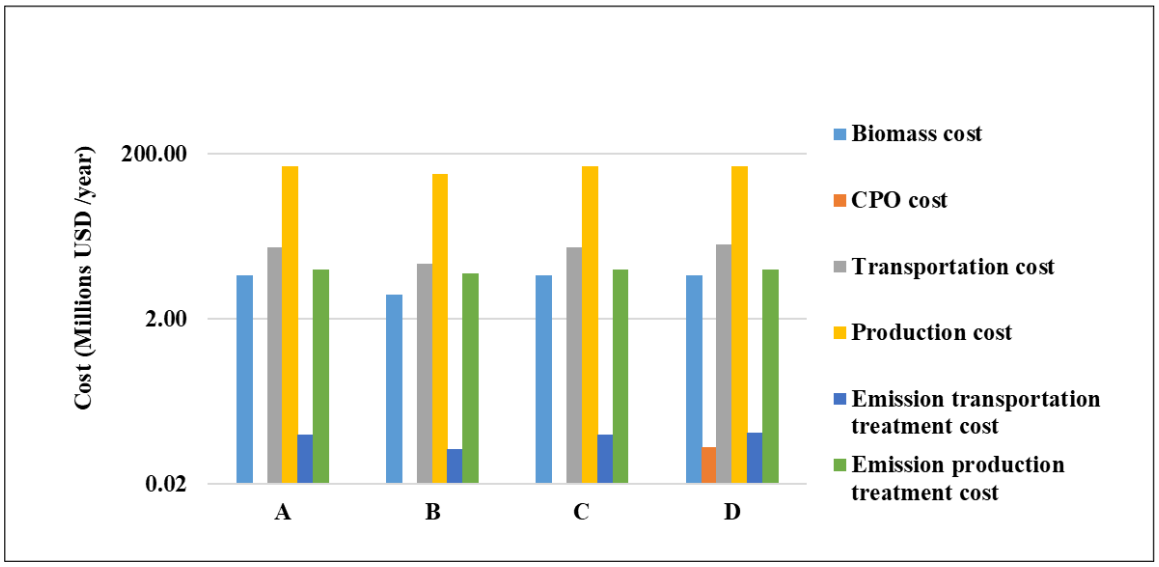


Figure 3.2 Total cost of each cases

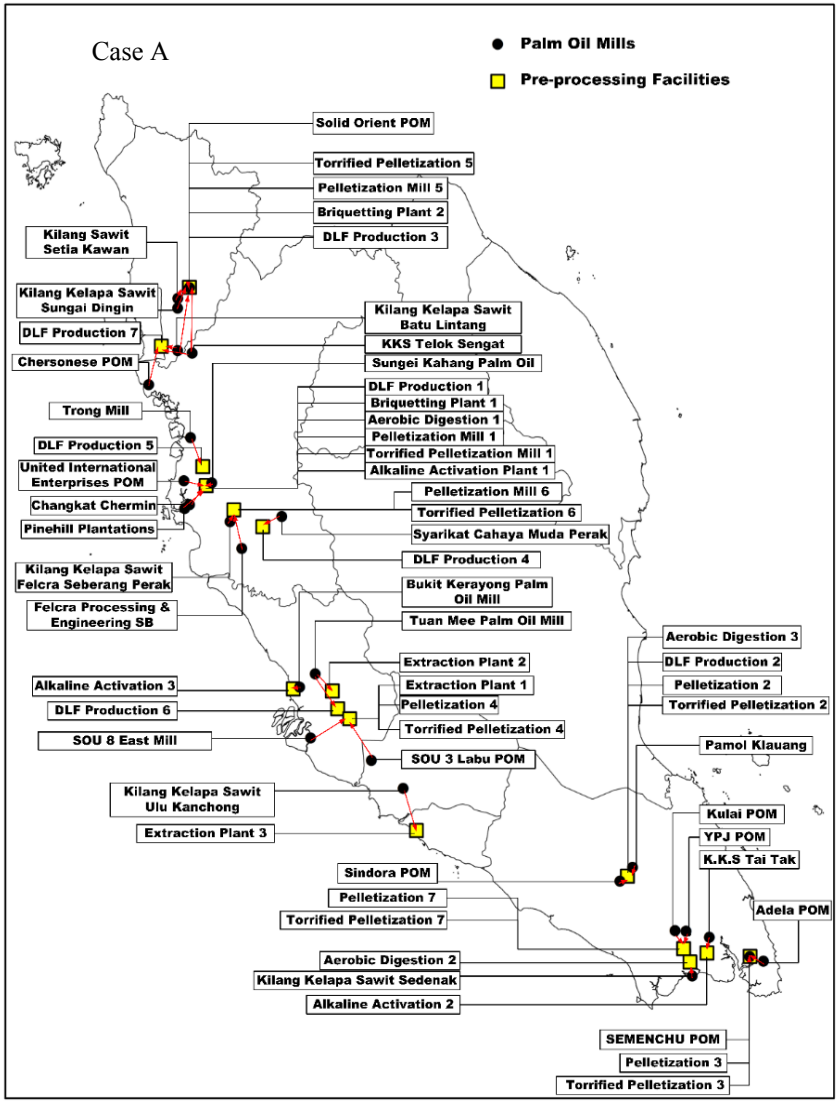
3.2 Distribution and production of EFB and products

The EFB distribution and optimal process superstructure of all cases are shown in Figures 3.3 and 3.5, respectively. The red line indicates the transportation of EFB or products. The blue line indicates the products produced in the respective processing facilities without further processing. The red and blue dashed lines indicate the products sold. The black dashed line indicates that no transportation of EFB or products to the respective processing facilities. The EFB distributions in Cases A, C, and D have the same EFB suppliers, which are from nearby 27 palm oil mills with the same total EFB feed flow rate of 1,123,741 ton/year. However, all of these cases have a different EFB distribution because the preprocessing facilities in each case require different amounts of EFB depending on the objective of the model. For Case B, only 15 nearest palm oil mills are selected to supply EFB because the process focuses on maximizing biodiesel production, and these mills are sufficient to supply EFB. By considering the availability of EFB and the processing capacities of the facilities, EFB can be transported as much as possible to increase the amount of preprocessed products, which in turn could increase the total sales. However, the distances and amount of EFB transported should be considered because they increase the transportation cost and transportation CO_2 emissions. In this case, each palm oil mill cannot avoid the transportation costs and transportation CO_2 emissions because the preprocessing facilities are located outside the palm oil mills. These findings can help the owners of preprocessing facilities determine which EFB supplier has the minimum transportation costs and transportation CO_2 emissions.

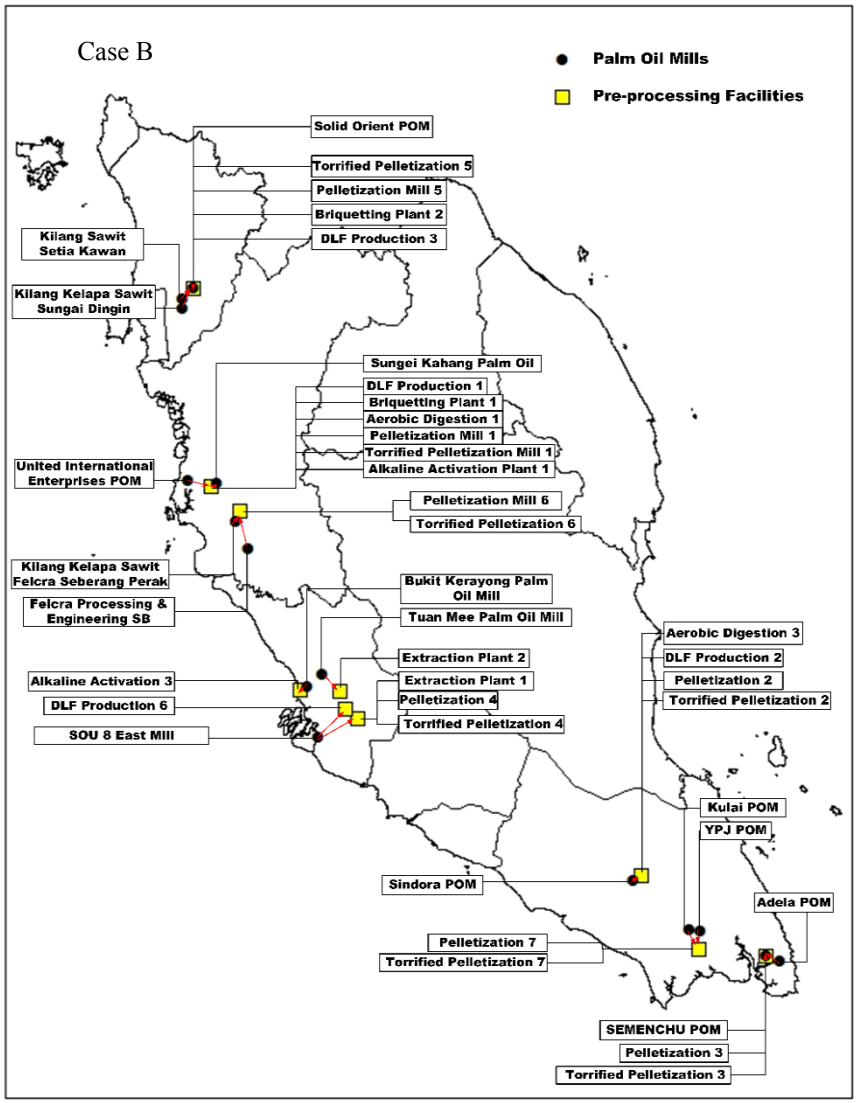
In Peninsular Malaysia, only 20% of millers are involved in the conversion of EFB into value-added products; other millers return EFB for mulching (Abas et al., 2011). Mulching of EFB for fertilizers in plantation estates is the only mean of utilization of EFB. It is a good practice and would ensure that all EFB is managed in such a way that zero waste is achieved (Liew et al., 2017). The developed model demonstrates the significant economic benefits of EFB utilization, alternative means that can be employed to utilize EFB other than mulching. The case studies clearly show that not all EFB from the 146 palm oil mills can be utilized because of the biomass cost factor and capacity limitations of existing preprocessing facilities. The capacity limitation of processing facilities makes it difficult to utilize all of the remaining EFB in palm oil mills. Installation of processing facilities near the palm oil mills could be a solution. However, this approach could increase production costs (Krishnan et al., 2017). Although only small amounts of EFB are utilized for the processing facilities, EFB can still be used as feedstock for the production of multiple products. Therefore, this study could help encourage millers around Peninsular Malaysia to participate in biomass activities for environmental and financial benefits (Umar et al., 2013) and for policy makers to improve the EFB utilization by planning of additional and future expansion of biomass processing facilities.

Figure 3.4 shows the optimal production level of all cases. For all cases, biosyngas dominates the total production of EFB utilization. Biosyngas is an important product for producing other products, such as biomethanol, biohydrogen, biogasoline, biodiesel, formaldehyde, and ammonia. Therefore, biosyngas is produced in high amounts compared with other products to meet the demand for other products. Biosyngas is the highest product produced in all cases, and biodiesel has the highest sales in all cases because biodiesel is sold as an end product without further processing. Figures 3.5 (b) and 3.5 (c) show the process superstructure of Cases B and C with the maximum biodiesel yield. The green line indicates the pathways of biodiesel production. The supply of preprocessed feedstock, such as pellet and torrified pellet, is the main factor for biodiesel production. No pellet and torrified pellet are sold, and all of them undergo further processing. In this case, all pelletization and torrified pelletization mill suppliers are selected to maximize the biodiesel yield. Judging from these results, large-scale EFB pelletization and torrified pelletization plants in Malaysia are vital in maximizing the production of biodiesel and other products. Furthermore, exporting pellets and torrified pellets to central Europe and Asian markets would add economic value while minimizing the unutilized EFB (Umar et al., 2018). A small increment in biodiesel yield can be seen in these cases compared with the biodiesel in Case A because of the capacity limitation of the associated processing facilities and the total cost consideration.The addition of transesterification and CPO as feedstock in Case D is expected to increase the biodiesel yield with the objective function of maximizing the profit. However, only a 0.09% increment in biodiesel from Case C can be achieved. As shown in Figure 3.5, only one transesterification facility is considered. More biodiesel could be obtained if all transesterification facilities are considered. However, given that the cost associated with biodiesel production could increase the overall cost, one facility is sufficient to achieve a high profit margin.

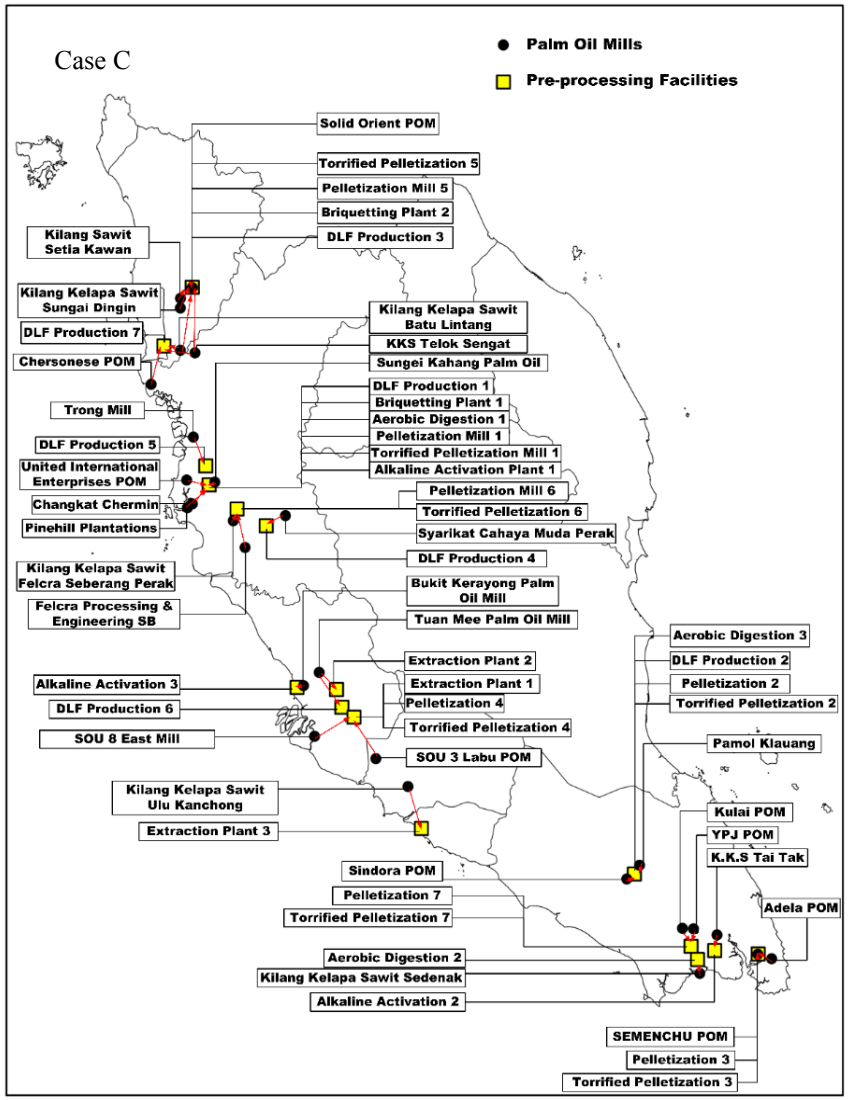
All cases show that the maximum yield of biodiesel can be produced while achieving profit gain. The increment in biodiesel yield is very small because of the production cost consideration. This study reveals that conversion of EFB to biodiesel through gasification is possible and could enhance economic gain. However, conversion of EFB to biodiesel via gasification is a complex process (Li and Chen, 2018; Pradana and Budiman, 2015). In addition, gasification technology in Malaysia is still at the pilot scale (Chan et al., 2019). Therefore, strategies to ease the operational complexity of EFB conversion to biodiesel should be developed. The government can also encourage all renewable energy-related industries to participate in EFB utilization without having to build many facilities.


Case A
Palm Oil Mills
Pre-processing Facilities
Solid Orient POM
Torrified Pelletization 5
Pelletization Mill 5
Briquetting Plant 2
DLF Production 3
Kilang Sawit Setia Kawan
Kilang Kelapa Sawit Sungai Dingin
Kilang Kelapa Sawit Batu Lintang
DLF Production 7
KKS Telok Sengat
Chersonese POM
Sungei Kahang Palm Oil
DLF Production 1
Briquetting Plant 1
Trong Mill
Aerobic Digestion 1
Pelletization Mill 1
DLF Production 5
Torrified Pelletization Mill 1
United International Enterprises POM
Alkaline Activation Plant 1
Pelletization Mill 6
Changkat Chermin
Torrified Pelletization 6
Pinehill Plantations
Syarikat Cahaya Muda Perak
DLF Production 4
Kilang Kelapa Sawit Felcra Seberang Perak
Bukit Kerayong Palm Oil Mill
Felcra Processing & Engineering SB
Tuan Mee Palm Oil Mill
Aerobic Digestion 3
Extraction Plant 2
DLF Production 2
Alkaline Activation 3
Extraction Plant 1
Pelletization 2
DLF Production 6
Pelletization 4
Torrified Pelletization 2
SOU 8 East Mill
Torrified Pelletization 4
Pamol Klauang
SOU 3 Labu POM
Kilang Kelapa Sawit Ulu Kanchong
Kulai POM
Extraction Plant 3
YPJ POM
K.K.S Tai Tak
Sindora POM
Pelletization 7
Adela POM
Torrified Pelletization 7
Aerobic Digestion 2
Kilang Kelapa Sawit Sedenak
Alkaline Activation 2
SEMENCHU POM
Pelletization 3
Torrified Pelletization 3

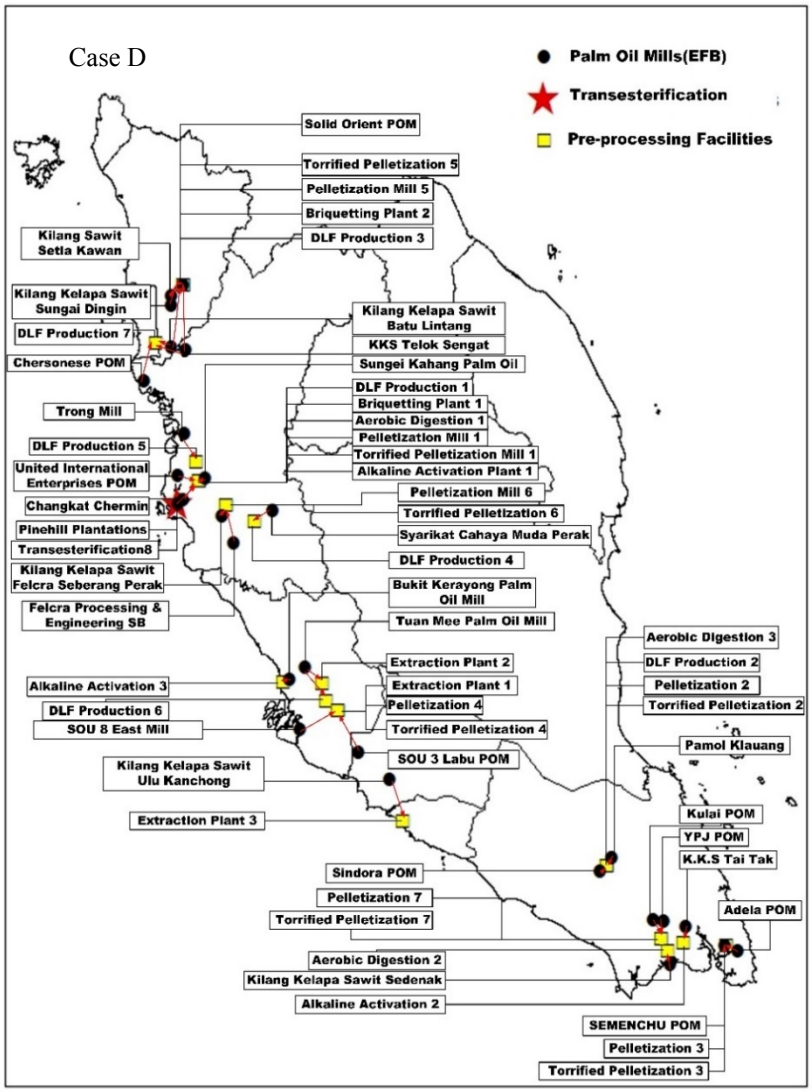
a)


Case B
Palm Oil Mills
Pre-processing Facilities
Solid Orient POM
Torrified Pelletization 5
Pelletization Mill 5
Briquetting Plant 2
DLF Production 3
Kilang Sawit Setia Kawan
Kilang Kelapa Sawit Sungai Dingin
Sungei Kahang Palm Oil
DLF Production 1
Briquetting Plant 1
Aerobic Digestion 1
Pelletization Mill 1
Torrified Pelletization Mill 1
Alkaline Activation Plant 1
United International Enterprises POM
Pelletization Mill 6
Torrified Pelletization 6
Kilang Kelapa Sawit Felcra Seberang Perak
Bukit Kerayong Palm Oil Mill
Felcra Processing & Engineering SB
Tuan Mee Palm Oil Mill
Aerobic Digestion 3
Extraction Plant 2
DLF Production 2
Alkaline Activation 3
Extraction Plant 1
Pelletization 2
DLF Production 6
Pelletization 4
Torrified Pelletization 2
SOU 8 East Mill
Torrified Pelletization 4
Kulai POM
YPJ POM
Sindora POM
Adela POM
Pelletization 7
Torrified Pelletization 7
SEMENCHU POM
Pelletization 3
Torrified Pelletization 3

b)



c)



d)

Figure 3.3 EFB distribution to pre-processing facilities for (a) Case A, (b) Case B, (c) Case C, (d) Case D

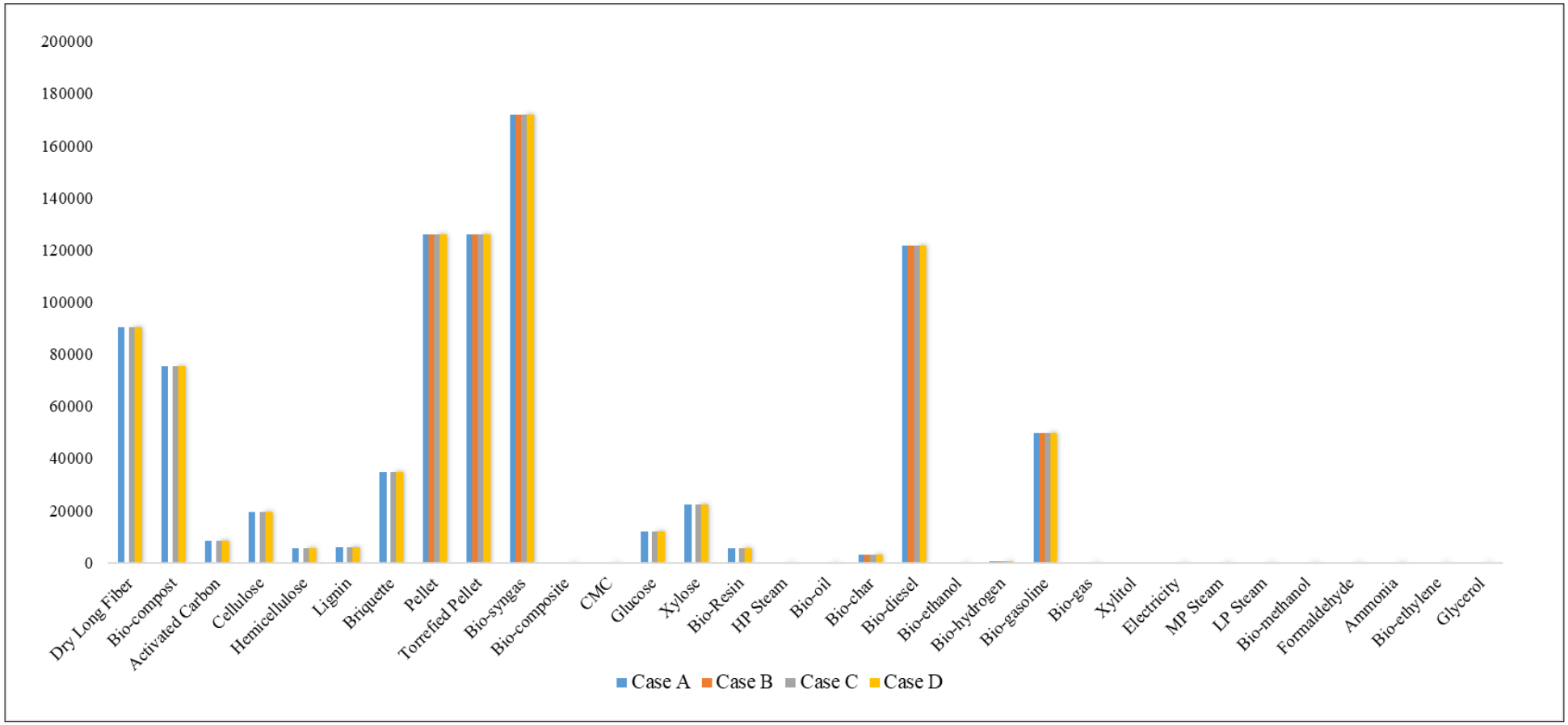
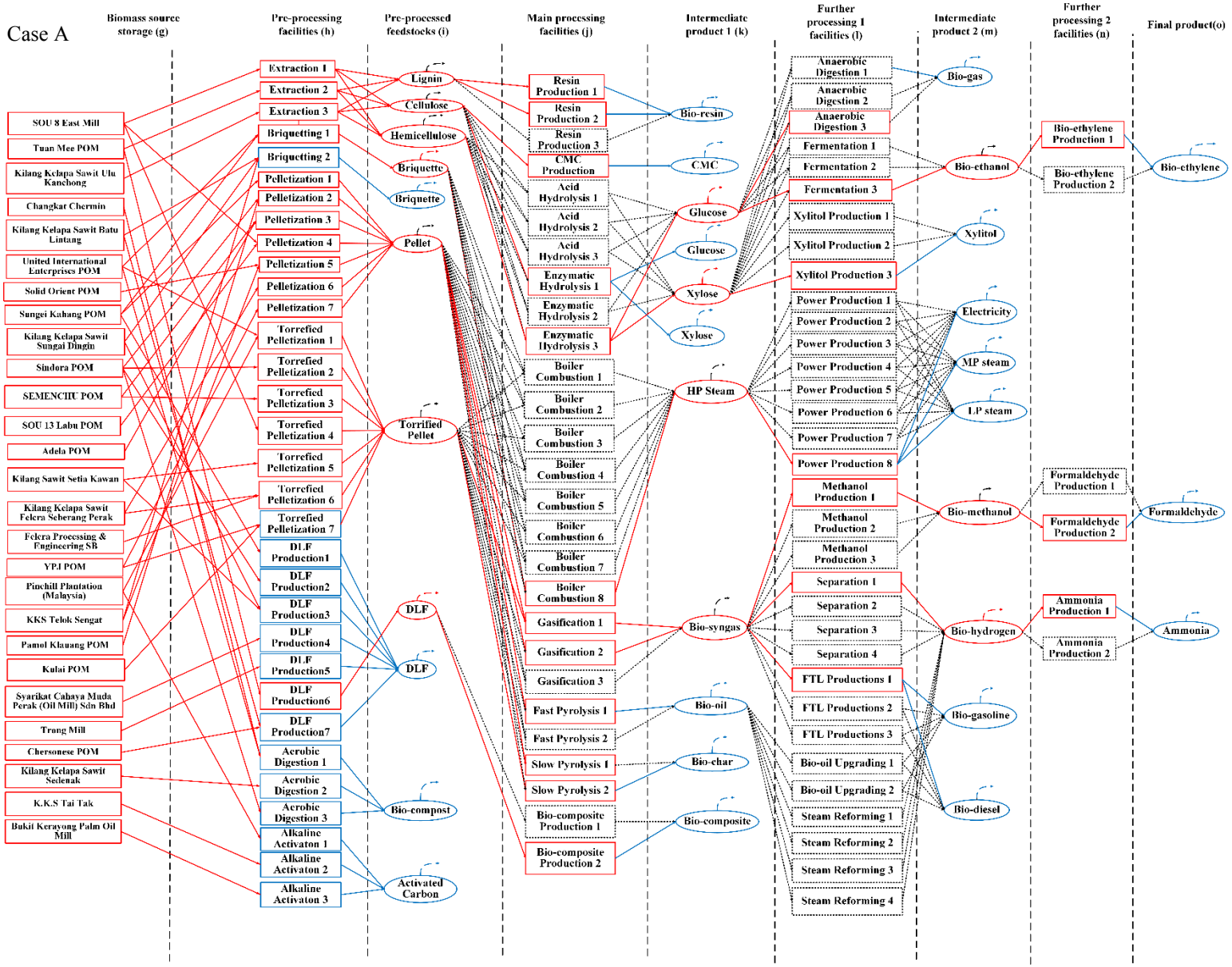
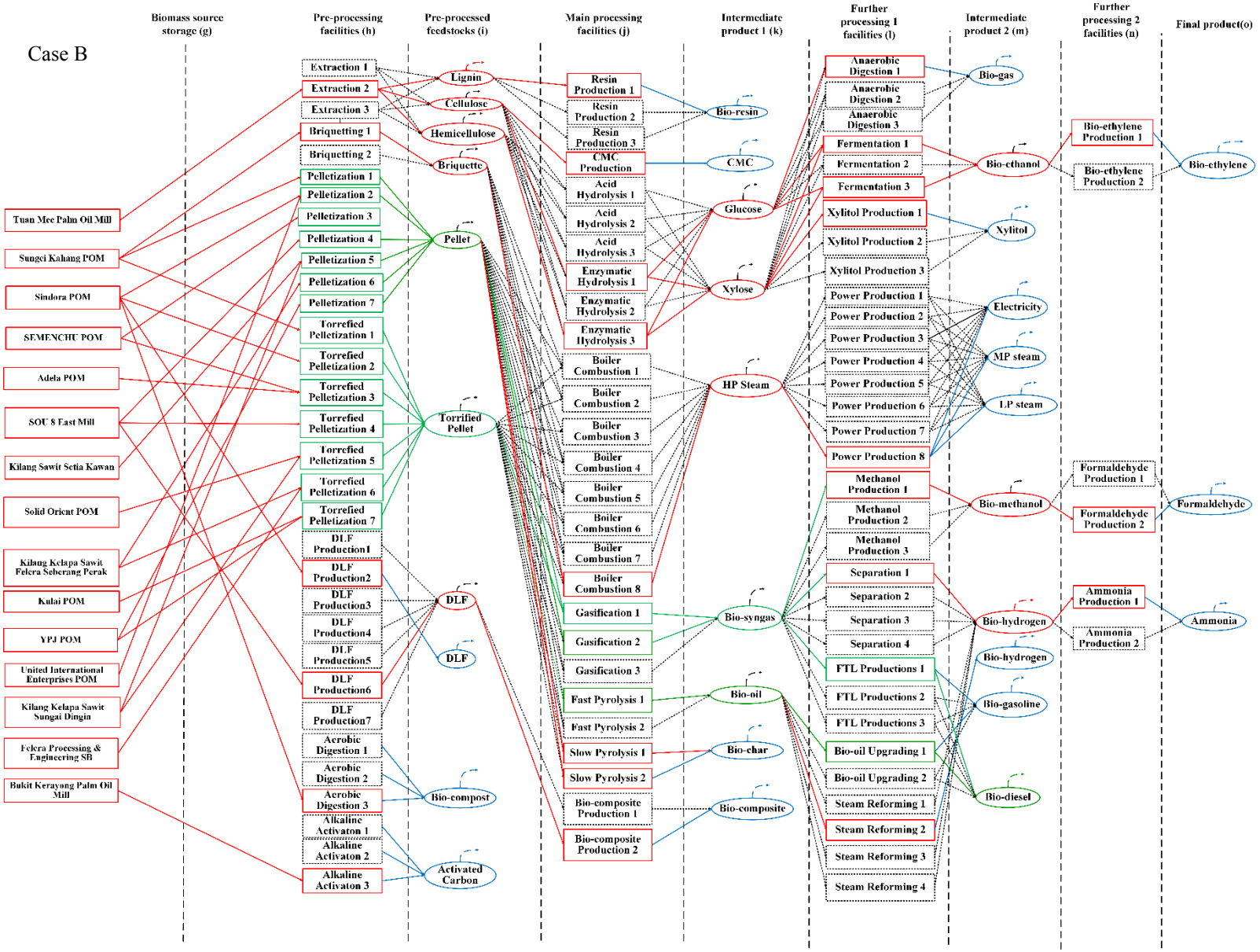


Figure 3.3 Optimal production levels


Case A
Biomass source storage (g)
Pre-processing facilities (h)
Pre-processed feedstocks (i)
Main processing facilities (j)
Intermediate product 1 (k)
Further processing 1 facilities (l)
Intermediate product 2 (m)
Further processing 2 facilities (n)
Final product(o)
SOU 8 East Mill
Tuan Mee POM
Kilang Kelapa Sawit Ulu Kanchong
Changkat Chermin
Kilang Kelapa Sawit Batu Lintang
United International Enterprises POM
Solid Orient POM
Sungei Kahang POM
Kilang Kelapa Sawit Sungai Dingin
Sindora POM
SEMENCIIU POM
SOU 13 Labu POM
Adela POM
Kilang Sawit Setia Kawan
Kilang Kelapa Sawit Felcra Seberang Perak
Felcra Processing & Engineering SB
YPJ POM
Pinchill Plantation (Malaysia)
KKS Telok Sengat
Pamol Kluang POM
Kulai POM
Syarikat Cahaya Muda Perak (Oil Mill) Sdn Bhd
Trong Mill
Chersonese POM
Kilang Kelapa Sawit Sedenak
K.K.S Tai Tak
Bukit Kerayong Palm Oil Mill
Extraction 1
Extraction 2
Extraction 3
Briquetting 1
Briquetting 2
Pelletization 1
Pelletization 2
Pelletization 3
Pelletization 4
Pelletization 5
Pelletization 6
Pelletization 7
Torrefied Pelletization 1
Torrefied Pelletization 2
Torrefied Pelletization 3
Torrefied Pelletization 4
Torrefied Pelletization 5
Torrefied Pelletization 6
Torrefied Pelletization 7
DLF Production1
DLF Production2
DLF Production3
DLF Production4
DLF Production5
DLF Production6
DLF Production7
Aerobic Digestion 1
Aerobic Digestion 2
Aerobic Digestion 3
Alkaline Activaton 1
Alkaline Activaton 2
Alkaline Activaton 3
Lignin
Cellulose
Hemicellulose
Briquette
Briquette
Pellet
Torrified Pellet
DLF
DLF
Bio-compost
Activated Carbon
Resin Production 1
Resin Production 2
Resin Production 3
CMC Production
Acid Hydrolysis 1
Acid Hydrolysis 2
Acid Hydrolysis 3
Enzymatic Hydrolysis 1
Enzymatic Hydrolysis 2
Enzymatic Hydrolysis 3
Boiler Combustion 1
Boiler Combustion 2
Boiler Combustion 3
Boiler Combustion 4
Boiler Combustion 5
Boiler Combustion 6
Boiler Combustion 7
Boiler Combustion 8
Gasification 1
Gasification 2
Gasification 3
Fast Pyrolysis 1
Fast Pyrolysis 2
Slow Pyrolysis 1
Slow Pyrolysis 2
Bio-composite Production 1
Bio-composite Production 2
Bio-resin
CMC
Glucose
Glucose
Xylose
Xylose
HP Steam
Bio-syngas
Bio-oil
Bio-char
Bio-composite
Anaerobic Digestion 1
Anaerobic Digestion 2
Anaerobic Digestion 3
Fermentation 1
Fermentation 2
Fermentation 3
Xylitol Production 1
Xylitol Production 2
Xylitol Production 3
Power Production 1
Power Production 2
Power Production 3
Power Production 4
Power Production 5
Power Production 6
Power Production 7
Power Production 8
Methanol Production 1
Methanol Production 2
Methanol Production 3
Separation 1
Separation 2
Separation 3
Separation 4
FTL Productions 1
FTL Productions 2
FTL Productions 3
Bio-oil Upgrading 1
Bio-oil Upgrading 2
Steam Reforming 1
Steam Reforming 2
Steam Reforming 3
Steam Reforming 4
Bio-gas
Bio-ethanol
Xylitol
Electricity
MP steam
LP steam
Bio-methanol
Bio-hydrogen
Bio-gasoline
Bio-diesel
Bio-ethylene Production 1
Bio-ethylene Production 2
Formaldehyde Production 1
Formaldehyde Production 2
Ammonia Production 1
Ammonia Production 2
Bio-ethylene
Formaldehyde
Ammonia

Case B


Biomass source storage (g)
Pre-processing facilities (h)
Pre-processed feedstocks (i)
Main processing facilities (j)
Intermediate product 1 (k)
Further processing 1 facilities (l)
Intermediate product 2 (m)
Further processing 2 facilities (n)
Final product(o)
Tuan Mee Palm Oil Mill
Sungei Kahang POM
Sindora POM
SEMENCHU POM
Adela POM
SOU 8 East Mill
Kilang Sawit Setia Kawan
Solid Oricut POM
Kilang Kelapa Sawit Felcra Seberang Perak
Kulai POM
YPJ POM
United International Enterprises POM
Kilang Kelapa Sawit Sungai Dingin
Felcra Processing & Engineering SB
Bukit Kerayong Palm Oil Mill
Extraction 1
Extraction 2
Extraction 3
Briquetting 1
Briquetting 2
Pelletization 1
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Pelletization 3
Pelletization 4
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DLF Production1
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Alkaline Activaton 1
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Resin Production 1
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Resin Production 3
CMC Production
Acid Hydrolysis 1
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Acid Hydrolysis 3
Enzymatic Hydrolysis 1
Enzymatic Hydrolysis 2
Enzymatic Hydrolysis 3
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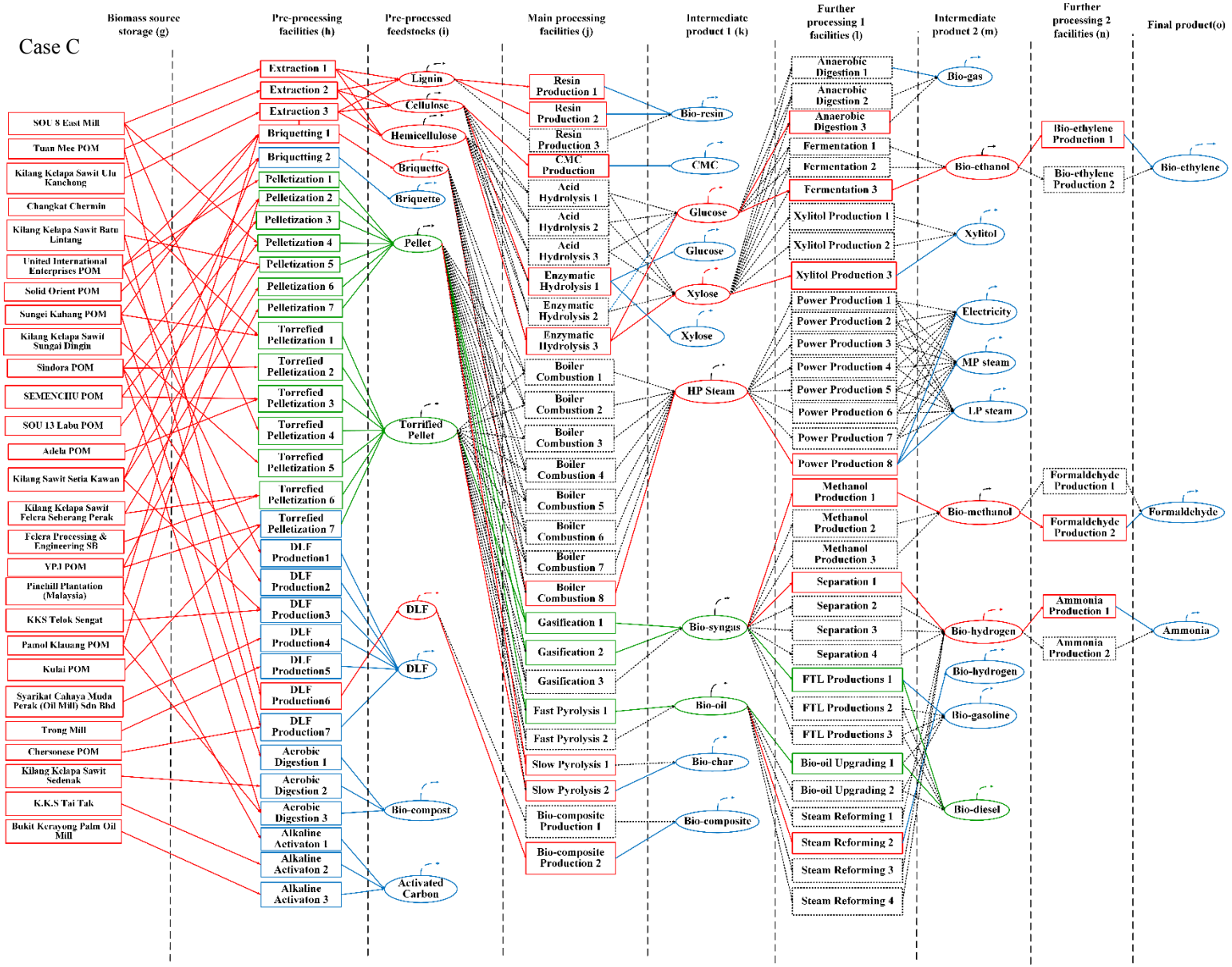
Boiler Combustion 4
Boiler Combustion 5
Boiler Combustion 6
Boiler Combustion 7
Boiler Combustion 8
Gasification 1
Gasification 2
Gasification 3
Fast Pyrolysis 1
Fast Pyrolysis 2
Slow Pyrolysis 1
Slow Pyrolysis 2
Bio-composite Production 1
Bio-composite Production 2
Bio-resin
CMC
Glucose
Xylose
HP Steam
Bio-syngas
Bio-oil
Bio-char
Bio-composite
Anaerobic Digestion 1
Anaerobic Digestion 2
Anaerobic Digestion 3
Fermentation 1
Fermentation 2
Fermentation 3
Xylitol Production 1
Xylitol Production 2
Xylitol Production 3
Power Production 1
Power Production 2
Power Production 3
Power Production 4
Power Production 5
Power Production 6
Power Production 7
Power Production 8
Methanol Production 1
Methanol Production 2
Methanol Production 3
Separation 1
Separation 2
Separation 3
Separation 4
FTL Productions 1
FTL Productions 2
FTL Productions 3
Bio-oil Upgrading 1
Bio-oil Upgrading 2
Steam Reforming 1
Steam Reforming 2
Steam Reforming 3
Steam Reforming 4
Bio-gas
Bio-ethanol
Xylitol
Electricity
MP steam
LP steam
Bio-methanol
Bio-hydrogen
Bio-hydrogen
Bio-gasoline
Bio-diesel
Bio-ethylene Production 1
Bio-ethylene Production 2
Formaldehyde Production 1
Formaldehyde Production 2
Ammonia Production 1
Ammonia Production 2
Bio-ethylene
Formaldehyde
Ammonia


Case C
Biomass source storage (g)
Pre-processing facilities (h)
Pre-processed feedstocks (i)
Main processing facilities (j)
Intermediate product 1 (k)
Further processing 1 facilities (l)
Intermediate product 2 (m)
Further processing 2 facilities (n)
Final product(o)
SOU 8 East Mill
Tuan Mee POM
Kilang Kelapa Sawit Ulu Kanchong
Changkat Chermin
Kilang Kelapa Sawit Batu Lintang
United International Enterprises POM
Solid Orient POM
Sungei Kahang POM
Kilang Kelapa Sawit Sungai Dingin
Sindora POM
SEMENCIIU POM
SOU 13 Labu POM
Adela POM
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Briquette
Briquette
Pellet
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Slow Pyrolysis 1
Slow Pyrolysis 2
Bio-composite Production 1
Bio-composite Production 2
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Glucose
Glucose
Xylose
Xylose
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Bio-oil
Bio-char
Bio-composite
Anaerobic Digestion 1
Anaerobic Digestion 2
Anaerobic Digestion 3
Fermentation 1
Fermentation 2
Fermentation 3
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Xylitol Production 2
Xylitol Production 3
Power Production 1
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Power Production 3
Power Production 4
Power Production 5
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Power Production 7
Power Production 8
Methanol Production 1
Methanol Production 2
Methanol Production 3
Separation 1
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Separation 3
Separation 4
FTL Productions 1
FTL Productions 2
FTL Productions 3
Bio-oil Upgrading 1
Bio-oil Upgrading 2
Steam Reforming 1
Steam Reforming 2
Steam Reforming 3
Steam Reforming 4
Bio-gas
Bio-ethanol
Xylitol
Electricity
MP steam
LP steam
Bio-methanol
Bio-hydrogen
Bio-hydrogen
Bio-gasoline
Bio-diesel
Bio-ethylene Production 1
Bio-ethylene Production 2
Formaldehyde Production 1
Formaldehyde Production 2
Ammonia Production 1
Ammonia Production 2
Bio-ethylene
Formaldehyde
Ammonia

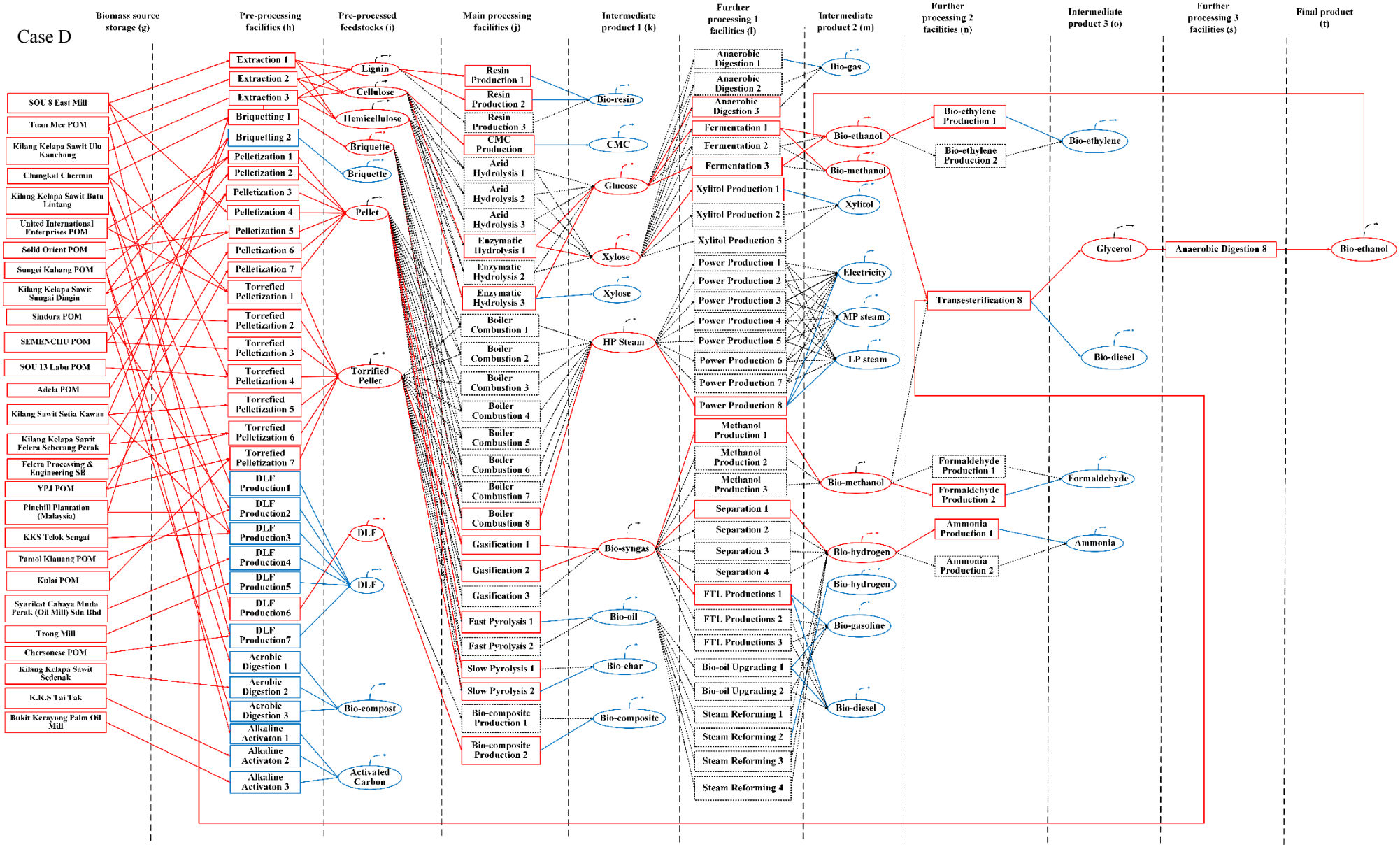

Figure 3.5 Optimal process superstructure for (a) Case A, (b) Case B, (c) Case C, (d) Case D

3.3 Interactions in the environment–food–energy nexus

Understanding the best way to utilize EFB in Malaysia and the interactions among all elements in the nexus is important. This nexus is known as the environment–food–energy–water (EFEW) nexus. The benefits from EFB utilization should be evaluated and analyzed together with the environmental concerns. Figure 3.6 shows the amount of CO_2 generated in all cases. Cases A and C generate the same CO_2 emissions. Among the three case studies, Case C has the highest rate of CO_2 emissions (200,543 ton CO_2eq per year). CO_2 emissions can be reduced to 177,384 ton CO_2eq per year but with a profit reduction of 82%. EFB utilization in this study contributes to the generation of CO_2 emissions. However, the generated emissions are lower than those of fossil-based products (Zahan and Kano, 2018). Trade-off analysis between economic gain and climate change impact is important for transportation and production planning. However, such an analysis is beyond the scope of this study and is recommended for future research.

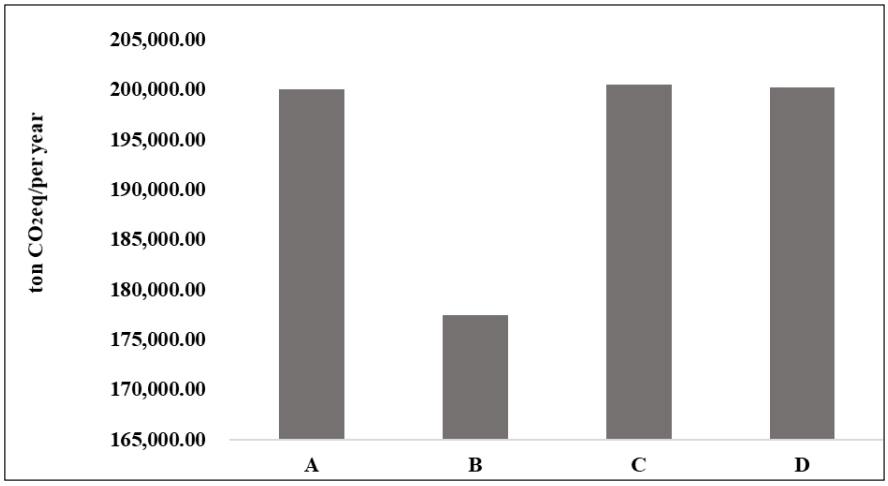

Figure 3.6 Amount of CO_2 emissions generated

Bioethanol production is an interesting case to use in the investigation of the interaction in the food–energy–water nexus. In Case A, the amount of bioethanol produced is 141 tons per year and that of glucose as a sugar (food) is 11,836 tons per year. Bioethanol can be a source of energy and food. The result in Case A reveals that 1 ton of EFB can produce 0.02 ton of glucose. The production of glucose can exert positive impacts on the food industry, but the acceptance, safety, and health issues involved in the consumption of these products need to be resolved (Berłowska et al., 2016; Martinez-Hernandez and Samsatli, 2017). Glucose production in this study shows that it can fulfil the food requirement in terms of sugar and therefore minimize the food-versus-fuel competition. Bioethanol and glucose production are interconnected and require the same resources, such as water and energy. A typical ethanol plant requires 2–10 L of processing water. Water usage during bioethanol production may have a serious implication on water quality, especially during effluent discharge (Ghani et al., 2019; Martinez-Hernandez, and Samsatli, 2017). Therefore, increasing bioethanol or glucose production should be able to balance the water footprint and thus avoid negative water impacts.

Biodiesel production using EFB can help promote the sustainable production and utilization of environmentally friendly biofuels, as proposed by the National Biofuel Policy of Malaysia. Biodiesel can reduce Malaysia's dependence on fossil-based fuels in the transportation industry (Johari et al., 2015).The production of biodiesel from EFB rather than CPO as in Cases B and C has no competition with the food industry (Zabid et al., 2018). In fact, biodiesel production via EFB can reduce the waste from palm oil mills in Peninsular Malaysia. CPO consideration in Case D exerts negative impacts on the food industry (Anuar and Abdullah, 2016). However, low consumption of CPO with 95.4 tons per year would not considerably affect

the food industry. Other food-based products that can be produced through EFB utilization can help combat the shortage in food consumption.

Simultaneous implementation of relevant footprint indicators, such as water, carbon, and energy, along with the economic performance of the EFB value chain could enhance our understanding of the environment–food–energy–water nexus in Malaysia. Although a trade-off is identified between the elements in the nexus, it cannot explain the nexus as a whole. Such an analysis is recommended in future studies.

4.0 CONCLUSIONS AND FUTURE WORK

The economic potentials of utilizing palm oil EFB as renewable feedstock for the production of products that range from energy, chemicals, and materials are realized by obtaining the optimal value chain. In this study, different potential pathways that can be derived from palm-based biomass are presented in a superstructure design. This work presents the development of an EFB value chain, which is considered important in every screening and planning stage. This study can help the owners of palm oil mills and processing facilities in their planning and operation decisions. The owners could make effective decisions on whether to sell the produced products directly or subject them to further processing based on market conditions and the emissions generated by processing facilities. The interaction of EFB utilization with the environment–food–energy–water nexus is also provided, but this study does not fully capture the trade-off between the elements in the nexus. Such an analysis will be conducted in the future. Considering that the current model only emphasizes the economic efficiency of the EFB value chain, other criteria, such as environmental impacts, could be added in future studies. The general framework of the proposed optimization model could be applicable and may be extended to other biomass utilization projects. However, the proposed model cannot solve a complex value chain similar to the one in this study. In future work, the developed model will be further extended by including optimal decisions involving multiple biomass resources and the impacts on the environment–food–energy–water nexus from production and transportation perspectives.

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APPENDIX

Table A.1 Products' selling prices derived from EFB

Product	Selling price (USD/tonne or USD /MWh*)
Dry Long Fiber (DLF)	210
Bio-compost	100
Activated carbon	1756
Cellulose	2200
Hemicellulose	2000
Lignin	1500
Briquette	120
Pellet	140
Torrefied Pellet	160
Bio-composite	625
Carboxymethyl Cellulose (CMC)	3500
Glucose	1890
Xylose	1990
Bio-resin	9072
High Pressure Steam	26
Bio-syngas	600
Bio-oil	800
Bio-char	380
Bio-hydrogen	818
Xylitol	4200
Bio-ethanol	523
Bio-gas	398
Bio-methanol	870
Electricity	140*
Medium Pressure Steam	17
Low Pressure Steam	12
Bio-ethylene	1544
Bio-diesel	790
Bio-gasoline	1315
Ammonia	745
Formaldehyde	463

(Abdulrazik et al., 2017)

Table A.2 Distance from EFB supplier, *g* to pre-processing facilities, *h*

	Pelletization Mill1	Pelletization Mill2	Pelletization Mill3	Pelletization Mill4	Pelletization Mill5	Pelletization Mill6	Pelletization Mill7	Torrefied Pelletization1	Torrefied Pelletization2	Torrefied Pelletization3	Torrefied Pelletization4	Torrefied Pelletization5	Torrefied Pelletization6	Torrefied Pelletization7	DLF Production1	DLF Production2	DLF Production3	DLF Production4	DLF Production5	DLF Production6	DLF Production7	Aerobic Digestion1	Aerobic Digestion2	Aerobic Digestion3	Extraction Plant1	Extraction Plant2	Extraction Plant3	Briquetting Plant1	Briquetting Plant2	Alkaline Activation Plant1	Alkaline Activation Plant2	Alkaline Activation Plant3
TENGGAROH	426	57	63	264	523	401	55	426	57	63	264	523	401	55	426	57	523	379	435	274	508	426	62	57	264	282	201	426	523	426	55	307
TENGGAROH TIMUR	425	62	68	265	520	400	64	425	62	68	265	520	400	64	425	62	520	378	434	275	506	425	71	62	265	283	205	425	520	425	63	308
Kilang Sawit Risda Sg Ambat	423	57	68	262	519	398	60	423	57	68	262	519	398	60	423	57	519	376	432	272	505	423	68	57	262	280	200	423	519	423	60	305
Tunjuk Laut	443	68	46	279	540	418	48	443	68	46	279	540	418	48	443	68	540	396	452	289	526	443	53	68	279	298	214	443	540	443	43	322
ulu Sibol Oil mill	419	35	64	249	522	394	31	419	35	64	249	522	394	31	419	35	522	372	429	259	505	419	40	35	249	269	178	419	522	419	40	292
Sg kachur POM	438	55	44	269	541	414	19	438	55	44	269	541	414	19	438	55	541	392	449	279	524	438	26	55	269	288	197	438	541	438	22	312
Kilang sawit Wa ha	464	85	24	298	563	439	45	464	85	24	298	563	439	45	464	85	563	417	474	309	548	464	46	85	298	317	230	464	563	464	33	341
Kulai POM	433	48	53	261	538	408	13	433	48	53	261	538	408	13	433	48	538	386	443	271	520	433	23	48	261	281	187	433	538	433	26	303
YPJ POM	438	54	46	267	542	414	12	438	54	46	267	542	414	12	438	54	542	392	448	277	525	438	21	54	267	287	194	438	542	438	20	310
K.K.S Tai Tak	453	69	30	283	555	428	19	453	69	30	283	555	428	19	453	69	555	406	463	293	539	453	21	69	283	302	210	453	555	453	11	326
SEMENCHU POM	482	98	0	313	583	457	45	482	98	0	313	583	457	45	482	98	583	435	492	323	567	482	41	98	313	332	240	482	583	482	29	356
Adela POM	491	108	10	322	591	466	54	491	108	10	322	591	466	54	491	108	591	444	500	332	575	491	50	108	322	342	250	491	591	491	38	365
KILANG KELAPA SAWIT SIANG	493	110	12	325	593	468	57	493	110	12	325	593	468	57	493	110	593	446	503	335	578	493	52	110	325	344	252	493	593	493	41	368
Kilang Kelapa Sawit Sedenak	462	79	41	287	569	437	19	462	79	41	287	569	437	19	462	79	569	416	472	298	550	462	9	79	287	308	210	462	569	462	18	330
Masai Palm Oil Mill	473	88	16	302	576	448	31	473	88	16	302	576	448	31	473	88	576	426	483	312	559	473	25	88	302	322	227	473	576	473	15	345
Keck Seng POM	473	88	16	302	576	448	31	473	88	16	302	576	448	31	473	88	576	426	483	312	559	473	25	88	302	322	227	473	576	473	15	344
Pagoh Palm Oil Mill	336	67	160	158	450	312	116	336	67	160	158	450	312	116	336	67	450	291	347	168	428	336	124	67	158	179	80	336	450	336	132	200
Pamol Plantation	334	71	164	155	448	309	120	334	71	164	155	448	309	120	334	71	448	288	345	165	425	334	128	71	155	176	76	334	448	334	136	197

Muar oil mill	337	76	165	157	453	313	121	337	76	165	157	453	313	121	337	76	453	292	348	167	429	337	128	76	157	178	76	337	453	337	137	198
Pamol Klauang	383	7	99	215	487	359	64	383	7	99	215	487	359	64	383	7	487	337	393	225	469	383	74	7	215	234	148	383	487	383	76	258
Tereh Palm oil mill	372	18	110	206	475	347	76	372	18	110	206	475	347	76	372	18	475	325	382	216	458	372	86	18	206	224	142	372	475	372	88	249
Sindpra POM	383	6	101	212	489	358	62	383	6	101	212	489	358	62	383	6	489	337	393	222	471	383	71	6	212	231	141	383	489	383	76	255
Dara Lam Soon	380	11	105	208	486	355	65	380	11	105	208	486	355	65	380	11	486	333	390	218	468	380	75	11	208	227	136	380	486	380	79	250
Ayer Itam Oil Mill	381	24	109	206	490	356	66	381	24	109	206	490	356	66	381	24	490	335	391	216	470	381	75	24	206	226	131	381	490	381	82	248
Bukit Benut Oil Palm Mill	393	14	93	220	500	368	52	393	14	93	220	500	368	52	393	14	500	347	403	231	481	393	61	14	220	240	148	393	500	393	66	263
Bukit Benut POM	393	17	93	220	501	369	52	393	17	93	220	501	369	52	393	17	501	347	404	231	482	393	61	17	220	240	147	393	501	393	66	263
Bukit Lawiang POM	397	13	86	227	503	373	48	397	13	86	227	503	373	48	397	13	503	351	408	237	485	397	58	13	227	246	156	397	503	397	61	270
KKS Belitong	405	20	78	234	509	380	41	405	20	78	234	509	380	41	405	20	509	358	415	245	492	405	51	20	234	254	164	405	509	405	54	277
Ulu remis oil mill	410	27	77	237	516	385	35	410	27	77	237	516	385	35	410	27	516	363	420	247	497	410	45	27	237	257	163	410	516	410	50	280
Nam Heng Oil mill Co Sdn bhd	370	47	129	192	483	346	85	370	47	129	192	483	346	85	370	47	483	325	381	202	461	370	92	47	192	213	112	370	483	370	101	234
Gomali Oil Mill	403	29	88	228	511	378	44	403	29	88	228	511	378	44	403	29	511	357	413	239	492	403	53	29	228	249	152	403	511	403	60	271
Hadapan Palm Oil Mill	413	30	74	240	519	388	32	413	30	74	240	519	388	32	413	30	519	366	423	250	500	413	42	30	240	260	166	413	519	413	47	283
KKS Nitar	386	51	105	230	481	361	87	386	51	105	230	481	361	87	386	51	481	339	395	240	467	386	96	51	230	247	175	386	481	386	92	272
Wujud Wawasan	272	123	214	130	369	247	184	272	123	214	130	369	247	184	272	123	369	225	281	138	353	272	193	123	130	142	115	272	369	272	195	168
Kota bahagia palm oil mill	284	113	202	141	380	260	173	284	113	202	141	380	260	173	284	113	380	238	293	149	365	284	182	113	141	154	120	284	380	284	183	180
KKS Keratong 9	289	109	198	145	384	264	169	289	109	198	145	384	264	169	289	109	384	242	298	153	370	289	179	109	145	158	122	289	384	289	180	184
Keratong 3 palm oil mill	282	110	203	133	381	257	171	282	110	203	133	381	257	171	282	110	381	235	291	142	364	282	181	110	133	147	110	282	381	282	182	173
Keratong 2 Palm oil mill	287	111	200	143	383	262	171	287	111	200	143	383	262	171	287	111	383	240	296	151	368	287	180	111	143	156	121	287	383	287	181	182
Palong Timor Palm oil mill	279	105	202	118	385	255	166	279	105	202	118	385	255	166	279	105	385	233	290	127	366	279	176	105	118	135	83	279	385	279	179	160
Pukin Palm Oil Mill	298	89	184	141	401	274	150	298	89	184	141	401	274	150	298	89	401	252	308	150	383	298	160	89	141	157	102	298	401	298	162	183
Palong cocoa pom	295	90	187	133	400	271	151	295	90	187	133	400	271	151	295	90	400	249	305	142	382	295	160	90	133	150	90	295	400	295	164	175

RISDA ulu keratong	300	85	182	136	405	275	146	300	85	182	136	405	275	146	300	85	405	253	310	146	386	300	156	85	136	153	90	300	405	300	159	178
Selancar 2b	312	76	170	153	414	287	137	312	76	170	153	414	287	137	312	76	414	265	322	162	397	312	147	76	153	169	108	312	414	312	149	195
Selancar 2A	313	76	170	154	414	288	137	313	76	170	154	414	288	137	313	76	414	266	322	164	397	313	147	76	154	171	110	313	414	313	149	196
Johor Labis POM	344	41	139	174	452	320	101	344	41	139	174	452	320	101	344	41	452	298	355	184	432	344	110	41	174	193	108	344	452	344	114	217
Kekayaan Palm oil mill	361	23	122	192	467	337	84	361	23	122	192	467	337	84	361	23	467	315	372	202	449	361	93	23	192	211	125	361	467	361	97	235
SOU 20 Chaah	346	43	140	173	455	322	100	346	43	140	173	455	322	100	346	43	455	300	357	183	435	346	108	43	173	193	103	346	455	346	114	216
SELENDANG POM	348	72	145	199	440	323	123	348	72	145	199	440	323	123	348	72	440	301	356	208	427	348	133	72	199	214	157	348	440	348	131	240
Seri Intan Palm Oil Mill	381	34	103	220	479	356	78	381	34	103	220	479	356	78	381	34	479	334	390	230	464	381	88	34	220	238	161	381	479	381	86	262
Lima Blas POM	105	280	378	82	224	81	340	105	280	378	82	224	81	340	105	280	224	60	116	74	197	105	349	280	82	61	168	105	224	105	354	60
SOU 13 Labu POM	214	189	287	31	337	190	245	214	189	287	31	337	190	245	214	189	337	171	225	41	309	214	253	189	31	53	56	214	337	214	260	71
SOU 14 Tanah Merah	222	186	283	40	346	199	241	222	186	283	40	346	199	241	222	186	346	180	234	49	318	222	249	186	40	62	48	222	346	222	256	77
Kilang Kelapa Sawit Ulu Kanchong	241	162	259	58	362	217	217	241	162	259	58	362	217	217	241	162	362	198	252	69	335	241	225	162	58	80	29	241	362	241	232	99
SOU 15 - Sua Betong POM	240	171	267	58	363	217	224	240	171	267	58	363	217	224	240	171	363	198	252	67	335	240	232	171	58	79	30	240	363	240	240	95
Pasoh Palm oil mill	225	160	258	68	334	200	220	225	160	258	68	334	200	220	225	160	334	178	235	76	313	225	230	160	68	81	79	225	334	225	234	108
KS SERTING HILIR-N. SEMBILAN	242	143	240	89	347	217	204	242	143	240	89	347	217	204	242	143	347	195	252	98	328	242	214	143	89	103	86	242	347	242	217	129
Kok Foh oil mill	260	125	223	95	368	235	185	260	125	223	95	368	235	185	260	125	368	213	270	105	348	260	195	125	95	112	69	260	368	260	199	137
Kilang Kelapa Sawit Serting	246	138	236	86	354	222	199	246	138	236	86	354	222	199	246	138	354	200	256	95	334	246	208	138	86	102	75	246	354	246	212	128
Pasir Besar Palm oil mill	273	113	211	102	385	249	172	273	113	211	102	385	249	172	273	113	385	227	284	112	363	273	181	113	102	121	58	273	385	273	186	145
Jeram Padang Mill	256	130	229	86	367	231	190	256	130	229	86	367	231	190	256	130	367	210	266	96	346	256	199	130	86	104	57	256	367	256	204	129
Nam bee oil mill	282	108	206	106	395	257	166	282	108	206	106	395	257	166	282	108	395	236	293	117	373	282	175	108	106	126	49	282	395	282	180	149
Kempas oil mill	292	108	204	112	409	268	161	292	108	204	112	409	268	161	292	108	409	248	303	123	385	292	169	108	112	134	39	292	409	292	177	154

Diamond Jubilee Oil mill	296	102	198	117	411	272	156	296	102	198	117	411	272	156	296	102	411	251	307	127	388	296	164	102	117	138	45	296	411	296	171	159
Dominion Square	296	102	198	117	412	272	156	296	102	198	117	412	272	156	296	102	412	251	307	127	388	296	164	102	117	138	45	296	412	296	171	159
SOU 8 East Mill	181	233	330	29	310	160	288	181	233	330	29	310	160	288	181	233	310	144	194	26	279	181	296	233	29	34	94	181	310	181	303	34
SOU 9 West Mill	175	243	340	37	304	153	298	175	243	340	37	304	153	298	175	243	304	138	187	32	272	175	306	243	37	37	104	175	304	175	313	29
Lepar Utara 4 POM	230	211	293	160	301	209	269	230	211	293	160	301	209	269	230	211	301	188	236	163	294	230	279	211	160	160	191	230	301	230	278	182
lepar utara 6 palm oil mill	215	225	309	156	283	193	284	215	225	309	156	283	193	284	215	225	283	173	220	158	277	215	294	225	156	154	195	215	283	215	293	175
Carotino POM	232	205	287	156	305	210	263	232	205	287	156	305	210	263	232	205	305	189	238	159	298	232	272	205	156	157	185	232	305	232	272	180
Jengka 8 POM	214	199	288	128	297	191	260	214	199	288	128	297	191	260	214	199	297	169	221	131	286	214	269	199	128	129	161	214	297	214	270	152
Kilang Kelapa Sawit Felcra Maran	229	183	270	129	314	205	243	229	183	270	129	314	205	243	229	183	314	183	236	133	302	229	252	183	129	132	153	229	314	229	253	157
Bukit kepayang palm oil mil	230	166	258	109	325	206	227	230	166	258	109	325	206	227	230	166	325	184	239	115	310	230	237	166	109	116	127	230	325	230	239	142
Tementi palm oil mill	235	159	251	107	332	211	220	235	159	251	107	332	211	220	235	159	332	189	244	113	316	235	229	159	107	115	119	235	332	235	231	141
Bukit Sagu POM	264	214	286	196	325	244	268	264	214	286	196	325	244	268	264	214	325	223	269	199	322	264	277	214	196	197	217	264	325	264	274	220
SOU 12 Jabor POM	282	208	276	209	341	261	260	282	208	276	209	341	261	260	282	208	341	241	287	213	339	282	270	208	209	211	224	282	341	282	266	235
Panching Palm oil mill	270	198	271	190	335	248	252	270	198	271	190	335	248	252	270	198	335	227	275	194	331	270	261	198	190	192	205	270	335	270	258	216
Ladang Cheong wing chan	269	186	261	180	339	247	241	269	186	261	180	339	247	241	269	186	339	225	275	185	333	269	250	186	180	184	193	269	339	269	248	209
Lepar hilir palm oil mill	259	181	260	165	334	236	237	259	181	260	165	334	236	237	259	181	334	214	265	170	326	259	247	181	165	169	179	259	334	259	245	194
Kilang Sawit LCSB Lepar	268	173	251	170	344	245	229	268	173	251	170	344	245	229	268	173	344	223	275	175	336	268	239	173	170	175	179	268	344	268	237	200
Sungai jernih mill	280	145	225	163	364	257	202	280	145	225	163	364	257	202	280	145	364	235	288	169	353	280	212	145	163	171	159	280	364	280	210	197
Bukit Lee Lau	286	141	220	166	370	262	197	286	141	220	166	370	262	197	286	141	370	240	293	173	359	286	206	141	166	175	160	286	370	286	205	201
CHINI 2 POM	262	153	238	146	348	238	212	262	153	238	146	348	238	212	262	153	348	216	270	152	337	262	221	153	146	153	149	262	348	262	221	179
Chini 3 Palm oil mill	262	153	238	145	348	238	212	262	153	238	145	348	238	212	262	153	348	216	270	152	337	262	221	153	145	153	149	262	348	262	221	179
KS KRAU-PAHANG	154	234	330	80	256	130	295	154	234	330	80	256	130	295	154	234	256	107	163	78	237	154	305	234	80	70	147	154	256	154	308	89

Kuantan Trading POM	289	119	204	154	380	265	178	289	119	204	154	380	265	178	289	119	380	243	298	162	367	289	187	119	154	166	138	289	380	289	187	192
Padang Piol POM	194	229	316	137	270	172	289	194	229	316	137	270	172	289	194	229	270	151	200	138	261	194	298	229	137	133	183	194	270	194	299	153
Kota Gelanggi palm oil mill	194	229	316	137	270	172	289	194	229	316	137	270	172	289	194	229	270	151	200	138	261	194	298	229	137	133	183	194	270	194	299	153
Jengka 21 POM	200	209	299	121	285	177	270	200	209	299	121	285	177	270	200	209	285	155	207	123	273	200	280	209	121	119	161	200	285	200	280	142
Jengka 3 POM	202	217	305	133	281	179	277	202	217	305	133	281	179	277	202	217	281	158	208	134	270	202	287	217	133	130	174	202	281	202	287	152
KS SEROJA (JENGKA 18)-PAHANG	205	211	299	129	286	183	271	205	211	299	129	286	183	271	205	211	286	161	212	131	276	205	280	211	129	128	168	205	286	205	281	150
Kerdau Palm Oil Mill	197	205	296	108	287	173	266	197	205	296	108	287	173	266	197	205	287	151	204	110	273	197	275	205	108	107	149	197	287	197	277	130
KKS Bukit Mendi	212	173	270	74	317	188	235	212	173	270	74	317	188	235	212	173	317	165	222	80	298	212	244	173	74	82	100	212	317	212	247	108
Kemasul POM	216	169	266	76	321	192	230	216	169	266	76	321	192	230	216	169	321	169	226	82	302	216	240	169	76	85	98	216	321	216	243	111
Syarikat penanaman bukti senorang	223	163	259	79	328	198	224	223	163	259	79	328	198	224	223	163	328	176	233	86	309	223	233	163	79	89	95	223	328	223	236	116
Selaba oil mill	54	332	430	128	181	31	392	54	332	430	128	181	31	392	54	332	181	18	66	119	150	54	401	332	128	107	215	54	181	54	406	95
Seri Pelangi POM	58	327	425	125	183	34	387	58	327	425	125	183	34	387	58	327	183	18	70	115	153	58	397	327	125	103	212	58	183	58	401	93
Flemington POM	51	347	445	138	183	37	407	51	347	445	138	183	37	407	51	347	183	40	64	127	148	51	416	347	138	116	224	51	183	51	421	99
Jendarata Palm Oil Mill (P01)	63	329	427	121	193	42	389	63	329	427	121	193	42	389	63	329	193	34	75	111	160	63	398	329	121	99	208	63	193	63	403	84
Southern Perak Plantation S/B	69	325	423	116	199	49	384	69	325	423	116	199	49	384	69	325	199	40	81	106	166	69	393	325	116	94	202	69	199	69	399	79
Ulu bernam POM	79	312	410	104	208	57	372	79	312	410	104	208	57	372	79	312	208	44	91	94	176	79	381	312	104	82	191	79	208	79	386	68
Trolak palm oil mill	79	306	403	111	195	54	366	79	306	403	111	195	54	366	79	306	195	32	89	102	169	79	376	306	111	90	196	79	195	79	380	85
Sungai Tengi palm oil mill	112	275	373	71	234	88	335	112	275	373	71	234	88	335	112	275	234	69	124	62	206	112	344	275	71	50	158	112	234	112	349	47
Kilang Kelapa Sawit Ulu Basir	89	298	396	93	214	66	358	89	298	396	93	214	66	358	89	298	214	48	101	84	185	89	367	298	93	71	180	89	214	89	372	62
Tanjung Malim palm oil mill	95	291	389	89	217	71	351	95	291	389	89	217	71	351	95	291	217	51	106	80	189	95	360	291	89	68	176	95	217	95	365	62

KS MEMPAGA-PAHANG	141	246	345	44	262	117	306	141	246	345	44	262	117	306	141	246	262	98	153	36	235	141	315	246	44	24	129	141	262	141	320	36
Tennamaram Palm Oil Mill	129	265	364	54	255	106	324	129	265	364	54	255	106	324	129	265	255	89	141	44	225	129	333	265	54	32	140	129	255	129	339	22
Tuan mee palm oil mill	145	250	348	38	270	122	308	145	250	348	38	270	122	308	145	250	270	104	157	28	241	145	317	250	38	16	124	145	270	145	323	18
SOU 7 Bukit Kerayong	148	254	352	39	275	125	311	148	254	352	39	275	125	311	148	254	275	109	160	29	244	148	320	254	39	21	123	148	275	148	326	5
Bukit Kerayong Palm Oil Mill	148	254	353	40	275	126	312	148	254	353	40	275	126	312	148	254	275	109	160	29	244	148	320	254	40	22	124	148	275	148	327	4
Kilang Kelapa Sawit Risda Durian Mas	291	300	362	274	312	275	350	291	300	362	274	312	275	350	291	300	312	259	292	275	322	291	359	300	274	270	307	291	312	291	354	289
K.K.S Rasau Kerteh	280	280	344	253	310	263	331	280	280	344	253	310	263	331	280	280	310	246	281	255	317	280	340	280	253	250	285	280	310	280	336	270
Kilang Kelapa Sawit Kemaman	287	249	313	239	329	268	299	287	249	313	239	329	268	299	287	249	329	249	290	242	333	287	309	249	239	238	263	287	329	287	304	260
Ladang rakyat mill	269	232	301	213	321	250	285	269	232	301	213	321	250	285	269	232	321	230	273	216	321	269	294	232	213	213	238	269	321	269	291	235
Neram palm oil mill	279	217	285	211	336	259	269	279	217	285	211	336	259	269	279	217	336	238	283	215	334	279	278	217	211	213	230	279	336	279	274	236
TDM kemaman palm oil mill	271	261	328	234	311	253	313	271	261	328	234	311	253	313	271	261	311	235	274	236	315	271	322	261	234	232	265	271	311	271	319	253
Temerloh Mill	271	261	328	234	311	253	313	271	261	328	234	311	253	313	271	261	311	235	274	236	315	271	322	261	234	232	264	271	311	271	319	253
Kechau	142	286	377	151	208	123	347	142	286	377	151	208	123	347	142	286	208	105	145	147	200	142	357	286	151	138	218	142	208	142	358	149
Bukit Puteri Palm Oil Mill	110	297	390	135	193	89	358	110	297	390	135	193	89	358	110	297	193	70	115	129	178	110	367	297	135	118	211	110	193	110	370	125
Tersang palm oil mill	115	286	380	124	203	93	347	115	286	380	124	203	93	347	115	286	203	73	121	119	187	115	357	286	124	108	200	115	203	115	359	116
Minsawi Industries (K. Kangsar)	55	415	510	226	81	71	476	55	415	510	226	81	71	476	55	415	81	86	44	216	57	55	486	415	226	204	311	55	81	55	489	195
SOU 3 Elphil Mill	65	403	497	220	87	73	464	65	403	497	220	87	73	464	65	403	87	83	55	212	72	65	474	403	220	199	305	65	87	65	476	193
Trong mill	34	414	511	215	100	56	475	34	414	511	215	100	56	475	34	414	100	77	21	205	64	34	484	414	215	193	302	34	100	34	488	180
United International Enterprises POM	15	398	495	193	128	39	458	15	398	495	193	128	39	458	15	398	128	61	16	183	91	15	467	398	193	172	280	15	128	15	472	156

Sungei Kahang Palm Oil	4	383	480	182	131	23	444	4	383	480	182	131	23	444	4	383	131	45	12	172	97	4	453	383	182	160	269	4	131	4	457	147
Changkat Chermin	17	385	482	178	144	30	445	17	385	482	178	144	30	445	17	385	144	51	27	168	107	17	454	385	178	157	265	17	144	17	458	141
Pinehill Plantations (Malaysia)	21	386	483	178	147	33	446	21	386	483	178	147	33	446	21	386	147	54	30	168	109	21	455	386	178	157	265	21	147	21	459	140
Syarikat Cahaya Muda Perak (Oil Mil) Sdn Bhd	55	334	430	142	164	33	395	55	334	430	142	164	33	395	55	334	164	15	63	133	139	55	404	334	142	121	227	55	164	55	408	115
Kilang Kelapa Sawit Felcra Seberang Perak	29	357	454	154	158	8	417	29	357	454	154	158	8	417	29	357	158	22	41	144	125	29	426	357	154	132	240	29	158	29	430	119
Felcra Processing & Engineering SB	48	339	437	134	177	26	399	48	339	437	134	177	26	399	48	339	177	20	60	124	145	48	408	339	134	113	221	48	177	48	413	99
Felcra Bidor Palm oil mill	59	325	423	125	182	35	386	59	325	423	125	182	35	386	59	325	182	16	70	115	153	59	395	325	125	103	211	59	182	59	399	94
KKS Besout	71	314	411	119	187	46	375	71	314	411	119	187	46	375	71	314	187	24	81	110	161	71	384	314	119	97	204	71	187	71	388	92
Chalok palm oil mill	249	383	455	300	231	242	438	249	383	455	300	231	242	438	249	383	231	233	246	297	251	249	447	383	300	288	356	249	231	249	444	300
Kilang Sungai Tong	255	365	435	291	246	245	419	255	365	435	291	246	245	419	255	365	246	235	252	289	264	255	428	365	291	281	344	255	246	255	425	295
K.K.S Jerangau Barat	260	328	396	270	270	247	381	260	328	396	270	270	247	381	260	328	270	233	259	270	282	260	390	328	270	263	316	260	270	260	387	279
K.K.S Maokil	246	343	415	271	249	234	398	246	343	415	271	249	234	398	246	343	249	222	244	270	262	246	407	343	271	262	322	246	249	246	404	276
Ladang Serasa	172	363	446	240	172	164	422	172	363	446	240	172	164	422	172	363	172	156	168	236	183	172	432	363	240	226	308	172	172	172	431	234
Kilang Kelapa Sawit Kemahang	217	438	518	317	163	218	496	217	438	518	317	163	218	496	217	438	163	216	210	312	191	217	506	438	317	301	387	217	163	217	504	307
Kuala Pertang POM	210	415	495	299	170	208	473	210	415	495	299	170	208	473	210	415	170	204	204	294	194	210	483	415	299	283	367	210	170	210	481	290
Kilang Kelapa Sawit Paloh 3	177	349	431	232	186	167	407	177	349	431	232	186	167	407	177	349	186	157	175	229	195	177	417	349	232	219	298	177	186	177	416	228
Kilang sawit Chiku	167	345	429	224	180	157	405	167	345	429	224	180	157	405	167	345	180	147	165	220	188	167	414	345	224	210	291	167	180	167	414	219
Solid Orient POM	132	489	583	306	0	151	551	132	489	583	306	0	151	551	132	489	0	166	119	297	43	132	560	489	306	284	391	132	0	132	563	275
Kilang Kelapa Sawit Sungai Dingin	126	488	582	302	11	145	550	126	488	582	302	11	145	550	126	488	11	162	113	293	34	126	559	488	302	280	388	126	11	126	562	270

Kilang Sawit Setia Kawan	119	484	578	296	16	139	545	119	484	578	296	16	139	545	119	484	16	156	107	287	28	119	554	484	296	275	382	119	16	119	557	264
Kilang Kelapa Sawit Batu Lintang	92	462	557	270	43	112	523	92	462	557	270	43	112	523	92	462	43	130	79	261	11	92	533	462	270	249	357	92	43	92	536	238
KKS Telok Sengat	88	454	549	265	44	108	516	88	454	549	265	44	108	516	88	454	44	125	76	256	21	88	525	454	265	243	351	88	44	88	528	233
Chersonese POM	77	459	555	260	70	101	520	77	459	555	260	70	101	520	77	459	70	122	65	250	27	77	529	459	260	238	346	77	70	77	533	224

Table A.3 Approximated transportation cost factor from EFB supplier, *g* to pre-processing facilities, *h*

	Pelletization Mill1	Pelletization Mill2	Pelletization Mill3	Pelletization Mill4	Pelletization Mill5	Pelletization Mill6	Pelletization Mill7	Torrefied Pelletization1	Torrefied Pelletization2	Torrefied Pelletization3	Torrefied Pelletization4	Torrefied Pelletization5	Torrefied Pelletization6	Torrefied Pelletization7	DLF Production1	DLF Production2	DLF Production3	DLF Production4	DLF Production5	DLF Production6	DLF Production7	Briquetting Plant1	Briquetting Plant2	Aerobic Digestion1	Aerobic Digestion2	Aerobic Digestion3	Extraction Plant1	Extraction Plant2	Extraction Plant3	Alkaline Activation Plant1	Alkaline Activation Plant2	Alkaline Activation Plant3
Tanjung Malim palm oil mill	22	30	33	21	28	18	32	22	30	33	21	28	18	32	22	30	28	15	24	20	27	22	28	22	33	30	21	18	26	22	33	17
KS MEMPAGA-PAHANG	25	29	32	14	29	24	31	25	29	32	14	29	24	31	25	29	29	23	26	13	28	25	29	25	31	29	14	11	25	25	31	13
Tennamaram Palm Oil Mill	25	29	33	16	29	24	31	25	29	33	16	29	24	31	25	29	29	21	25	14	28	25	29	25	32	29	16	12	25	25	32	10
Tuan mee palm oil mill	25	29	32	13	30	25	31	25	29	32	13	30	25	31	25	29	30	24	26	11	29	25	30	25	31	29	13	10	25	25	31	10
SOU 7 Bukit Kerayong	25	29	32	13	30	25	31	25	29	32	13	30	25	31	25	29	30	24	26	12	29	25	30	25	31	29	13	10	25	25	31	8
Bukit Kerayong Palm Oil Mill	25	29	32	13	30	25	31	25	29	32	13	30	25	31	25	29	30	24	26	12	29	25	30	25	31	29	13	10	25	25	31	8
Kilang Kelapa Sawit Risda Durian Mas	30	31	33	30	31	30	32	30	31	33	30	31	30	32	30	31	31	29	30	30	31	30	31	30	32	31	30	29	31	30	32	30
K.K.S Rasau Kerteh	30	30	32	29	31	29	32	30	30	32	29	31	29	32	30	30	31	29	30	29	31	30	31	30	32	30	29	29	30	30	32	30
Kilang Kelapa Sawit Kemaman	30	29	31	28	31	29	30	30	29	31	28	31	29	30	30	29	31	29	30	29	32	30	31	30	31	29	28	28	29	30	31	29
Ladang rakyat mill	29	28	31	28	31	29	30	29	28	31	28	31	29	30	29	28	31	28	30	28	31	29	31	29	30	28	28	28	28	29	30	28
Neram palm oil mill	30	28	30	28	32	29	29	30	28	30	28	32	29	29	30	28	32	28	30	28	32	30	32	30	30	28	28	28	28	30	30	28
TDM kemaman palm oil mill	30	29	31	28	31	29	31	30	29	31	28	31	29	31	30	29	31	28	30	28	31	30	31	30	31	29	28	28	29	30	31	29
Temerloh Mill	30	29	31	28	31	29	31	30	29	31	28	31	29	31	30	29	31	28	30	28	31	30	31	30	31	29	28	28	29	30	31	29
Kechau	25	30	33	26	27	25	32	25	30	33	26	27	25	32	25	30	27	24	25	25	27	25	27	25	32	30	26	25	28	25	32	25
Bukit Puteri Palm Oil Mill	24	30	34	25	27	22	32	24	30	34	25	27	22	32	24	30	27	18	24	25	26	24	27	24	33	30	25	24	28	24	33	25

Tersang palm oil mill	24	30	33	25	27	22	32	24	30	33	25	27	22	32	24	30	27	19	25	24	27	24	27	24	32	30	25	24	27	24	32	24
Minsawi Industries (K. Kangsar)	16	34	38	28	20	18	36	16	34	38	28	20	18	36	16	34	20	21	14	28	16	16	20	16	37	34	28	27	31	16	37	27
SOU 3 Elphil Mill	17	34	37	28	21	19	36	17	34	37	28	21	19	36	17	34	21	21	16	28	19	17	21	17	36	34	28	27	31	17	36	27
Trong mill	12	34	38	28	23	16	36	12	34	38	28	23	16	36	12	34	23	19	10	27	17	12	23	12	37	34	28	27	31	12	37	27
United International Enterprises POM	9	34	37	27	25	13	36	9	34	37	27	25	13	36	9	34	25	17	9	27	22	9	25	9	36	34	27	26	30	9	36	26
Sungei Kahang Palm Oil	8	33	37	27	25	11	35	8	33	37	27	25	11	35	8	33	25	14	9	26	23	8	25	8	36	33	27	26	29	8	36	25
Changkat Chermin	10	33	37	26	25	12	35	10	33	37	26	25	12	35	10	33	25	15	11	26	24	10	25	10	36	33	26	26	29	10	36	25
Pinehill Plantations (Malaysia)	10	33	37	26	25	12	35	10	33	37	26	25	12	35	10	33	25	16	12	26	24	10	25	10	36	33	26	26	29	10	36	25
Syarikat Cahaya Muda Perak (Oil Mil) Sdn Bhd	16	32	35	25	26	12	34	16	32	35	25	26	12	34	16	32	26	9	17	25	25	16	26	16	34	32	25	25	28	16	34	24
Kilang Kelapa Sawit Felcra Seberang Perak	12	32	36	26	26	8	34	12	32	36	26	26	8	34	12	32	26	10	14	25	25	12	26	12	35	32	26	25	29	12	35	24
Felcra Processing & Engineering SB	15	32	35	25	26	11	34	15	32	35	25	26	11	34	15	32	26	10	17	25	25	15	26	15	34	32	25	24	28	15	34	23
Felcra Bidor Palm oil mill	17	31	35	25	27	13	33	17	31	35	25	27	13	33	17	31	27	9	18	24	26	17	27	17	34	31	25	24	28	17	34	22
KKS Besout	18	31	34	24	27	14	33	18	31	34	24	27	14	33	18	31	27	11	20	24	26	18	27	18	33	31	24	23	27	18	33	22
Chalok palm oil mill	29	33	36	30	28	29	35	29	33	36	30	28	29	35	29	33	28	28	29	30	29	29	28	29	35	33	30	30	32	29	35	31
Kilang Sungai Tong	29	33	35	30	29	29	34	29	33	35	30	29	29	34	29	33	29	28	29	30	29	29	29	29	35	33	30	30	32	29	35	30
K.K.S Jerangau Barat	29	31	34	30	30	29	33	29	31	34	30	30	29	33	29	31	30	28	29	30	30	29	30	29	34	31	30	29	31	29	33	30
K.K.S Maokil	29	32	34	30	29	28	34	29	32	34	30	29	28	34	29	32	29	28	29	30	29	29	29	29	34	32	30	29	31	29	34	30
Ladang Serasa	26	33	35	29	26	26	35	26	33	35	29	26	26	35	26	33	26	26	26	28	27	26	26	26	35	33	29	28	31	26	35	28
Kilang Kelapa Sawit Kemahang	28	35	38	31	26	28	37	28	35	38	31	26	28	37	28	35	26	28	28	31	27	28	26	28	37	35	31	31	33	28	37	31
Kuala Pertang POM	28	34	37	30	26	27	36	28	34	37	30	26	27	36	28	34	26	27	27	30	27	28	26	28	37	34	30	30	33	28	37	30

Kilang Kelapa Sawit Paloh 3	26	32	35	28	27	26	34	26	32	35	28	27	26	34	26	32	27	26	26	28	27	26	27	26	34	32	28	28	30	26	34	28
Kilang sawit Chiku	26	32	35	28	27	26	34	26	32	35	28	27	26	34	26	32	27	25	26	28	27	26	27	26	34	32	28	28	30	26	34	28
Solid Orient POM	25	37	40	31		26	39	25	37	40	31		26	39	25	37	0	26	24	30	14	25	0	25	39	37	31	30	34	25	39	30
Kilang Kelapa Sawit Sungai Dingin	25	37	40	31	9	25	39	25	37	40	31	9	25	39	25	37	9	26	24	30	12	25	9	25	39	37	31	30	33	25	39	30
Kilang Sawit Setia Kawan	24	37	40	30	9	25	39	24	37	40	30	9	25	39	24	37	9	26	24	30	11	24	9	24	39	37	30	30	33	24	39	29
Kilang Kelapa Sawit Batu Lintang	22	36	39	30	14	24	38	22	36	39	30	14	24	38	22	36	14	25	20	29	9	22	14	22	38	36	30	29	32	22	38	28
KKS Telok Sengat	21	36	39	29	14	24	38	21	36	39	29	14	24	38	21	36	14	25	19	29	10	21	14	21	38	36	29	29	32	21	38	28
Chersonese POM	20	36	39	29	18	24	38	20	36	39	29	18	24	38	20	36	18	25	18	29	11	20	18	20	38	36	29	28	32	20	38	28
Johor Labis POM	135	14	67	78	171	127	54	135	14	67	78	171	127	54	135	14	171	120	139	82	164	135	171	135	57	14	78	85	57	135	59	93
Kekayaan Palm oil mill	141	11	61	84	176	133	21	141	11	61	84	176	133	21	141	11	176	125	144	88	170	141	176	141	22	11	84	91	62	141	23	99
SOU 20 Chaah	136	14	67	78	172	128	23	136	14	67	78	172	128	23	136	14	172	120	139	82	165	136	172	136	57	14	78	85	55	136	58	92
SELENDANG POM	136	19	69	87	167	128	62	136	19	69	87	167	128	62	136	19	167	121	139	90	163	136	167	136	65	19	87	92	73	136	64	100
Seri Intan Palm Oil Mill	147	12	55	94	180	139	20	147	12	55	94	180	139	20	147	12	180	132	151	97	175	147	180	147	21	12	94	100	74	147	21	108
Lima Blas POM	55	114	146	20	95	20	134	55	114	146	20	95	20	134	55	114	95	17	59	19	86	55	95	55	137	114	20	17	76	55	138	17
SOU 13 Labu POM	92	84	116	12	133	84	102	92	84	116	12	133	84	102	92	84	133	78	96	14	123	92	133	92	105	84	12	16	16	92	107	18
SOU 14 Tanah Merah	94	83	115	13	136	87	101	94	83	115	13	136	87	101	94	83	136	81	98	15	126	94	136	94	103	83	13	17	15	94	106	20
Kilang Kelapa Sawit Ulu Kanchong	101	75	107	16	141	93	93	101	75	107	16	141	93	93	101	75	141	86	105	18	132	101	141	101	96	75	16	20	12	101	98	23
SOU 15 - Sua Betong POM	100	77	110	16	141	93	95	100	77	110	16	141	93	95	100	77	141	86	104	18	132	100	141	100	98	77	16	20	12	100	100	22
Pasoh Palm oil mill	95	74	106	18	132	87	94	95	74	106	18	132	87	94	95	74	132	80	99	19	125	95	132	95	97	74	18	20	20	95	98	56
KS SERTING HILIR-N. SEMBILAN	101	68	100	21	136	93	89	101	68	100	21	136	93	89	101	68	136	85	104	23	130	101	136	101	92	68	21	55	21	101	93	63
Kok Foh oil mill	107	62	95	22	143	99	82	107	62	95	22	143	99	82	107	62	143	92	110	55	136	107	143	107	85	62	22	58	18	107	87	66
Kilang Kelapa Sawit Serting	103	67	99	21	139	94	87	103	67	99	21	139	94	87	103	67	139	87	106	23	132	103	139	103	90	67	21	54	19	103	91	63
Pasir Besar Palm oil mill	112	58	91	55	149	103	78	112	58	91	55	149	103	78	112	58	149	96	115	58	141	112	149	112	81	58	55	61	16	112	83	69

Jeram Padang Mill	106	64	97	21	143	97	84	106	64	97	21	143	97	84	106	64	143	90	109	23	136	106	143	106	87	64	21	55	16	106	88	63
Nam bee oil mill	114	57	89	56	152	106	76	114	57	89	56	152	106	76	114	57	152	99	118	59	145	114	152	114	79	57	56	63	15	114	81	70
Kempas oil mill	118	56	88	58	157	110	74	118	56	88	58	157	110	74	118	56	157	103	122	61	149	118	157	118	77	56	58	65	13	118	79	72
Diamond Jubilee Oil mill	119	54	87	59	158	111	73	119	54	87	59	158	111	73	119	54	158	104	123	63	150	119	158	119	75	54	59	66	14	119	78	74
Dominion Square	119	54	87	59	158	111	73	119	54	87	59	158	111	73	119	54	158	104	123	63	150	119	158	119	75	54	59	66	14	119	78	74
SOU 8 East Mill	81	98	130	12	124	74	116	81	98	130	12	124	74	116	81	98	124	68	85	11	113	81	124	81	119	98	12	12	22	81	121	12
SOU 9 West Mill	79	101	134	13	122	72	120	79	101	134	13	122	72	120	79	101	122	67	83	12	111	79	122	79	122	101	13	13	55	79	125	12
Lepar Utara 4 POM	97	91	118	74	121	90	110	97	91	118	74	121	90	110	97	91	121	83	99	75	118	97	121	97	113	91	74	74	84	97	113	81
lepar utara 6 palm oil mill	92	96	123	73	115	85	115	92	96	123	73	115	85	115	92	96	115	78	94	73	113	92	115	92	118	96	73	72	85	92	118	79
Carotino POM	98	89	116	73	122	91	108	98	89	116	73	122	91	108	98	89	122	83	100	74	120	98	122	98	111	89	73	73	82	98	111	80
Jengka 8 POM	92	87	116	63	120	84	107	92	87	116	63	120	84	107	92	87	120	77	94	64	116	92	120	92	110	87	63	63	74	92	110	71
Kilang Kelapa Sawit Felcra Maran	97	81	111	63	125	89	101	97	81	111	63	125	89	101	97	81	125	82	99	65	121	97	125	97	105	81	63	64	71	97	105	73
Bukit kepayang palm oil mil	97	76	107	57	129	89	96	97	76	107	57	129	89	96	97	76	129	82	100	59	124	97	129	97	99	76	57	59	63	97	100	68
Tementi palm oil mill	99	73	104	56	131	91	94	99	73	104	56	131	91	94	99	73	131	83	102	58	126	99	131	99	97	73	56	59	60	99	97	68
Bukit Sagu POM	109	92	116	86	129	102	110	109	92	116	86	129	102	110	109	92	129	95	110	87	128	109	129	109	113	92	86	86	93	109	112	94
SOU 12 Jabor POM	114	90	113	90	134	108	107	114	90	113	90	134	108	107	114	90	134	101	116	91	133	114	134	114	110	90	90	91	95	114	109	99
Panching Palm oil mill	110	86	111	84	132	103	104	110	86	111	84	132	103	104	110	86	132	96	112	85	131	110	132	110	107	86	84	84	89	110	107	93
Ladang Cheong wing chan	110	82	107	81	134	103	101	110	82	107	81	134	103	101	110	82	134	96	112	82	132	110	134	110	104	82	81	82	85	110	103	90
Lepar hilir palm oil mill	107	81	107	75	132	99	100	107	81	107	75	132	99	100	107	81	132	92	109	77	129	107	132	107	103	81	75	77	80	107	102	85
Kilang Sawit LCSB Lepar	110	78	104	77	135	102	97	110	78	104	77	135	102	97	110	78	135	95	112	79	132	110	135	110	100	78	77	79	80	110	99	87
Sungai jernih mill	114	69	96	75	142	106	88	114	69	96	75	142	106	88	114	69	142	99	116	77	138	114	142	114	91	69	75	78	74	114	91	86
Bukit Lee Lau	116	67	94	76	144	108	86	116	67	94	76	144	108	86	116	67	144	100	118	78	140	116	144	116	89	67	76	79	74	116	89	87
CHINI 2 POM	108	71	100	69	136	100	91	108	71	100	69	136	100	91	108	71	136	92	110	71	133	108	136	108	94	71	69	71	70	108	94	80
Chini 3 Palm oil mill	108	71	100	69	136	100	91	108	71	100	69	136	100	91	108	71	136	92	110	71	133	108	136	108	94	71	69	71	70	108	94	80

KS KRAU-PAHANG	72	99	130	20	106	64	119	72	99	130	20	106	64	119	72	99	106	56	75	20	100	72	106	72	122	99	20	18	69	72	123	21
Kuantan Trading POM	117	60	88	72	147	109	80	117	60	88	72	147	109	80	117	60	147	101	120	74	143	117	147	117	83	60	72	76	66	117	83	84
Padang Piol POM	85	97	126	66	110	78	117	85	97	126	66	110	78	117	85	97	110	71	87	66	107	85	110	85	120	97	66	65	81	85	120	72
Kota Gelanggi palm oil mill	85	97	126	66	110	78	117	85	97	126	66	110	78	117	85	97	110	71	87	66	107	85	110	85	120	97	66	65	81	85	120	72
Jengka 21 POM	87	90	120	61	115	80	110	87	90	120	61	115	80	110	87	90	115	72	90	61	111	87	115	87	114	90	61	60	74	87	114	68
Jengka 3 POM	88	93	122	65	114	80	113	88	93	122	65	114	80	113	88	93	114	73	90	65	111	88	114	88	116	93	65	64	78	88	116	71
KS SEROJA (JENGKA 18)-PAHANG	89	91	120	64	116	81	111	89	91	120	64	116	81	111	89	91	116	74	91	64	112	89	116	89	114	91	64	63	76	89	114	71
Kerdau Palm Oil Mill	86	89	119	56	116	78	109	86	89	119	56	116	78	109	86	89	116	71	89	57	111	86	116	86	112	89	56	56	70	86	113	64
KKS Bukit Mendi	91	78	110	19	126	83	99	91	78	110	19	126	83	99	91	78	126	76	94	20	120	91	126	91	102	78	19	20	54	91	103	57
Kemasul POM	93	77	109	19	128	84	97	93	77	109	19	128	84	97	93	77	128	77	96	20	121	93	128	93	100	77	19	21	23	93	101	57
Syarikat penanaman bukti senorang	95	75	107	20	130	87	95	95	75	107	20	130	87	95	95	75	130	79	98	21	123	95	130	95	98	75	20	21	22	95	99	59
Selaba oil mill	16	131	164	63	81	12	151	16	131	164	63	81	12	151	16	131	81	10	18	60	70	16	81	16	154	131	63	56	92	16	156	22
Seri Pelangi POM	16	129	162	62	81	12	150	16	129	162	62	81	12	150	16	129	81	10	18	59	71	16	81	16	153	129	62	55	91	16	154	22
Flemington POM	15	136	169	66	82	13	156	15	136	169	66	82	13	156	15	136	82	13	17	63	70	15	82	15	159	136	66	59	95	15	161	23
Jendarata Palm Oil Mill (P01)	17	130	163	61	85	14	150	17	130	163	61	85	14	150	17	130	85	12	19	57	74	17	85	17	153	130	61	23	90	17	155	21
Southern Perak Plantation S/B	18	129	161	59	87	15	149	18	129	161	59	87	15	149	18	129	87	13	20	56	76	18	87	18	152	129	59	22	88	18	153	20
Ulu bernam POM	20	124	157	55	90	16	144	20	124	157	55	90	16	144	20	124	90	14	22	22	79	20	90	20	147	124	55	20	84	20	149	18
Trolak palm oil mill	20	122	155	57	86	16	143	20	122	155	57	86	16	143	20	122	86	12	21	54	77	20	86	20	146	122	57	22	86	20	147	21
Sungai Tengi palm oil mill	58	112	145	19	99	21	132	58	112	145	19	99	21	132	58	112	99	18	62	17	89	58	99	58	135	112	19	15	73	58	137	15
Kilang Kelapa Sawit Ulu Basir	21	120	152	22	92	18	140	21	120	152	22	92	18	140	21	120	92	15	54	21	82	21	92	21	143	120	22	19	80	21	144	17
Tanjung Malim palm oil mill	22	117	150	21	93	18	138	22	117	150	21	93	18	138	22	117	93	15	56	20	83	22	93	22	141	117	21	18	79	22	142	17
KS MEMPAGA-PAHANG	68	103	135	14	108	60	122	68	103	135	14	108	60	122	68	103	108	23	71	13	99	68	108	68	125	103	14	11	64	68	127	13

Tennamaram Palm Oil Mill	64	109	142	16	106	56	128	64	109	142	16	106	56	128	64	109	106	21	68	14	96	64	106	64	131	109	16	12	67	64	133	10
Tuan mee palm oil mill	69	104	136	13	110	61	123	69	104	136	13	110	61	123	69	104	110	55	73	11	101	69	110	69	126	104	13	10	62	69	128	10
SOU 7 Bukit Kerayong	70	105	138	13	112	62	124	70	105	138	13	112	62	124	70	105	112	57	74	12	102	70	112	70	127	105	13	10	62	70	129	8
Bukit Kerayong Palm Oil Mill	70	105	138	13	112	62	124	70	105	138	13	112	62	124	70	105	112	57	74	12	102	70	112	70	127	105	13	10	62	70	129	8
Kilang Kelapa Sawit Risda Durian Mas	117	120	141	112	125	112	137	117	120	141	112	125	112	137	117	120	125	107	118	112	128	117	125	117	140	120	112	110	123	117	139	117
K.K.S Rasau Kerteh	114	114	135	105	124	108	131	114	114	135	105	124	108	131	114	114	124	102	114	105	126	114	124	114	134	114	105	104	115	114	132	110
Kilang Kelapa Sawit Kemaman	116	103	125	100	130	110	120	116	103	125	100	130	110	120	116	103	130	103	117	101	131	116	130	116	123	103	100	100	108	116	122	107
Ladang rakyat mill	110	98	121	92	127	104	115	110	98	121	92	127	104	115	110	98	127	97	112	93	127	110	127	110	119	98	92	91	100	110	117	99
Neram palm oil mill	113	93	115	91	132	107	110	113	93	115	91	132	107	110	113	93	132	100	115	92	132	113	132	113	113	93	91	91	97	113	112	99
TDM kemaman palm oil mill	111	107	130	99	124	105	125	111	107	130	99	124	105	125	111	107	124	99	112	99	125	111	124	111	128	107	99	98	109	111	127	105
Temerloh Mill	111	107	130	99	124	105	125	111	107	130	99	124	105	125	111	107	124	99	112	99	125	111	124	111	128	107	99	98	109	111	127	105
Kechau	68	116	146	71	90	61	136	68	116	146	71	90	61	136	68	116	90	55	69	70	87	68	90	68	139	116	71	66	93	68	140	70
Bukit Puteri Palm Oil Mill	57	119	150	65	85	22	140	57	119	150	65	85	22	140	57	119	85	18	59	64	80	57	85	57	143	119	65	60	91	57	144	62
Tersang palm oil mill	59	116	147	62	88	22	136	59	116	147	62	88	22	136	59	116	88	19	61	60	83	59	88	59	139	116	62	56	87	59	140	59
Minsawi Industries (K. Kangsar)	16	159	190	96	20	18	179	16	159	190	96	20	18	179	16	159	20	21	14	93	16	16	20	16	182	159	96	88	124	16	183	85
SOU 3 Elphil Mill	17	155	186	94	21	19	175	17	155	186	94	21	19	175	17	155	21	21	16	91	19	17	21	17	178	155	94	87	122	17	179	85
Trong mill	12	158	191	92	23	16	179	12	158	191	92	23	16	179	12	158	23	19	10	89	17	12	23	12	182	158	92	85	121	12	183	81
United International Enterprises POM	9	153	185	85	63	13	173	9	153	185	85	63	13	173	9	153	63	17	9	82	22	9	63	9	176	153	85	78	114	9	178	73
Sungei Kahang Palm Oil	8	148	180	81	64	11	168	8	148	180	81	64	11	168	8	148	64	14	9	78	23	8	64	8	171	148	81	74	110	8	173	70
Changkat Chermin	10	149	181	80	68	12	169	10	149	181	80	68	12	169	10	149	68	15	11	77	56	10	68	10	172	149	80	73	109	10	173	67
Pinehill Plantations (Malaysia)	10	149	182	80	69	12	169	10	149	182	80	69	12	169	10	149	69	16	12	77	57	10	69	10	172	149	80	73	109	10	173	67

Syarikat Cahaya Muda Perak (Oil Mil) Sdn Bhd	16	132	164	68	75	12	152	16	132	164	68	75	12	152	16	132	75	9	17	65	67	16	75	16	155	132	68	61	96	16	156	59
Kilang Kelapa Sawit Felcra Seberang Perak	12	139	172	72	73	8	159	12	139	172	72	73	8	159	12	139	73	10	14	68	62	12	73	12	162	139	72	64	101	12	164	60
Felcra Processing & Engineering SB	15	133	166	65	79	11	153	15	133	166	65	79	11	153	15	133	79	10	17	62	69	15	79	15	156	133	65	58	94	15	158	23
Felcra Bidor Palm oil mill	17	129	161	62	81	13	149	17	129	161	62	81	13	149	17	129	81	9	18	59	71	17	81	17	152	129	62	55	91	17	154	22
KKS Besout	18	125	157	60	83	14	145	18	125	157	60	83	14	145	18	125	83	11	20	57	74	18	83	18	148	125	60	23	89	18	150	22
Chalok palm oil mill	104	148	172	120	97	101	166	104	148	172	120	97	101	166	104	148	97	98	102	119	104	104	97	104	169	148	120	116	139	104	169	120
Kilang Sungai Tong	105	142	166	117	103	102	160	105	142	166	117	103	102	160	105	142	103	99	105	117	108	105	103	105	163	142	117	114	135	105	162	119
K.K.S Jerangau Barat	107	130	153	111	110	103	147	107	130	153	111	110	103	147	107	130	110	98	107	110	114	107	110	107	150	130	111	108	126	107	149	113
K.K.S Maokil	102	135	159	111	103	99	153	102	135	159	111	103	99	153	102	135	103	94	102	110	108	102	103	102	156	135	111	108	128	102	155	113
Ladang Serasa	78	141	169	101	78	75	161	78	141	169	101	78	75	161	78	141	78	72	77	99	81	78	78	78	164	141	101	96	123	78	164	98
Kilang Kelapa Sawit Kemahang	93	166	193	126	75	93	186	93	166	193	126	75	93	186	93	166	75	92	90	124	84	93	75	93	189	166	126	121	149	93	188	123
Kuala Pertang POM	91	159	185	120	77	90	178	91	159	185	120	77	90	178	91	159	77	89	88	118	85	91	77	91	181	159	120	115	143	91	181	117
Kilang Kelapa Sawit Paloh 3	79	137	164	98	82	76	156	79	137	164	98	82	76	156	79	137	82	73	79	97	85	79	82	79	159	137	98	93	120	79	159	97
Kilang sawit Chiku	76	136	164	95	81	73	155	76	136	164	95	81	73	155	76	136	81	69	75	94	83	76	81	76	159	136	95	90	117	76	158	93
Solid Orient POM	64	184	215	122		71	204	64	184	215	122		71	204	64	184		76	60	119	14	64		64	207	184	122	115	151	64	208	112
Kilang Kelapa Sawit Sungai Dingin	62	183	214	121	9	69	204	62	183	214	121	9	69	204	62	183	9	74	58	118	12	62	9	62	207	183	121	114	150	62	208	111
Kilang Sawit Setia Kawan	60	182	213	119	9	67	202	60	182	213	119	9	67	202	60	182	9	72	56	116	11	60	9	60	205	182	119	112	148	60	206	109
Kilang Kelapa Sawit Batu Lintang	22	174	206	111	14	58	195	22	174	206	111	14	58	195	22	174	14	64	20	107	9	22	14	22	198	174	111	103	139	22	199	100
KKS Telok Sengat	21	172	203	109	14	56	192	21	172	203	109	14	56	192	21	172	14	62	19	106	10	21	14	21	195	172	109	102	137	21	196	98
Chersonese POM	20	173	205	107	18	54	194	20	173	205	107	18	54	194	20	173	18	61	18	104	11	20	18	20	197	173	107	100	136	20	198	95
SEMENCHU POM	181	23		125	215	173	14	181	23		125	215	173	14	181	23	215	165	184	128	209	181	215	181	13	23	125	131	100	181	12	139

Table A.4 Approximated CO_2 emission factor (10^{-3}) from EFB supplier, *g* to pre-processing facilities, *h*

	Pelletization Mill1	Pelletization Mill2	Pelletization Mill3	Pelletization Mill4	Pelletization Mill5	Pelletization Mill6	Pelletization Mill7	Torrefied Pelletization1	Torrefied Pelletization2	Torrefied Pelletization3	Torrefied Pelletization4	Torrefied Pelletization5	Torrefied Pelletization6	Torrefied Pelletization7	Aerobic Digestion1	Aerobic Digestion2	Aerobic Digestion3	Extraction Plant1	Extraction Plant2	Extraction Plant3	Briquetting Plant1	Briquetting Plant2	DLF Production1	DLF Production2	DLF Production3	DLF Production4	DLF Production5	DLF Production6	DLF Production7	Alkaline Activation Plant1	Alkaline Activation Plant2	Alkaline Activation Plant3
TENGGAROH	9.4	3.5	3.9	5.8	11.5	8.8	3.4	9.4	3.5	3.9	5.8	11.5	8.8	3.4	9.4	3.9	3.5	5.8	6.2	4.4	9.4	11.5	9.4	3.5	11.5	8.3	9.6	6.0	11.2	9.4	3.4	6.8
TENGGAROH TIMUR	9.3	3.9	4.2	5.8	11.4	8.8	4.0	9.3	3.9	4.2	5.8	11.4	8.8	4.0	9.3	4.4	3.9	5.8	6.2	4.5	9.3	11.4	9.3	3.9	11.4	8.3	9.5	6.1	11.1	9.3	3.9	6.8
Kilang Sawit Risda Sg Ambat	9.3	3.6	4.2	5.8	11.4	8.8	3.7	9.3	3.6	4.2	5.8	11.4	8.8	3.7	9.3	4.2	3.6	5.8	6.2	4.4	9.3	11.4	9.3	3.6	11.4	8.3	9.5	6.0	11.1	9.3	3.7	6.7
Tunjuk Laut	9.7	4.2	2.8	6.1	11.9	9.2	3.0	9.7	4.2	2.8	6.1	11.9	9.2	3.0	9.7	3.3	4.2	6.1	6.6	4.7	9.7	11.9	9.7	4.2	11.9	8.7	9.9	6.4	11.6	9.7	2.7	7.1
ulu Sibol Oil mill	9.2	2.1	4.0	5.5	11.5	8.7	1.9	9.2	2.1	4.0	5.5	11.5	8.7	1.9	9.2	2.5	2.1	5.5	5.9	3.9	9.2	11.5	9.2	2.1	11.5	8.2	9.4	5.7	11.1	9.2	2.5	6.4
Sg kachur POM	9.6	3.4	2.7	5.9	11.9	9.1	1.2	9.6	3.4	2.7	5.9	11.9	9.1	1.2	9.6	1.6	3.4	5.9	6.3	4.3	9.6	11.9	9.6	3.4	11.9	8.6	9.9	6.1	11.5	9.6	1.4	6.9
Kilang sawit Wa ha	10.2	5.2	1.5	6.6	12.4	9.7	2.8	10.2	5.2	1.5	6.6	12.4	9.7	2.8	10.2	2.9	5.2	6.6	7.0	5.1	10.2	12.4	10.2	5.2	12.4	9.2	10.4	6.8	12.0	10.2	2.1	7.5
Kulai POM	9.5	3.0	3.3	5.7	11.8	9.0	0.8	9.5	3.0	3.3	5.7	11.8	9.0	0.8	9.5	1.4	3.0	5.7	6.2	4.1	9.5	11.8	9.5	3.0	11.8	8.5	9.7	6.0	11.4	9.5	1.6	6.7
YPJ POM	9.6	3.3	2.9	5.9	11.9	9.1	0.7	9.6	3.3	2.9	5.9	11.9	9.1	0.7	9.6	1.3	3.3	5.9	6.3	4.3	9.6	11.9	9.6	3.3	11.9	8.6	9.9	6.1	11.5	9.6	1.3	6.8
K.K.S Tai Tak	10.0	4.3	1.9	6.2	12.2	9.4	1.2	10.0	4.3	1.9	6.2	12.2	9.4	1.2	10.0	1.3	4.3	6.2	6.7	4.6	10.0	12.2	10.0	4.3	12.2	8.9	10.2	6.4	11.8	10.0	0.7	7.2
Adela POM	10.8	2.4	0.6	7.1	13.0	10.3	3.4	10.8	2.4	0.6	7.1	13.0	10.3	3.4	10.8	3.1	2.4	7.1	7.5	5.5	10.8	13.0	10.8	2.4	13.0	9.8	11.0	7.3	12.7	10.8	2.4	8.0
KILANG KELAPA SAWIT SIANG	10.8	2.4	0.8	7.1	13.1	10.3	3.5	10.8	2.4	0.8	7.1	13.1	10.3	3.5	10.8	3.2	2.4	7.1	7.6	5.6	10.8	13.1	10.8	2.4	13.1	9.8	11.1	7.4	12.7	10.8	2.5	8.1
Kilang Kelapa Sawit Sedenak	10.2	4.9	2.5	6.3	12.5	9.6	1.2	10.2	4.9	2.5	6.3	12.5	9.6	1.2	10.2	0.6	4.9	6.3	6.8	4.6	10.2	12.5	10.2	4.9	12.5	9.1	10.4	6.6	12.1	10.2	1.1	7.3
Masai Palm Oil Mill	10.4	5.5	1.0	6.6	12.7	9.9	1.9	10.4	5.5	1.0	6.6	12.7	9.9	1.9	10.4	1.5	5.5	6.6	7.1	5.0	10.4	12.7	10.4	5.5	12.7	9.4	10.6	6.9	12.3	10.4	0.9	7.6
Keck Seng POM	10.4	5.5	1.0	6.6	12.7	9.9	1.9	10.4	5.5	1.0	6.6	12.7	9.9	1.9	10.4	1.5	5.5	6.6	7.1	5.0	10.4	12.7	10.4	5.5	12.7	9.4	10.6	6.9	12.3	10.4	0.9	7.6
Pagoh Palm Oil Mill	7.4	4.1	3.5	3.5	9.9	6.9	2.6	7.4	4.1	3.5	3.5	9.9	6.9	2.6	7.4	2.7	4.1	3.5	3.9	5.0	7.4	9.9	7.4	4.1	9.9	6.4	7.6	3.7	9.4	7.4	2.9	4.4
Pamol Plantation	7.3	4.4	3.6	3.4	9.9	6.8	2.6	7.3	4.4	3.6	3.4	9.9	6.8	2.6	7.3	2.8	4.4	3.4	3.9	4.7	7.3	9.9	7.3	4.4	9.9	6.3	7.6	3.6	9.4	7.3	3.0	4.3
Muar oil mill	7.4	4.7	3.6	3.4	10.0	6.9	2.7	7.4	4.7	3.6	3.4	10.0	6.9	2.7	7.4	2.8	4.7	3.4	3.9	4.7	7.4	10.0	7.4	4.7	10.0	6.4	7.7	3.7	9.4	7.4	3.0	4.4

Pamol Klauang	8.4	0.4	6.1	4.7	10.7	7.9	4.0	8.4	0.4	6.1	4.7	10.7	7.9	4.0	8.4	4.6	0.4	4.7	5.1	3.3	8.4	10.7	8.4	0.4	10.7	7.4	8.7	5.0	10.3	8.4	4.7	5.7
Tereh Palm oil mill	8.2	1.1	2.4	4.5	10.4	7.6	4.7	8.2	1.1	2.4	4.5	10.4	7.6	4.7	8.2	5.3	1.1	4.5	4.9	3.1	8.2	10.4	8.2	1.1	10.4	7.2	8.4	4.7	10.1	8.2	5.4	5.5
Sindpra POM	8.4	0.4	2.2	4.7	10.8	7.9	3.9	8.4	0.4	2.2	4.7	10.8	7.9	3.9	8.4	4.4	0.4	4.7	5.1	3.1	8.4	10.8	8.4	0.4	10.8	7.4	8.7	4.9	10.4	8.4	4.7	5.6
Dara Lam Soon	8.4	0.7	2.3	4.6	10.7	7.8	4.1	8.4	0.7	2.3	4.6	10.7	7.8	4.1	8.4	4.6	0.7	4.6	5.0	3.0	8.4	10.7	8.4	0.7	10.7	7.3	8.6	4.8	10.3	8.4	4.9	5.5
Ayer Itam Oil Mill	8.4	1.5	2.4	4.5	10.8	7.8	4.1	8.4	1.5	2.4	4.5	10.8	7.8	4.1	8.4	4.6	1.5	4.5	5.0	2.9	8.4	10.8	8.4	1.5	10.8	7.4	8.6	4.8	10.3	8.4	5.1	5.5
Bukit Benut Oil Palm Mill	8.6	0.9	5.8	4.9	11.0	8.1	3.2	8.6	0.9	5.8	4.9	11.0	8.1	3.2	8.6	3.8	0.9	4.9	5.3	3.3	8.6	11.0	8.6	0.9	11.0	7.6	8.9	5.1	10.6	8.6	4.1	5.8
Bukit Benut POM	8.7	1.0	5.8	4.8	11.0	8.1	3.2	8.7	1.0	5.8	4.8	11.0	8.1	3.2	8.7	3.8	1.0	4.8	5.3	3.2	8.7	11.0	8.7	1.0	11.0	7.6	8.9	5.1	10.6	8.7	4.1	5.8
Bukit Lawiang POM	8.7	0.8	5.3	5.0	11.1	8.2	3.0	8.7	0.8	5.3	5.0	11.1	8.2	3.0	8.7	3.6	0.8	5.0	5.4	3.4	8.7	11.1	8.7	0.8	11.1	7.7	9.0	5.2	10.7	8.7	3.8	5.9
KKS Belitong	8.9	1.3	4.9	5.2	11.2	8.4	2.6	8.9	1.3	4.9	5.2	11.2	8.4	2.6	8.9	3.2	1.3	5.2	5.6	3.6	8.9	11.2	8.9	1.3	11.2	7.9	9.1	5.4	10.8	8.9	3.3	6.1
Ulu remis oil mill	9.0	1.7	4.8	5.2	11.4	8.5	2.2	9.0	1.7	4.8	5.2	11.4	8.5	2.2	9.0	2.8	1.7	5.2	5.7	3.6	9.0	11.4	9.0	1.7	11.4	8.0	9.2	5.4	10.9	9.0	3.1	6.2
Nam Heng Oil mill Co Sdn bhd	8.1	2.9	2.8	4.2	10.6	7.6	5.3	8.1	2.9	2.8	4.2	10.6	7.6	5.3	8.1	5.7	2.9	4.2	4.7	2.5	8.1	10.6	8.1	2.9	10.6	7.1	8.4	4.4	10.1	8.1	2.2	5.1
Gomali Oil Mill	8.9	1.8	5.5	5.0	11.3	8.3	2.8	8.9	1.8	5.5	5.0	11.3	8.3	2.8	8.9	3.3	1.8	5.0	5.5	3.3	8.9	11.3	8.9	1.8	11.3	7.8	9.1	5.2	10.8	8.9	3.7	6.0
Hadapan Palm Oil Mill	9.1	1.9	4.6	5.3	11.4	8.5	2.0	9.1	1.9	4.6	5.3	11.4	8.5	2.0	9.1	2.6	1.9	5.3	5.7	3.6	9.1	11.4	9.1	1.9	11.4	8.1	9.3	5.5	11.0	9.1	2.9	6.2
KKS Nitar	8.5	3.1	2.3	5.1	10.6	8.0	5.4	8.5	3.1	2.3	5.1	10.6	8.0	5.4	8.5	6.0	3.1	5.1	5.4	3.9	8.5	10.6	8.5	3.1	10.6	7.5	8.7	5.3	10.3	8.5	5.7	6.0
Wujud Wawasan	6.0	2.7	4.7	2.9	8.1	5.4	4.0	6.0	2.7	4.7	2.9	8.1	5.4	4.0	6.0	4.3	2.7	2.9	3.1	2.5	6.0	8.1	6.0	2.7	8.1	4.9	6.2	3.0	7.8	6.0	4.3	3.7
Kota bahagia palm oil mill	6.3	2.5	4.5	3.1	8.4	5.7	3.8	6.3	2.5	4.5	3.1	8.4	5.7	3.8	6.3	4.0	2.5	3.1	3.4	2.6	6.3	8.4	6.3	2.5	8.4	5.2	6.5	3.3	8.0	6.3	4.0	4.0
KKS Keratong 9	6.4	2.4	4.4	3.2	8.5	5.8	3.7	6.4	2.4	4.4	3.2	8.5	5.8	3.7	6.4	3.9	2.4	3.2	3.5	2.7	6.4	8.5	6.4	2.4	8.5	5.3	6.5	3.4	8.1	6.4	3.9	4.1
Keratong 3 palm oil mill	6.2	2.4	4.5	2.9	8.4	5.7	3.8	6.2	2.4	4.5	2.9	8.4	5.7	3.8	6.2	4.0	2.4	2.9	3.2	2.4	6.2	8.4	6.2	2.4	8.4	5.2	6.4	3.1	8.0	6.2	4.0	3.8
Keratong 2 Palm oil mill	6.3	2.4	4.4	3.1	8.4	5.8	3.8	6.3	2.4	4.4	3.1	8.4	5.8	3.8	6.3	4.0	2.4	3.1	3.4	2.7	6.3	8.4	6.3	2.4	8.4	5.3	6.5	3.3	8.1	6.3	4.0	4.0
Palong Timor Palm oil mill	6.1	2.3	4.5	2.6	8.5	5.6	3.7	6.1	2.3	4.5	2.6	8.5	5.6	3.7	6.1	3.9	2.3	2.6	3.0	5.2	6.1	8.5	6.1	2.3	8.5	5.1	6.4	2.8	8.1	6.1	3.9	3.5
Pukin Palm Oil Mill	6.6	5.5	4.0	3.1	8.8	6.0	3.3	6.6	5.5	4.0	3.1	8.8	6.0	3.3	6.6	3.5	5.5	3.1	3.5	2.2	6.6	8.8	6.6	5.5	8.8	5.5	6.8	3.3	8.4	6.6	3.6	4.0
Palong cocoa pom	6.5	5.6	4.1	2.9	8.8	6.0	3.3	6.5	5.6	4.1	2.9	8.8	6.0	3.3	6.5	3.5	5.6	2.9	3.3	5.6	6.5	8.8	6.5	5.6	8.8	5.5	6.7	3.1	8.4	6.5	3.6	3.8
RISDA ulu keratong	6.6	5.3	4.0	3.0	8.9	6.1	3.2	6.6	5.3	4.0	3.0	8.9	6.1	3.2	6.6	3.4	5.3	3.0	3.4	5.6	6.6	8.9	6.6	5.3	8.9	5.6	6.8	3.2	8.5	6.6	3.5	3.9
Selancar 2b	6.9	4.7	3.7	3.4	9.1	6.3	3.0	6.9	4.7	3.7	3.4	9.1	6.3	3.0	6.9	3.2	4.7	3.4	3.7	2.4	6.9	9.1	6.9	4.7	9.1	5.8	7.1	3.6	8.7	6.9	3.3	4.3
Selancar 2A	6.9	4.7	3.7	3.4	9.1	6.3	3.0	6.9	4.7	3.7	3.4	9.1	6.3	3.0	6.9	3.2	4.7	3.4	3.8	2.4	6.9	9.1	6.9	4.7	9.1	5.8	7.1	3.6	8.7	6.9	3.3	4.3

Johor Labis POM	7.6	2.5	3.1	3.8	9.9	7.0	2.2	7.6	2.5	3.1	3.8	9.9	7.0	2.2	7.6	2.4	2.5	3.8	4.2	2.4	7.6	9.9	7.6	2.5	9.9	6.6	7.8	4.1	9.5	7.6	2.5	4.8
Kekayaan Palm oil mill	7.9	1.4	2.7	4.2	10.3	7.4	5.2	7.9	1.4	2.7	4.2	10.3	7.4	5.2	7.9	5.8	1.4	4.2	4.6	2.8	7.9	10.3	7.9	1.4	10.3	6.9	8.2	4.4	9.9	7.9	6.0	5.2
SOU 20 Chaah	7.6	2.6	3.1	3.8	10.0	7.1	6.2	7.6	2.6	3.1	3.8	10.0	7.1	6.2	7.6	2.4	2.6	3.8	4.2	2.3	7.6	10.0	7.6	2.6	10.0	6.6	7.8	4.0	9.6	7.6	2.5	4.7
SELENDANG POM	7.6	4.5	3.2	4.4	9.7	7.1	2.7	7.6	4.5	3.2	4.4	9.7	7.1	2.7	7.6	2.9	4.5	4.4	4.7	3.4	7.6	9.7	7.6	4.5	9.7	6.6	7.8	4.6	9.4	7.6	2.9	5.3
Seri Intan Palm Oil Mill	8.4	2.1	2.3	4.8	10.5	7.8	4.9	8.4	2.1	2.3	4.8	10.5	7.8	4.9	8.4	5.5	2.1	4.8	5.2	3.5	8.4	10.5	8.4	2.1	10.5	7.3	8.6	5.1	10.2	8.4	5.3	5.8
Lima Blas POM	2.3	6.2	8.3	5.1	4.9	5.0	7.5	2.3	6.2	8.3	5.1	4.9	5.0	7.5	2.3	7.7	6.2	5.1	3.8	3.7	2.3	4.9	2.3	6.2	4.9	3.7	2.5	4.6	4.3	2.3	7.8	3.7
SOU 13 Labu POM	4.7	4.2	6.3	1.9	7.4	4.2	5.4	4.7	4.2	6.3	1.9	7.4	4.2	5.4	4.7	5.6	4.2	1.9	3.3	3.4	4.7	7.4	4.7	4.2	7.4	3.8	5.0	2.5	6.8	4.7	5.7	4.4
SOU 14 Tanah Merah	4.9	4.1	6.2	2.5	7.6	4.4	5.3	4.9	4.1	6.2	2.5	7.6	4.4	5.3	4.9	5.5	4.1	2.5	3.8	3.0	4.9	7.6	4.9	4.1	7.6	4.0	5.1	3.1	7.0	4.9	5.6	4.8
Kilang Kelapa Sawit Ulu Kanchong	5.3	3.6	5.7	3.6	8.0	4.8	4.8	5.3	3.6	5.7	3.6	8.0	4.8	4.8	5.3	5.0	3.6	3.6	5.0	1.8	5.3	8.0	5.3	3.6	8.0	4.3	5.6	4.3	7.4	5.3	5.1	6.1
SOU 15 - Sua Betong POM	5.3	3.8	5.9	3.6	8.0	4.8	4.9	5.3	3.8	5.9	3.6	8.0	4.8	4.9	5.3	5.1	3.8	3.6	4.9	1.9	5.3	8.0	5.3	3.8	8.0	4.4	5.5	4.2	7.4	5.3	5.3	5.9
Pasoh Palm oil mill	4.9	3.5	5.7	4.2	7.4	4.4	4.8	4.9	3.5	5.7	4.2	7.4	4.4	4.8	4.9	5.1	3.5	4.2	5.0	4.9	4.9	7.4	4.9	3.5	7.4	3.9	5.2	4.7	6.9	4.9	5.1	2.4
KS SERTING HILIR-N. SEMBILAN	5.3	3.2	5.3	5.5	7.6	4.8	4.5	5.3	3.2	5.3	5.5	7.6	4.8	4.5	5.3	4.7	3.2	5.5	2.3	5.4	5.3	7.6	5.3	3.2	7.6	4.3	5.5	6.1	7.2	5.3	4.8	2.8
Kok Foh oil mill	5.7	2.7	4.9	5.9	8.1	5.2	4.1	5.7	2.7	4.9	5.9	8.1	5.2	4.1	5.7	4.3	2.7	5.9	2.5	4.3	5.7	8.1	5.7	2.7	8.1	4.7	5.9	2.3	7.7	5.7	4.4	3.0
Kilang Kelapa Sawit Serting	5.4	3.0	5.2	5.4	7.8	4.9	4.4	5.4	3.0	5.2	5.4	7.8	4.9	4.4	5.4	4.6	3.0	5.4	2.2	4.7	5.4	7.8	5.4	3.0	7.8	4.4	5.6	5.9	7.4	5.4	4.7	2.8
Pasir Besar Palm oil mill	6.0	2.5	4.7	2.2	8.5	5.5	3.8	6.0	2.5	4.7	2.2	8.5	5.5	3.8	6.0	4.0	2.5	2.2	2.7	3.6	6.0	8.5	6.0	2.5	8.5	5.0	6.2	2.5	8.0	6.0	4.1	3.2
Jeram Padang Mill	5.6	2.9	5.0	5.3	8.1	5.1	4.2	5.6	2.9	5.0	5.3	8.1	5.1	4.2	5.6	4.4	2.9	5.3	2.3	3.6	5.6	8.1	5.6	2.9	8.1	4.6	5.9	5.9	7.6	5.6	4.5	2.8
Nam bee oil mill	6.2	2.4	4.5	2.3	8.7	5.7	3.6	6.2	2.4	4.5	2.3	8.7	5.7	3.6	6.2	3.8	2.4	2.3	2.8	3.1	6.2	8.7	6.2	2.4	8.7	5.2	6.4	2.6	8.2	6.2	4.0	3.3
Kempas oil mill	6.4	2.4	4.5	2.5	9.0	5.9	3.6	6.4	2.4	4.5	2.5	9.0	5.9	3.6	6.4	3.7	2.4	2.5	2.9	2.4	6.4	9.0	6.4	2.4	9.0	5.4	6.7	2.7	8.5	6.4	3.9	3.4
Diamond Jubilee Oil mill	6.5	2.2	4.4	2.6	9.1	6.0	3.4	6.5	2.2	4.4	2.6	9.1	6.0	3.4	6.5	3.6	2.2	2.6	3.0	2.8	6.5	9.1	6.5	2.2	9.1	5.5	6.8	2.8	8.5	6.5	3.8	3.5
Dominion Square	6.5	2.2	4.4	2.6	9.1	6.0	3.4	6.5	2.2	4.4	2.6	9.1	6.0	3.4	6.5	3.6	2.2	2.6	3.0	2.8	6.5	9.1	6.5	2.2	9.1	5.5	6.8	2.8	8.5	6.5	3.8	3.5
SOU 8 East Mill	4.0	5.1	7.3	1.8	6.8	3.5	6.3	4.0	5.1	7.3	1.8	6.8	3.5	6.3	4.0	6.5	5.1	1.8	2.1	5.8	4.0	6.8	4.0	5.1	6.8	3.2	4.3	1.6	6.1	4.0	6.7	2.1
SOU 9 West Mill	3.8	5.3	7.5	2.3	6.7	3.4	6.6	3.8	5.3	7.5	2.3	6.7	3.4	6.6	3.8	6.7	5.3	2.3	2.3	2.3	3.8	6.7	3.8	5.3	6.7	3.0	4.1	2.0	6.0	3.8	6.9	1.8

Lepar Utara 4 POM	5.1	4.6	6.4	3.5	6.6	4.6	5.9	5.1	4.6	6.4	3.5	6.6	4.6	5.9	5.1	6.1	4.6	3.5	3.5	4.2	5.1	6.6	5.1	4.6	6.6	4.1	5.2	3.6	6.5	5.1	6.1	4.0
lepar utara 6 palm oil mill	4.7	5.0	6.8	3.4	6.2	4.3	6.2	4.7	5.0	6.8	3.4	6.2	4.3	6.2	4.7	6.5	5.0	3.4	3.4	4.3	4.7	6.2	4.7	5.0	6.2	3.8	4.8	3.5	6.1	4.7	6.4	3.9
Carotino POM	5.1	4.5	6.3	3.4	6.7	4.6	5.8	5.1	4.5	6.3	3.4	6.7	4.6	5.8	5.1	6.0	4.5	3.4	3.4	4.1	5.1	6.7	5.1	4.5	6.7	4.2	5.2	3.5	6.5	5.1	6.0	4.0
Jengka 8 POM	4.7	4.4	6.3	2.8	6.5	4.2	5.7	4.7	4.4	6.3	2.8	6.5	4.2	5.7	4.7	5.9	4.4	2.8	2.8	3.6	4.7	6.5	4.7	4.4	6.5	3.7	4.9	2.9	6.3	4.7	5.9	3.3
Kilang Kelapa Sawit Felcra Maran	5.0	4.0	6.0	2.8	6.9	4.5	5.3	5.0	4.0	6.0	2.8	6.9	4.5	5.3	5.0	5.6	4.0	2.8	2.9	3.4	5.0	6.9	5.0	4.0	6.9	4.0	5.2	2.9	6.7	5.0	5.6	3.4
Bukit kepayang palm oil mil	5.1	3.7	5.7	2.4	7.1	4.5	5.0	5.1	3.7	5.7	2.4	7.1	4.5	5.0	5.1	5.2	3.7	2.4	2.5	2.8	5.1	7.1	5.1	3.7	7.1	4.0	5.3	2.5	6.8	5.1	5.2	3.1
Tementi palm oil mill	5.2	3.5	5.5	2.4	7.3	4.6	4.8	5.2	3.5	5.5	2.4	7.3	4.6	4.8	5.2	5.0	3.5	2.4	2.5	2.6	5.2	7.3	5.2	3.5	7.3	4.1	5.4	2.5	7.0	5.2	5.1	3.1
Bukit Sagu POM	5.8	4.7	6.3	4.3	7.1	5.4	5.9	5.8	4.7	6.3	4.3	7.1	5.4	5.9	5.8	6.1	4.7	4.3	4.3	4.8	5.8	7.1	5.8	4.7	7.1	4.9	5.9	4.4	7.1	5.8	6.0	4.8
SOU 12 Jabor POM	6.2	4.6	6.1	4.6	7.5	5.7	5.7	6.2	4.6	6.1	4.6	7.5	5.7	5.7	6.2	5.9	4.6	4.6	4.6	4.9	6.2	7.5	6.2	4.6	7.5	5.3	6.3	4.7	7.5	6.2	5.9	5.2
Panching Palm oil mill	5.9	4.3	6.0	4.2	7.4	5.5	5.5	5.9	4.3	6.0	4.2	7.4	5.5	5.5	5.9	5.7	4.3	4.2	4.2	4.5	5.9	7.4	5.9	4.3	7.4	5.0	6.1	4.3	7.3	5.9	5.7	4.8
Ladang Cheong wing chan	5.9	4.1	5.7	4.0	7.5	5.4	5.3	5.9	4.1	5.7	4.0	7.5	5.4	5.3	5.9	5.5	4.1	4.0	4.0	4.2	5.9	7.5	5.9	4.1	7.5	5.0	6.0	4.1	7.3	5.9	5.5	4.6
Lepar hilir palm oil mill	5.7	4.0	5.7	3.6	7.3	5.2	5.2	5.7	4.0	5.7	3.6	7.3	5.2	5.2	5.7	5.4	4.0	3.6	3.7	3.9	5.7	7.3	5.7	4.0	7.3	4.7	5.8	3.7	7.2	5.7	5.4	4.3
Kilang Sawit LCSB Lepar	5.9	3.8	5.5	3.7	7.6	5.4	5.0	5.9	3.8	5.5	3.7	7.6	5.4	5.0	5.9	5.3	3.8	3.7	3.8	3.9	5.9	7.6	5.9	3.8	7.6	4.9	6.0	3.9	7.4	5.9	5.2	4.4
Sungai jernih mill	6.2	3.2	5.0	3.6	8.0	5.7	4.4	6.2	3.2	5.0	3.6	8.0	5.7	4.4	6.2	4.7	3.2	3.6	3.8	3.5	6.2	8.0	6.2	3.2	8.0	5.2	6.3	3.7	7.8	6.2	4.6	4.3
Bukit Lee Lau	6.3	3.1	4.8	3.7	8.1	5.8	4.3	6.3	3.1	4.8	3.7	8.1	5.8	4.3	6.3	4.5	3.1	3.7	3.8	3.5	6.3	8.1	6.3	3.1	8.1	5.3	6.5	3.8	7.9	6.3	4.5	4.4
CHINI 2 POM	5.8	3.4	5.2	3.2	7.7	5.2	4.7	5.8	3.4	5.2	3.2	7.7	5.2	4.7	5.8	4.9	3.4	3.2	3.4	3.3	5.8	7.7	5.8	3.4	7.7	4.8	5.9	3.3	7.4	5.8	4.9	3.9
Chini 3 Palm oil mill	5.8	3.4	5.2	3.2	7.7	5.2	4.7	5.8	3.4	5.2	3.2	7.7	5.2	4.7	5.8	4.9	3.4	3.2	3.4	3.3	5.8	7.7	5.8	3.4	7.7	4.8	5.9	3.3	7.4	5.8	4.9	3.9
KS KRAU-PAHANG	3.4	5.2	7.3	4.9	5.6	2.9	6.5	3.4	5.2	7.3	4.9	5.6	2.9	6.5	3.4	6.7	5.2	4.9	4.4	3.2	3.4	5.6	3.4	5.2	5.6	2.4	3.6	4.8	5.2	3.4	6.8	5.5
Kuantan Trading POM	6.4	2.6	4.5	3.4	8.4	5.8	3.9	6.4	2.6	4.5	3.4	8.4	5.8	3.9	6.4	4.1	2.6	3.4	3.6	3.0	6.4	8.4	6.4	2.6	8.4	5.3	6.5	3.6	8.1	6.4	4.1	4.2
Padang Piol POM	4.3	5.0	7.0	3.0	5.9	3.8	6.4	4.3	5.0	7.0	3.0	5.9	3.8	6.4	4.3	6.6	5.0	3.0	2.9	4.0	4.3	5.9	4.3	5.0	5.9	3.3	4.4	3.0	5.7	4.3	6.6	3.4
Kota Gelanggi palm oil mill	4.3	5.0	7.0	3.0	5.9	3.8	6.4	4.3	5.0	7.0	3.0	5.9	3.8	6.4	4.3	6.6	5.0	3.0	2.9	4.0	4.3	5.9	4.3	5.0	5.9	3.3	4.4	3.0	5.7	4.3	6.6	3.4
Jengka 21 POM	4.4	4.6	6.6	2.7	6.3	3.9	5.9	4.4	4.6	6.6	2.7	6.3	3.9	5.9	4.4	6.2	4.6	2.7	2.6	3.6	4.4	6.3	4.4	4.6	6.3	3.4	4.6	2.7	6.0	4.4	6.2	3.1
Jengka 3 POM	4.4	4.8	6.7	2.9	6.2	3.9	6.1	4.4	4.8	6.7	2.9	6.2	3.9	6.1	4.4	6.3	4.8	2.9	2.9	3.8	4.4	6.2	4.4	4.8	6.2	3.5	4.6	3.0	6.0	4.4	6.3	3.3

KS SEROJA (JENGKA 18)-PAHANG	4.5	4.6	6.6	2.8	6.3	4.0	6.0	4.5	4.6	6.6	2.8	6.3	4.0	6.0	4.5	6.2	4.6	2.8	2.8	3.7	4.5	6.3	4.5	4.6	6.3	3.5	4.7	2.9	6.1	4.5	6.2	3.3
Kerdau Palm Oil Mill	4.3	4.5	6.5	2.4	6.3	3.8	5.8	4.3	4.5	6.5	2.4	6.3	3.8	5.8	4.3	6.1	4.5	2.4	2.3	3.3	4.3	6.3	4.3	4.5	6.3	3.3	4.5	2.4	6.0	4.3	6.1	2.9
KKS Bukit Mendi	4.7	3.8	5.9	4.6	7.0	4.1	5.2	4.7	3.8	5.9	4.6	7.0	4.1	5.2	4.7	5.4	3.8	4.6	5.1	2.2	4.7	7.0	4.7	3.8	7.0	3.6	4.9	4.9	6.6	4.7	5.4	2.4
Kemasul POM	4.8	3.7	5.8	4.7	7.1	4.2	5.1	4.8	3.7	5.8	4.7	7.1	4.2	5.1	4.8	5.3	3.7	4.7	5.2	6.1	4.8	7.1	4.8	3.7	7.1	3.7	5.0	5.1	6.6	4.8	5.3	2.4
Syarikat penanaman bukti senorang	4.9	3.6	5.7	4.9	7.2	4.4	4.9	4.9	3.6	5.7	4.9	7.2	4.4	4.9	4.9	5.1	3.6	4.9	5.5	5.9	4.9	7.2	4.9	3.6	7.2	3.9	5.1	5.3	6.8	4.9	5.2	2.5
Selaba oil mill	3.4	7.3	9.5	2.8	4.0	1.9	8.6	3.4	7.3	9.5	2.8	4.0	1.9	8.6	3.4	8.8	7.3	2.8	2.3	4.7	3.4	4.0	3.4	7.3	4.0	1.1	4.1	2.6	3.3	3.4	8.9	5.9
Seri Pelangi POM	3.6	7.2	9.3	2.7	4.0	2.1	8.5	3.6	7.2	9.3	2.7	4.0	2.1	8.5	3.6	8.7	7.2	2.7	2.3	4.7	3.6	4.0	3.6	7.2	4.0	1.1	4.3	2.5	3.4	3.6	8.8	5.7
Flemington POM	3.2	7.6	9.8	3.0	4.0	2.3	8.9	3.2	7.6	9.8	3.0	4.0	2.3	8.9	3.2	9.1	7.6	3.0	2.6	4.9	3.2	4.0	3.2	7.6	4.0	2.5	4.0	2.8	3.3	3.2	9.3	6.1
Jendarata Palm Oil Mill (P01)	3.9	7.2	9.4	2.7	4.2	2.6	8.6	3.9	7.2	9.4	2.7	4.2	2.6	8.6	3.9	8.7	7.2	2.7	6.2	4.6	3.9	4.2	3.9	7.2	4.2	2.1	4.7	2.4	3.5	3.9	8.9	5.2
Southern Perak Plantation S/B	4.3	7.1	9.3	2.6	4.4	3.0	8.5	4.3	7.1	9.3	2.6	4.4	3.0	8.5	4.3	8.7	7.1	2.6	5.8	4.5	4.3	4.4	4.3	7.1	4.4	2.5	5.0	2.3	3.6	4.3	8.8	4.9
Ulu bernam POM	4.9	6.9	9.0	2.3	4.6	3.5	8.2	4.9	6.9	9.0	2.3	4.6	3.5	8.2	4.9	8.4	6.9	2.3	5.1	4.2	4.9	4.6	4.9	6.9	4.6	2.7	5.7	5.8	3.9	4.9	8.5	4.2
Trolak palm oil mill	4.9	6.7	8.9	2.4	4.3	3.4	8.1	4.9	6.7	8.9	2.4	4.3	3.4	8.1	4.9	8.3	6.7	2.4	5.6	4.3	4.9	4.3	4.9	6.7	4.3	2.0	5.5	2.2	3.7	4.9	8.4	5.3
Sungai Tengi palm oil mill	2.5	6.0	8.2	4.4	5.2	5.5	7.4	2.5	6.0	8.2	4.4	5.2	5.5	7.4	2.5	7.6	6.0	4.4	3.1	3.5	2.5	5.2	2.5	6.0	5.2	4.3	2.7	3.9	4.5	2.5	7.7	2.9
Kilang Kelapa Sawit Ulu Basir	5.5	6.6	8.7	5.8	4.7	4.1	7.9	5.5	6.6	8.7	5.8	4.7	4.1	7.9	5.5	8.1	6.6	5.8	4.4	4.0	5.5	4.7	5.5	6.6	4.7	3.0	2.2	5.2	4.1	5.5	8.2	3.8
Tanjung Malim palm oil mill	5.9	6.4	8.6	5.5	4.8	4.4	7.7	5.9	6.4	8.6	5.5	4.8	4.4	7.7	5.9	7.9	6.4	5.5	4.2	3.9	5.9	4.8	5.9	6.4	4.8	3.2	2.3	5.0	4.1	5.9	8.0	3.8
KS MEMPAGA-PAHANG	3.1	5.4	7.6	2.7	5.8	2.6	6.7	3.1	5.4	7.6	2.7	5.8	2.6	6.7	3.1	6.9	5.4	2.7	1.5	2.8	3.1	5.8	3.1	5.4	5.8	6.0	3.4	2.2	5.2	3.1	7.0	2.2
Tennamaram Palm Oil Mill	2.8	5.8	8.0	3.3	5.6	2.3	7.1	2.8	5.8	8.0	3.3	5.6	2.3	7.1	2.8	7.3	5.8	3.3	2.0	3.1	2.8	5.6	2.8	5.8	5.6	5.5	3.1	2.7	5.0	2.8	7.4	1.4
Tuan mee palm oil mill	3.2	5.5	7.7	2.3	5.9	2.7	6.8	3.2	5.5	7.7	2.3	5.9	2.7	6.8	3.2	7.0	5.5	2.3	1.0	2.7	3.2	5.9	3.2	5.5	5.9	2.3	3.5	1.7	5.3	3.2	7.1	1.1
SOU 7 Bukit Kerayong	3.2	5.6	7.7	2.4	6.1	2.8	6.9	3.2	5.6	7.7	2.4	6.1	2.8	6.9	3.2	7.0	5.6	2.4	1.3	2.7	3.2	6.1	3.2	5.6	6.1	2.4	3.5	1.8	5.4	3.2	7.2	0.3
Bukit Kerayong Palm Oil Mill	3.2	5.6	7.8	2.5	6.1	2.8	6.9	3.2	5.6	7.8	2.5	6.1	2.8	6.9	3.2	7.0	5.6	2.5	1.4	2.7	3.2	6.1	3.2	5.6	6.1	2.4	3.5	1.8	5.4	3.2	7.2	0.3

Kilang Kelapa Sawit Risda Durian Mas	6.4	6.6	8.0	6.0	6.9	6.1	7.7	6.4	6.6	8.0	6.0	6.9	6.1	7.7	6.4	7.9	6.6	6.0	5.9	6.8	6.4	6.9	6.4	6.6	6.9	5.7	6.4	6.0	7.1	6.4	7.8	6.4
K.K.S Rasau Kerteh	6.2	6.2	7.6	5.6	6.8	5.8	7.3	6.2	6.2	7.6	5.6	6.8	5.8	7.3	6.2	7.5	6.2	5.6	5.5	6.3	6.2	6.8	6.2	6.2	6.8	5.4	6.2	5.6	7.0	6.2	7.4	5.9
Kilang Kelapa Sawit Kemaman	6.3	5.5	6.9	5.3	7.2	5.9	6.6	6.3	5.5	6.9	5.3	7.2	5.9	6.6	6.3	6.8	5.5	5.3	5.2	5.8	6.3	7.2	6.3	5.5	7.2	5.5	6.4	5.3	7.3	6.3	6.7	5.7
Ladang rakyat mill	5.9	5.1	6.6	4.7	7.1	5.5	6.3	5.9	5.1	6.6	4.7	7.1	5.5	6.3	5.9	6.5	5.1	4.7	4.7	5.2	5.9	7.1	5.9	5.1	7.1	5.1	6.0	4.8	7.1	5.9	6.4	5.2
Neram palm oil mill	6.1	4.8	6.3	4.7	7.4	5.7	5.9	6.1	4.8	6.3	4.7	7.4	5.7	5.9	6.1	6.1	4.8	4.7	4.7	5.1	6.1	7.4	6.1	4.8	7.4	5.2	6.2	4.7	7.4	6.1	6.0	5.2
TDM kemaman palm oil mill	6.0	5.7	7.2	5.2	6.8	5.6	6.9	6.0	5.7	7.2	5.2	6.8	5.6	6.9	6.0	7.1	5.7	5.2	5.1	5.8	6.0	6.8	6.0	5.7	6.8	5.2	6.0	5.2	6.9	6.0	7.0	5.6
Temerloh Mill	6.0	5.7	7.2	5.2	6.8	5.6	6.9	6.0	5.7	7.2	5.2	6.8	5.6	6.9	6.0	7.1	5.7	5.2	5.1	5.8	6.0	6.8	6.0	5.7	6.8	5.2	6.0	5.2	6.9	6.0	7.0	5.6
Kechau	3.1	6.3	8.3	3.3	4.6	2.7	7.6	3.1	6.3	8.3	3.3	4.6	2.7	7.6	3.1	7.9	6.3	3.3	3.0	4.8	3.1	4.6	3.1	6.3	4.6	2.3	3.2	3.2	4.4	3.1	7.9	3.3
Bukit Puteri Palm Oil Mill	2.4	6.5	8.6	3.0	4.2	5.5	7.9	2.4	6.5	8.6	3.0	4.2	5.5	7.9	2.4	8.1	6.5	3.0	2.6	4.6	2.4	4.2	2.4	6.5	4.2	4.4	2.5	2.8	3.9	2.4	8.1	2.7
Tersang palm oil mill	2.5	6.3	8.4	2.7	4.5	5.8	7.6	2.5	6.3	8.4	2.7	4.5	5.8	7.6	2.5	7.9	6.3	2.7	2.4	4.4	2.5	4.5	2.5	6.3	4.5	4.5	2.7	2.6	4.1	2.5	7.9	2.5
Minsawi Industries (K. Kangsar)	3.4	9.1	11.2	5.0	5.0	4.4	10.5	3.4	9.1	11.2	5.0	5.0	4.4	10.5	3.4	10.7	9.1	5.0	4.5	6.9	3.4	5.0	3.4	9.1	5.0	5.3	2.7	4.8	3.5	3.4	10.8	4.3
SOU 3 Elphil Mill	4.0	8.9	10.9	4.8	5.4	4.5	10.2	4.0	8.9	10.9	4.8	5.4	4.5	10.2	4.0	10.4	8.9	4.8	4.4	6.7	4.0	5.4	4.0	8.9	5.4	5.2	3.4	4.7	4.5	4.0	10.5	4.2
Trong mill	2.1	9.1	11.2	4.7	6.2	3.5	10.4	2.1	9.1	11.2	4.7	6.2	3.5	10.4	2.1	10.7	9.1	4.7	4.3	6.6	2.1	6.2	2.1	9.1	6.2	4.7	1.3	4.5	3.9	2.1	10.7	4.0
United International Enterprises POM	0.9	8.8	10.9	4.3	2.8	2.4	10.1	0.9	8.8	10.9	4.3	2.8	2.4	10.1	0.9	10.3	8.8	4.3	3.8	6.2	0.9	2.8	0.9	8.8	2.8	3.8	1.0	4.0	5.6	0.9	10.4	3.4
Sungei Kahang Palm Oil	0.3	8.4	10.6	4.0	2.9	1.4	9.8	0.3	8.4	10.6	4.0	2.9	1.4	9.8	0.3	10.0	8.4	4.0	3.5	5.9	0.3	2.9	0.3	8.4	2.9	2.8	0.8	3.8	6.0	0.3	10.1	3.2
Changkat Chermin	1.0	8.5	10.6	3.9	3.2	1.9	9.8	1.0	8.5	10.6	3.9	3.2	1.9	9.8	1.0	10.0	8.5	3.9	3.4	5.8	1.0	3.2	1.0	8.5	3.2	3.2	1.7	3.7	2.3	1.0	10.1	3.1
Pinehill Plantations (Malaysia)	1.3	8.5	10.6	3.9	3.2	2.1	9.8	1.3	8.5	10.6	3.9	3.2	2.1	9.8	1.3	10.0	8.5	3.9	3.4	5.8	1.3	3.2	1.3	8.5	3.2	3.3	1.9	3.7	2.4	1.3	10.1	3.1
Syarikat Cahaya Muda Perak (Oil Mil) Sdn Bhd	3.4	7.3	9.5	3.1	3.6	2.0	8.7	3.4	7.3	9.5	3.1	3.6	2.0	8.7	3.4	8.9	7.3	3.1	2.7	5.0	3.4	3.6	3.4	7.3	3.6	0.9	3.9	2.9	3.1	3.4	9.0	2.5
Kilang Kelapa Sawit Felcra Seberang Perak	1.8	7.8	10.0	3.4	3.5	0.5	9.2	1.8	7.8	10.0	3.4	3.5	0.5	9.2	1.8	9.4	7.8	3.4	2.9	5.3	1.8	3.5	1.8	7.8	3.5	1.4	2.5	3.2	2.8	1.8	9.5	2.6

Felcra Processing & Engineering SB	3.0	7.5	9.6	3.0	3.9	1.6	8.8	3.0	7.5	9.6	3.0	3.9	1.6	8.8	3.0	9.0	7.5	3.0	2.5	4.9	3.0	3.9	3.0	7.5	3.9	1.2	3.7	2.7	3.2	3.0	9.1	6.2
Felcra Bidor Palm oil mill	3.7	7.2	9.3	2.7	4.0	2.2	8.5	3.7	7.2	9.3	2.7	4.0	2.2	8.5	3.7	8.7	7.2	2.7	2.3	4.7	3.7	4.0	3.7	7.2	4.0	1.0	4.4	2.5	3.4	3.7	8.8	5.8
KKS Besout	4.4	6.9	9.0	2.6	4.1	2.9	8.2	4.4	6.9	9.0	2.6	4.1	2.9	8.2	4.4	8.4	6.9	2.6	6.0	4.5	4.4	4.1	4.4	6.9	4.1	1.5	5.0	2.4	3.5	4.4	8.5	5.7
Chalok palm oil mill	5.5	8.4	10.0	6.6	5.1	5.3	9.6	5.5	8.4	10.0	6.6	5.1	5.3	9.6	5.5	9.8	8.4	6.6	6.3	7.8	5.5	5.1	5.5	8.4	5.1	5.1	5.4	6.5	5.5	5.5	9.8	6.6
Kilang Sungai Tong	5.6	8.0	9.6	6.4	5.4	5.4	9.2	5.6	8.0	9.6	6.4	5.4	5.4	9.2	5.6	9.4	8.0	6.4	6.2	7.6	5.6	5.4	5.6	8.0	5.4	5.2	5.5	6.4	5.8	5.6	9.4	6.5
K.K.S Jerangau Barat	5.7	7.2	8.7	5.9	5.9	5.4	8.4	5.7	7.2	8.7	5.9	5.9	5.4	8.4	5.7	8.6	7.2	5.9	5.8	6.9	5.7	5.9	5.7	7.2	5.9	5.1	5.7	5.9	6.2	5.7	8.5	6.1
K.K.S Maokil	5.4	7.5	9.1	6.0	5.5	5.2	8.7	5.4	7.5	9.1	6.0	5.5	5.2	8.7	5.4	9.0	7.5	6.0	5.8	7.1	5.4	5.5	5.4	7.5	5.5	4.9	5.4	5.9	5.8	5.4	8.9	6.1
Ladang Serasa	3.8	8.0	9.8	5.3	3.8	3.6	9.3	3.8	8.0	9.8	5.3	3.8	3.6	9.3	3.8	9.5	8.0	5.3	5.0	6.8	3.8	3.8	3.8	8.0	3.8	3.4	3.7	5.2	4.0	3.8	9.5	5.1
Kilang Kelapa Sawit Kemahang	4.8	9.6	11.4	7.0	3.6	4.8	10.9	4.8	9.6	11.4	7.0	3.6	4.8	10.9	4.8	11.1	9.6	7.0	6.6	8.5	4.8	3.6	4.8	9.6	3.6	4.8	4.6	6.9	4.2	4.8	11.1	6.7
Kuala Pertang POM	4.6	9.1	10.9	6.6	3.7	4.6	10.4	4.6	9.1	10.9	6.6	3.7	4.6	10.4	4.6	10.6	9.1	6.6	6.2	8.1	4.6	3.7	4.6	9.1	3.7	4.5	4.5	6.5	4.3	4.6	10.6	6.4
Kilang Kelapa Sawit Paloh 3	3.9	7.7	9.5	5.1	4.1	3.7	9.0	3.9	7.7	9.5	5.1	4.1	3.7	9.0	3.9	9.2	7.7	5.1	4.8	6.5	3.9	4.1	3.9	7.7	4.1	3.5	3.8	5.0	4.3	3.9	9.2	5.0
Kilang sawit Chiku	3.7	7.6	9.4	4.9	4.0	3.5	8.9	3.7	7.6	9.4	4.9	4.0	3.5	8.9	3.7	9.1	7.6	4.9	4.6	6.4	3.7	4.0	3.7	7.6	4.0	3.2	3.6	4.8	4.1	3.7	9.1	4.8
Solid Orient POM	2.9	10.8	12.8	6.7	0.0	3.3	12.1	2.9	10.8	12.8	6.7	0.0	3.3	12.1	2.9	12.3	10.8	6.7	6.3	8.6	2.9	0.0	2.9	10.8	0.0	3.7	2.6	6.5	2.7	2.9	12.4	6.1
Kilang Kelapa Sawit Sungai Dingin	2.8	10.7	12.8	6.6	0.7	3.2	12.1	2.8	10.7	12.8	6.6	0.7	3.2	12.1	2.8	12.3	10.7	6.6	6.2	8.5	2.8	0.7	2.8	10.7	0.7	3.6	2.5	6.4	2.1	2.8	12.4	5.9
Kilang Sawit Setia Kawan	2.6	10.6	12.7	6.5	1.0	3.1	12.0	2.6	10.6	12.7	6.5	1.0	3.1	12.0	2.6	12.2	10.6	6.5	6.0	8.4	2.6	1.0	2.6	10.6	1.0	3.4	2.3	6.3	1.7	2.6	12.3	5.8
Kilang Kelapa Sawit Batu Lintang	5.7	10.2	12.3	5.9	2.6	2.5	11.5	5.7	10.2	12.3	5.9	2.6	2.5	11.5	5.7	11.7	10.2	5.9	5.5	7.8	5.7	2.6	5.7	10.2	2.6	2.9	4.9	5.7	0.7	5.7	11.8	5.2
KKS Telok Sengat	5.5	10.0	12.1	5.8	2.7	2.4	11.3	5.5	10.0	12.1	5.8	2.7	2.4	11.3	5.5	11.6	10.0	5.8	5.4	7.7	5.5	2.7	5.5	10.0	2.7	2.7	4.7	5.6	1.3	5.5	11.6	5.1
Chersonese POM	4.8	10.1	12.2	5.7	4.3	2.2	11.4	4.8	10.1	12.2	5.7	4.3	2.2	11.4	4.8	11.6	10.1	5.7	5.2	7.6	4.8	4.3	4.8	10.1	4.3	2.7	4.1	5.5	1.7	4.8	11.7	4.9
SEMENCHU POM	10.6	6.1	0.0	6.9	12.8	10.1	2.8	10.6	6.1	0.0	6.9	12.8	10.1	2.8	10.6	2.5	6.1	6.9	7.3	5.3	10.6	12.8	10.6	6.1	12.8	9.6	10.8	7.1	12.5	10.6	1.8	7.8

Table A.5 Distance from pre-processing facilities, *h* to main processing facilities, *j*

	Resin Production1	Resin Production2	Resin Production3	Boiler Combustion1	Boiler Combustion2	Boiler Combustion3	Boiler Combustion4	Boiler Combustion5	Boiler Combustion6	Boiler Combustion7	Boiler Combustion8	Slow Pyrolysis1	Slow Pyrolysis2	Acid Hydrolysis1	Acid Hydrolysis2	Acid Hydrolysis3	Enzymatic Hydrolysis1	Enzymatic Hydrolysis2	Enzymatic Hydrolysis3	Bio-composite Production1	Bio-composite Production2	Fast Pyrolysis1	Fast Pyrolysis2	Gasification1	Gasification2	CMC Production
Pelletization Mill1	71	166	358	103	183	117	190	196	128	100	27	90	66	35	384	110	35	384	110	201	83	90	66		117	290
Pelletization Mill2	221	126	69	103	107	175	105	95	162	191	262	201	227	257	95	180	257	95	180	126	209	201	227	290	174	51
Pelletization Mill3	305	209	16	103	191	259	187	178	245	275	346	284	311	341	11	264	341	11	264	199	292	284	311	373	257	101
Pelletization Mill4	32	64	257	103	82	16	94	98	32	4	74	12	38	72	284	9	72	284	9	121	20	12	38	102	16	194
Pelletization Mill5	94	185	376	103	200	137	204	212	145	121	50	110	89	50	401	130	50	401	130	210	104	110	89	27	137	303
Pelletization Mill6	54	147	340	103	164	98	171	177	109	81	9	71	48	18	365	92	18	365	92	184	64	71	48	19	98	271
Pelletization Mill7	260	164	30	103	146	214	144	135	201	230	302	240	266	297	56	219	297	56	219	162	248	240	266	329	213	71
Torrefied Pelletization 1	71	166	358	103	183	117	190	196	128	100	27	90	66	35	384	110	35	384	110	201	83	90	66	0	117	290
Torrefied Pelletization 2	221	126	69	103	107	175	105	95	162	191	262	201	227	257	95	180	257	95	180	126	209	201	227	290	174	51
Torrefied Pelletization 3	305	209	16	103	191	259	187	178	245	275	346	284	311	341	11	264	341	11	264	199	292	284	311	373	257	101
Torrefied Pelletization 4	32	64	257	103	82	16	94	98	32	4	74	12	38	72	284	9	72	284	9	121	20	12	38	102	16	194
Torrefied Pelletization 5	94	185	376	103	200	137	204	212	145	121	50	110	89	50	401	130	50	401	130	210	104	110	89	27	137	303
Torrefied Pelletization 6	54	147	340	103	164	98	171	177	109	81	9	71	48	18	365	92	18	365	92	184	64	71	48	19	98	271
Torrefied Pelletization 7	260	164	30	103	146	214	144	135	201	230	302	240	266	297	56	219	297	56	219	162	248	240	266	329	213	71
DLF Production1	71	166	358	103	183	117	190	196	128	100	27	90	66	35	384	110	35	384	110	201	83	90	66		117	290

DLF Production2	221	126	69	103	107	175	105	95	162	191	262	201	227	257	95	180	257	95	180	126	209	201	227	290	174	51
DLF Production3	94	185	376	103	200	137	204	212	145	121	50	110	89	50	401	130	50	401	130	210	104	110	89	27	137	303
DLF Production4	37	128	320	103	144	79	151	158	90	63	13	53	33	11	346	73	11	346	73	165	46	53	33	39	80	251
DLF Production5	75	169	361	103	185	120	192	199	131	103	30	93	69	37	387	113	37	387	113	203	86	93	69	3	120	292
DLF Production6	24	72	266	103	91	23	102	106	39	7	66	4	30	65	292	17	65	292	17	127	12	4	30	93	24	202
DLF Production7	106	200	392	103	216	151	222	229	161	134	62	124	101	66	418	145	66	418	145	230	117	124	101	35	151	321
Extraction Plant1	32	64	257	103	82	16	94	98	32	4	74	12	38	72	284	9	72	284	9	121	20	12	38	102	16	194
Extraction Plant2	21	76	270	103	94	28	105	109	42	11	62	2	27	60	296	21	60	296	21	129	9	2	27	89	28	205
Extraction Plant3	79	17	211	103	39	33	59	57	31	49	122	59	85	119	237	39	119	237	39	99	67	59	85	149	32	153
Aerobic Digestion1	71	166	358	103	183	117	190	196	128	100	27	90	66	35	384	110	35	384	110	201	83	90	66	0	117	290
Aerobic Digestion2	264	169	25	103	151	218	149	139	206	235	306	244	270	302	52	224	302	52	224	166	252	244	270	333	217	75
Aerobic Digestion3	221	126	69	103	107	175	105	95	162	191	262	201	227	257	95	180	257	95	180	126	209	201	227	290	174	51
Briquetting Plant1	71	166	358	103	183	117	190	196	128	100	27	90	66	35	384	110	35	384	110	201	83	90	66	0	117	290
Briquetting Plant2	94	185	376	103	200	137	204	212	145	121	50	110	89	50	401	130	50	401	130	210	104	110	89	27	137	303
Alkaline Activation Plant1	71	166	358	103	183	117	190	196	128	100	27	90	66	35	384	110	35	384	110	201	83	90	66	0	117	290
Alkaline Activation Plant2	276	180	14	103	162	230	159	150	217	246	317	256	282	312	40	235	312	40	235	175	263	256	282	345	228	80
Alkaline Activation Plant3	8	102	296	103	121	53	131	136	68	36	37	27	5	40	322	47	40	322	47	152	19	27	5	64	54	232

Table A.6 Approximated transportation cost factor from pre-processing facilities, *h* to main processing facilities, *j*

	Resin Production1	Resin Production2	Resin Production3	Boiler Combustion1	Boiler Combustion2	Boiler Combustion3	Boiler Combustion4	Boiler Combustion5	Boiler Combustion6	Boiler Combustion7	Boiler Combustion8	Gasification1	Gasification2	Acid Hydrolysis1	Acid Hydrolysis2	Acid Hydrolysis3	Enzymatic Hydrolysis1	Enzymatic Hydrolysis2	Enzymatic Hydrolysis3	Bio-composite Production1	Bio-composite Production2	Fast Pyrolysis1	Fast Pyrolysis2	Slow Pyrolysis1	Slow Pyrolysis2	CMC Production
Pelletization Mill1	19	26	32	24	27	24	27	27	25	23	11		24	13	33	24	13	33	24	27	20	22	18	22	18	30
Pelletization Mill2	28	25	18	24	24	26	24	22	26	27	29	30	26	29	22	27	29	22	27	25	27	27	28	27	28	15
Pelletization Mill3	31	27	9	24	27	29	27	26	29	30	32	33	29	32	9	29	32	9	29	27	30	30	31	30	31	24
Pelletization Mill4	12	17	29	24	20	9	22	23	12	8	19	24	9	19	30	8	19	30	8	25	10	9	13	9	13	27
Pelletization Mill5	22	27	33	24	27	25	27	28	25	25	15	11	25	15	34	25	15	34	25	28	24	24	21	24	21	31
Pelletization Mill6	16	25	32	24	26	23	26	26	24	20	8	10	23	10	33	22	10	33	22	27	17	19	15	19	15	30
Pelletization Mill7	29	26	12	24	25	28	25	25	27	28	31	31	28	30	16	28	30	16	28	26	29	29	29	29	29	18
Torrefied Pelletization1	19	26	32	24	27	24	27	27	25	23	11		24	13	33	24	13	33	24	27	20	22	18	22	18	30
Torrefied Pelletization2	28	25	18	24	24	26	24	22	26	27	29	30	26	29	22	27	29	22	27	25	27	27	28	27	28	15
Torrefied Pelletization3	31	27	9	24	27	29	27	26	29	30	32	33	29	32	9	29	32	9	29	27	30	30	31	30	31	24
Torrefied Pelletization4	12	17	29	24	20	9	22	23	12	8	19	24	9	19	30	8	19	30	8	25	10	9	13	9	13	27
Torrefied Pelletization5	22	27	33	24	27	25	27	28	25	25	15	11	25	15	34	25	15	34	25	28	24	24	21	24	21	31
Torrefied Pelletization6	16	25	32	24	26	23	26	26	24	20	8	10	23	10	33	22	10	33	22	27	17	19	15	19	15	30
Torrefied Pelletization7	29	26	12	24	25	28	25	25	27	28	31	31	28	30	16	28	30	16	28	26	29	29	29	29	29	18
DLF Production1	19	26	32	24	27	24	27	27	25	23	11		24	13	33	24	13	33	24	27	20	22	18	22	18	30
DLF Production2	28	25	18	24	24	26	24	22	26	27	29	30	26	29	22	27	29	22	27	25	27	27	28	27	28	15
DLF Production3	22	27	33	24	27	25	27	28	25	25	15	11	25	15	34	25	15	34	25	28	24	24	21	24	21	31
DLF Production4	13	25	31	24	25	20	26	26	22	17	9	13	20	9	32	19	9	32	19	26	14	15	12	15	12	29
DLF Production5	19	26	33	24	27	24	27	27	25	24	12	7	25	13	33	24	13	33	24	27	21	22	18	22	18	30
DLF Production6	11	19	29	24	22	11	24	24	13	8	18	22	11	17	30	10	17	30	10	25	9	7	12	7	12	27

DLF Production7	24	27	34	24	28	26	28	28	26	25	17	13	26	18	34	25	18	34	25	28	24	25	24	25	24	31
Aerobic Digestion1	19	26	32	24	27	24	27	27	25	23	11	0	24	13	33	24	13	33	24	27	20	22	18	22	18	30
Aerobic Digestion2	29	26	11	24	26	28	25	25	27	28	31	32	28	31	15	28	31	15	28	26	29	29	30	29	30	19
Aerobic Digestion3	28	25	18	24	24	26	24	22	26	27	29	30	26	29	22	27	29	22	27	25	27	27	28	27	28	15
Briquetting Plant1	19	26	32	24	27	24	27	27	25	23	11	0	24	13	33	24	13	33	24	27	20	22	18	22	18	30
Briquetting Plant2	22	27	33	24	27	25	27	28	25	25	15	11	25	15	34	25	15	34	25	28	24	24	21	24	21	31
Extraction Plant1	12	17	29	24	20	9	22	23	12	8	19	24	9	19	30	8	19	30	8	25	10	9	13	9	13	27
Extraction Plant2	10	19	29	24	22	11	24	24	14	9	17	21	11	17	30	10	17	30	10	25	8	7	11	7	11	27
Extraction Plant3	20	10	28	24	13	12	17	16	12	15	25	25	12	24	28	13	24	28	13	23	18	17	21	17	21	26
Alkaline Activation Plant1	19	26	32	24	27	24	27	27	25	23	11		24	13	33	24	13	33	24	27	20	22	18	22	18	30
Alkaline Activation Plant2	30	27	9	24	26	28	26	26	28	29	31	32	28	31	13	28	31	13	28	26	29	29	30	29	30	20
Alkaline Activation Plant3	8	24	30	24	25	15	25	25	18	13	13	17	16	13	31	15	13	31	15	26	10	11	8	11	8	28

Table A.7 Approximated CO_2 emission factor (10^{-3}) from pre-processing facilities, *h* to main processing facilities, *j*

	Resin Production1	Resin Production2	Resin Production3	Boiler Combustion1	Boiler Combustion2	Boiler Combustion3	Boiler Combustion4	Boiler Combustion5	Boiler Combustion6	Boiler Combustion7	Boiler Combustion8	Gasification1	Gasification2	Acid Hydrolysis1	Acid Hydrolysis2	Acid Hydrolysis3	Enzymatic Hydrolysis1	Enzymatic Hydrolysis2	Enzymatic Hydrolysis3	Bio-composite Production1	Bio-composite Production2	Fast Pyrolysis1	Fast Pyrolysis2	Slow Pyrolysis1	Slow Pyrolysis2	CMC Production
Pelletization Mill1	4.4	3.6	7.9	2.3	4.0	2.6	4.2	4.3	2.8	6.2	1.7	0.0	2.6	2.2	8.5	2.4	2.2	8.5	2.4	4.4	5.1	5.6	4.1	5.6	4.1	6.4
Pelletization Mill2	4.9	2.8	4.3	2.3	2.4	3.9	2.3	5.9	3.6	4.2	5.8	6.4	3.8	5.7	5.9	4.0	5.7	5.9	4.0	2.8	4.6	4.4	5.0	4.4	5.0	3.2
Pelletization Mill3	6.7	4.6	1.0	2.3	4.2	5.7	4.1	3.9	5.4	6.0	7.6	8.2	5.7	7.5	0.7	5.8	7.5	0.7	5.8	4.4	6.4	6.3	6.8	6.3	6.8	2.2
Pelletization Mill4	2.0	4.0	5.7	2.3	5.1	1.0	5.8	6.1	2.0	0.3	4.6	2.2	1.0	4.5	6.2	0.6	4.5	6.2	0.6	2.7	1.2	0.7	2.4	0.7	2.4	4.3
Pelletization Mill5	5.8	4.1	8.3	2.3	4.4	3.0	4.5	4.7	3.2	2.7	3.1	1.7	3.0	3.1	8.8	2.9	3.1	8.8	2.9	4.6	2.3	2.4	5.5	2.4	5.5	6.7
Pelletization Mill6	3.3	3.2	7.5	2.3	3.6	6.1	3.8	3.9	2.4	5.1	0.6	1.2	6.1	1.1	8.0	5.7	1.1	8.0	5.7	4.0	4.0	4.4	3.0	4.4	3.0	6.0
Pelletization Mill7	5.7	3.6	1.8	2.3	3.2	4.7	3.2	3.0	4.4	5.1	6.6	7.2	4.7	6.5	3.5	4.8	6.5	3.5	4.8	3.6	5.4	5.3	5.8	5.3	5.8	4.4
Torrefied Pelletization1	4.4	3.6	7.9	2.3	4.0	2.6	4.2	4.3	2.8	6.2	1.7	0.0	2.6	2.2	8.5	2.4	2.2	8.5	2.4	4.4	5.1	5.6	4.1	5.6	4.1	6.4
Torrefied Pelletization2	4.9	2.8	4.3	2.3	2.4	3.9	2.3	5.9	3.6	4.2	5.8	6.4	3.8	5.7	5.9	4.0	5.7	5.9	4.0	2.8	4.6	4.4	5.0	4.4	5.0	3.2
Torrefied Pelletization3	6.7	4.6	1.0	2.3	4.2	5.7	4.1	3.9	5.4	6.0	7.6	8.2	5.7	7.5	0.7	5.8	7.5	0.7	5.8	4.4	6.4	6.3	6.8	6.3	6.8	2.2
Torrefied Pelletization4	2.0	4.0	5.7	2.3	5.1	1.0	5.8	6.1	2.0	0.3	4.6	2.2	1.0	4.5	6.2	0.6	4.5	6.2	0.6	2.7	1.2	0.7	2.4	0.7	2.4	4.3
Torrefied Pelletization5	5.8	4.1	8.3	2.3	4.4	3.0	4.5	4.7	3.2	2.7	3.1	1.7	3.0	3.1	8.8	2.9	3.1	8.8	2.9	4.6	2.3	2.4	5.5	2.4	5.5	6.7
Torrefied Pelletization6	3.3	3.2	7.5	2.3	3.6	6.1	3.8	3.9	2.4	5.1	0.6	1.2	6.1	1.1	8.0	5.7	1.1	8.0	5.7	4.0	4.0	4.4	3.0	4.4	3.0	6.0
Torrefied Pelletization7	5.7	3.6	1.8	2.3	3.2	4.7	3.2	3.0	4.4	5.1	6.6	7.2	4.7	6.5	3.5	4.8	6.5	3.5	4.8	3.6	5.4	5.3	5.8	5.3	5.8	4.4
DLF Production1	4.4	3.6	7.9	2.3	4.0	2.6	4.2	4.3	2.8	6.2	1.7	0.0	2.6	2.2	8.5	2.4	2.2	8.5	2.4	4.4	5.1	5.6	4.1	5.6	4.1	6.4
DLF Production2	4.9	2.8	4.3	2.3	2.4	3.9	2.3	5.9	3.6	4.2	5.8	6.4	3.8	5.7	5.9	4.0	5.7	5.9	4.0	2.8	4.6	4.4	5.0	4.4	5.0	3.2
DLF Production3	5.8	4.1	8.3	2.3	4.4	3.0	4.5	4.7	3.2	2.7	3.1	1.7	3.0	3.1	8.8	2.9	3.1	8.8	2.9	4.6	2.3	2.4	5.5	2.4	5.5	6.7
DLF Production4	2.3	2.8	7.0	2.3	3.2	4.9	3.3	3.5	5.6	3.9	0.8	2.4	4.9	0.7	7.6	4.5	0.7	7.6	4.5	3.6	2.8	3.3	2.0	3.3	2.0	5.5
DLF Production5	4.6	3.7	7.9	2.3	4.1	2.6	4.2	4.4	2.9	2.3	1.9	0.2	2.6	2.3	8.5	2.5	2.3	8.5	2.5	4.5	5.3	5.8	4.3	5.8	4.3	6.4

DLF Production6	1.5	4.5	5.8	2.3	5.6	1.5	2.2	2.3	2.4	0.4	4.1	5.8	1.5	4.0	6.4	1.1	4.0	6.4	1.1	2.8	0.7	0.2	1.9	0.2	1.9	4.4
DLF Production7	2.3	4.4	8.6	2.3	4.8	3.3	4.9	5.0	3.5	3.0	3.8	2.2	3.3	4.1	9.2	3.2	4.1	9.2	3.2	5.1	2.6	2.7	2.2	2.7	2.2	7.1
Extraction Plant1	2.0	4.0	5.7	2.3	5.1	1.0	5.8	6.1	2.0	0.3	4.6	2.2	1.0	4.5	6.2	0.6	4.5	6.2	0.6	2.7	1.2	0.7	2.4	0.7	2.4	4.3
Extraction Plant2	1.3	4.7	5.9	2.3	5.9	1.7	2.3	2.4	2.6	0.7	3.8	5.5	1.7	3.7	6.5	1.3	3.7	6.5	1.3	2.8	0.5	0.1	1.7	0.1	1.7	4.5
Extraction Plant3	4.9	1.0	4.6	2.3	2.4	2.0	3.7	3.5	1.9	3.0	2.7	3.3	2.0	2.6	5.2	2.4	2.6	5.2	2.4	6.2	4.1	3.7	5.2	3.7	5.2	3.4
Aerobic Digestion1	4.4	3.6	7.9	2.3	4.0	2.6	4.2	4.3	2.8	6.2	1.7	0.0	2.6	2.2	8.5	2.4	2.2	8.5	2.4	4.4	5.1	5.6	4.1	5.6	4.1	6.4
Aerobic Digestion2	5.8	3.7	1.6	2.3	3.3	4.8	3.3	3.1	4.5	5.2	6.7	7.3	4.8	6.6	3.2	4.9	6.6	3.2	4.9	3.7	5.5	5.4	5.9	5.4	5.9	4.6
Aerobic Digestion3	4.9	2.8	4.3	2.3	2.4	3.9	2.3	5.9	3.6	4.2	5.8	6.4	3.8	5.7	5.9	4.0	5.7	5.9	4.0	2.8	4.6	4.4	5.0	4.4	5.0	3.2
Briquetting Plant1	4.4	3.6	7.9	2.3	4.0	2.6	4.2	4.3	2.8	6.2	1.7	0.0	2.6	2.2	8.5	2.4	2.2	8.5	2.4	4.4	5.1	5.6	4.1	5.6	4.1	6.4
Briquetting Plant2	5.8	4.1	8.3	2.3	4.4	3.0	4.5	4.7	3.2	2.7	3.1	1.7	3.0	3.1	8.8	2.9	3.1	8.8	2.9	4.6	2.3	2.4	5.5	2.4	5.5	6.7
Alkaline Activation Plant1	4.4	3.6	7.9	2.3	4.0	2.6	4.2	4.3	2.8	6.2	1.7	0.0	2.6	2.2	8.5	2.4	2.2	8.5	2.4	4.4	5.1	5.6	4.1	5.6	4.1	6.4
Alkaline Activation Plant2	6.1	4.0	0.9	2.3	3.6	5.1	3.5	3.3	4.8	5.4	7.0	7.6	5.0	6.9	2.5	5.2	6.9	2.5	5.2	3.8	5.8	5.6	6.2	5.6	6.2	5.0
Alkaline Activation Plant3	0.5	2.2	6.5	2.3	2.7	3.3	2.9	3.0	4.2	2.2	2.3	4.0	3.3	2.5	7.1	2.9	2.5	7.1	2.9	3.4	1.2	1.6	0.3	1.6	0.3	5.1

Table A.8 Distance from main processing facilities, *j* to further processing 1 facilities, *l*

	Power Production1	Power Production2	Power Production3	Power Production4	Power Production5	Power Production6	Power Production7	Power Production8	FTL production 1	FTL production 2	FTL production 3	Methanol Production1	Methanol Production2	Methanol Production3	Fermentation Plant1	Fermentation Plant2	Fermentation Plant3	Xylitol Production1	Xylitol Production2	Xylitol Production3	Separation Plant1	Separation Plant2	Separation Plant3	Separation Plant4	Bio-oil upgrading1	Bio-oil upgrading2	Steam reforming1	Steam reforming2	Steam reforming3	Steam reforming4	Anaerobic Digestion Plant1	Anaerobic Digestion Plant2	Anaerobic Digestion Plant3
Resin Production1	170	115	46	126	130	63	30	44	40	224	232	40	224	232	47	316	41	47	316	41	40	224	232	20	21	6	40	20	224	232	47	316	41
Resin Production2	74	25	50	48	43	43	66	138	57	135	146	57	135	146	135	220	55	135	220	55	57	135	146	77	76	102	57	77	135	146	135	220	55
Resin Production3	120	176	243	173	164	231	260	331	250	92	101	250	92	101	326	27	249	326	27	249	250	92	101	270	269	295	250	270	92	101	326	27	249
Boiler Combustion1	0	58	124	63	51	112	140	212	131	75	91	131	75	91	208	146	129	208	146	129	131	75	91	151	150	176	131	151	75	91	208	146	129
Boiler Combustion2	58	0	70	25	18	55	85	156	75	111	122	75	111	122	151	202	74	151	202	74	75	111	122	95	94	121	75	95	111	122	151	202	74
Boiler Combustion3	124	70	0	85	86	27	17	89	11	180	190	11	180	190	88	270	9	88	270	9	11	180	190	28	27	52	11	28	180	190	88	270	9
Boiler Combustion4	63	25	85	0	14	63	98	163	87	98	106	87	98	106	156	198	86	156	198	86	87	98	106	107	105	132	87	107	98	106	156	198	86
Boiler Combustion5	51	18	86	14	0	68	101	169	90	94	104	90	94	104	163	189	89	163	189	89	90	94	104	111	109	136	90	111	94	104	163	189	89
Boiler Combustion6	112	55	27	63	68	0	35	101	25	161	169	25	161	169	96	256	24	96	256	24	25	161	169	44	43	69	25	44	161	169	96	256	24
Boiler Combustion7	140	85	17	98	101	35	0	73	11	195	203	11	195	203	72	286	12	72	286	12	11	195	203	11	10	36	11	11	195	203	72	286	12
Boiler Combustion8	212	156	89	163	169	101	73	0	81	261	268	81	261	268	17	357	83	17	357	83	81	261	268	62	63	39	81	62	261	268	17	357	83
Enzymatic Hydrolysis1	208	151	88	156	163	96	72	17	79	253	259	79	253	259	0	352	81	0	352	81	79	253	259	61	61	44	79	61	253	259	0	352	81
Enzymatic Hydrolysis2	146	202	270	198	189	256	286	357	276	111	117	276	111	117	352	0	275	352	0	275	276	111	117	297	296	322	276	297	111	117	352	0	275
Enzymatic Hydrolysis3	129	74	9	86	89	24	12	83	2	183	191	2	183	191	81	275	0	81	275	0	2	183	191	22	21	47	2	22	183	191	81	275	0
Acid Hydrolysis1	208	151	88	156	163	96	72	17	79	253	259	79	253	259		352	81	0	352	81	79	253	259	61	61	44	79	61	253	259	0	352	81
Acid Hydrolysis2	146	202	270	198	189	256	286	357	276	111	117	276	111	117	352	0	275	352	0	275	276	111	117	297	296	322	276	297	111	117	352	0	275
Acid Hydrolysis3	129	74	9	86	89	24	12	83	2	183	191	2	183	191	81	275	0	81	275	0	2	183	191	22	21	47	2	22	183	191	81	275	0
Fast Pyrolysis1	150	94	27	105	109	43	10	63	19	203	211	19	203	211	61	296	21	61	296	21	19	203	211	1	0	27	19	1	203	211	61	296	21
Fast Pyrolysis2	176	121	52	132	136	69	36	39	46	230	238	46	230	238	44	322	47	44	322	47	46	230	238	26	27	0	46	26	230	238	44	322	47
Gasification1	136	80	16	90	94	28	9	76	5	188	196	5	188	196	73	281	7	73	281	7	5	188	196	16	15	42	5	16	188	196	73	281	7
Gasification2	123	68	4	82	84	23	17	90	9	178	187	9	178	187	88	269	7	88	269	7	9	178	187	28	27	53	9	28	178	187	88	269	7
Bio-composite Production1	100	73	116	48	60	90	125	178	114	99	99	114	99	99	167	209	114	167	209	114	114	99	99	131	130	154	114	131	99	99	167	209	114
Bio-composite Production2	158	102	34	114	117	51	18	55	27	211	219	27	211	219	55	303	29	55	303	29	27	211	219	7	8	19	27	7	211	219	55	303	29

Slow Pyrolysis1	150	94	27	105	109	43	10	63	19	203	211	19	203	211	61	296	21	61	296	21	19	203	211	1	0	27	19	1	203	211	61	296	21
Slow Pyrolysis2	176	121	52	132	136	69	36	39	46	230	238	46	230	238	44	322	47	44	322	47	46	230	238	26	27		46	26	230	238	44	322	47
CMC Production	78	114	183	100	97	163	197	264	187	3	15	187	3	15	256	110	185	256	110	185	187	3	15	207	206	232	187	207	3	15	256	110	185

Table A.9 Approximated transportation cost from main processing facilities, *j* to further processing 1 facilities, *l*

	Power Production1	Power Production2	Power Production3	Power Production4	Power Production5	Power Production6	Power Production7	Power Production8	Separation Plant1	Separation Plant2	Separation Plant3	Separation Plant4	FTL production 1	FTL production 2	FTL production 3	Methanol Production1	Methanol Production2	Methanol Production3	Fermentation Plant1	Fermentation Plant2	Fermentation Plant3	Xylitol Production1	Xylitol Production2	Xylitol Production3	Bio-oil upgrading1	Bio-oil upgrading2	Anaerobic Digestion Plant1	Anaerobic Digestion Plant2	Anaerobic Digestion Plant3	Steam reforming1	Steam reforming2	Steam reforming3	Steam reforming4
Acid Hydrolysis1	27	26	21	26	26	23	19	10	20	29	29	17	20	29	29	20	29	29	0	32	20	0	32	20	17	14	0	32	20	20	17	29	29
Acid Hydrolysis2	25	27	30	27	27	29	30	32	30	24	24	30	30	24	24	30	24	24	32	0	30	32		30	30	31	32		30	30	30	24	24
Acid Hydrolysis3	25	19	8	21	21	11	9	20	7	27	27	10	7	27	27	7	27	27	20	30		20	30		10	15	20	30		7	10	27	27
Bio-composite Production1	23	19	24	15	17	22	25	26	24	23	23	25	24	23	23	24	23	23	26	27	24	26	27	24	25	26	26	27	24	24	25	23	23
Bio-composite Production2	26	24	12	24	24	15	10	16	11	28	28	8	11	28	28	11	28	28	16	31	12	16	31	12	8	10	16	31	12	11	8	28	28
Boiler Combustion1	0	5	25	6	5	24	25	28	25	19	22	26	25	19	22	25	19	22	27	25	25	27	25	25	26	26	27	25	25	25	26	19	22
Boiler Combustion2	5		6	2	2	5	8	26	19	24	25	22	19	24	25	19	24	25	26	27	19	26	27	19	22	25	26	27	19	19	22	24	25
Boiler Combustion3	25	6	0	8	8	2	2	8	9	27	27	11	9	27	27	9	27	27	21	30	8	21	30	8	11	15	21	30	8	9	11	27	27
Boiler Combustion4	6	2	8	0	1	6	9	26	21	23	24	24	21	23	24	21	23	24	26	27	21	26	27	21	24	25	26	27	21	21	24	23	24
Boiler Combustion5	5	2	8	1	0	6	24	26	22	22	24	24	22	22	24	22	22	24	26	27	21	26	27	21	24	25	26	27	21	22	24	22	24
Boiler Combustion6	24	16	11	17	18	0	13	24	11	26	26	14	11	26	26	11	26	26	23	29	11	23	29	11	14	18	23	29	11	11	14	26	26
Boiler Combustion7	25	21	10	23	24	13	0	19	9	27	27	9	9	27	27	9	27	27	19	30	9	19	30	9	9	13	19	30	9	9	9	27	27
Boiler Combustion8	28	26	21	26	26	24	19	0	20	29	29	17	20	29	29	20	29	29	10	32	20	10	32	20	17	13	10	32	20	20	17	29	29
CMC Production	20	24	27	24	23	26	27	29	27	7	9	27	27	7	9	27	7	9	29	24	27	29	24	27	27	28	29	24	27	27	27	7	9
Enzymatic Hydrolysis1	27	26	21	26	26	23	19	10	20	29	29	17	20	29	29	20	29	29	0	32	20	0	32	20	17	14	0	32	20	20	17	29	29
Enzymatic Hydrolysis2	25	27	30	27	27	29	30	32	30	24	24	30	30	24	24	30	24	24	32	0	30	32	0	30	30	31	32		30	30	30	24	24
Enzymatic Hydrolysis3	25	19	8	21	21	11	9	20	7	27	27	10	7	27	27	7	27	27	20	30		20	30	0	10	15	20	30		7	10	27	27
Fast Pyrolysis1	26	22	11	24	24	14	9	17	10	27	28	7	10	27	28	10	27	28	17	30	10	17	30	10	0	11	17	30	10	10	7	27	28
Fast Pyrolysis2	26	25	15	25	25	18	13	13	14	28	28	11	14	28	28	14	28	28	14	31	15	14	31	15	11	0	14	31	15	14	11	28	28
Gasification1	25	20	9	22	22	11	8	19	1	17	18	2	1	17	18	1	17	18	19	30	8	19	30	8	9	14	19	30	8	8	10	27	27
Gasification2	25	18	8	20	21	11	10	22	1	16	17	3	1	16	17	1	16	17	21	29	8	21	29	8	11	16	21	29	8	8	11	26	27
Resin Production1	26	24	14	25	25	17	12	14	13	28	28	10	13	28	28	13	28	28	15	31	14	15	31	14	10	8	15	31	14	13	10	28	28
Resin Production2	19	11	15	15	14	14	18	25	16	25	25	19	16	25	25	16	25	25	25	28	16	25	28	16	19	24	25	28	16	16	19	25	25
Resin Production3	25	26	29	26	26	28	29	32	29	22	24	30	29	22	24	29	22	24	31	11	29	31	11	29	29	30	31	11	29	29	30	22	24
Slow Pyrolysis	26	22	11	24	24	14	9	17	10	27	28	7	10	27	28	10	27	28	17	30	10	17	30	10	0	11	17	30	10	10	7	27	28
Slow Pyrolysis2	26	25	15	25	25	18	13	13	14	28	28	11	14	28	28	14	28	28	14	31	15	14	31	15	11	0	14	31	15	14	11	28	28

Table A.10 Approximated CO_2 emission factor (10^{-3}) from main processing facilities, *j* to further processing 1 facilities, *l*

	Power Production1	Power Production2	Power Production3	Power Production4	Power Production5	Power Production6	Power Production7	Power Production8	FTL production 1	FTL production 2	FTL production 3	Methanol Production1	Methanol Production2	Methanol Production3	Fermentation Plant1	Fermentation Plant2	Fermentation Plant3	Xylitol Production	Xylitol Production2	Xylitol Production3	Bio-oil upgrading1	Bio-oil upgrading2	Steam reforming1	Steam reforming2	Steam reforming3	Steam reforming4	Anaerobic Digestion Plant1	Anaerobic Digestion Plant2	Anaerobic Digestion Plant3	Separation Plant1	Separation Plant2	Separation Plant3	Separation Plant4
Acid Hydrolysis1	4.6	3.3	5.5	3.4	3.6	5.9	4.4	1.0	4.9	5.6	5.7	4.9	5.6	5.7	0.0	7.7	5.0	0.0	7.7	5.0	3.8	2.7	4.9	3.8	5.6	5.7	0.0	7.7	5.0	4.9	5.6	5.7	3.8
Acid Hydrolysis2	3.2	4.4	5.9	4.4	4.2	5.6	6.3	7.9	6.1	2.5	2.6	6.1	2.5	2.6	7.7	0.0	6.0	7.7	0.0	6.0	6.5	7.1	6.1	6.5	2.5	2.6	7.7	0.0	6.0	6.1	2.5	2.6	6.5
Acid Hydrolysis3	2.8	4.6	0.6	5.3	5.5	1.5	0.7	5.2	0.1	4.0	4.2	0.1	4.0	4.2	5.0	6.0	0.0	5.0	6.0	0.0	1.3	2.9	0.1	1.4	4.0	4.2	5.0	6.0	0.0	0.1	4.0	4.2	1.4
Bio-composite Production1	6.2	4.5	2.6	3.0	3.7	5.6	2.7	3.9	2.5	6.1	6.1	2.5	6.1	6.1	3.7	4.6	2.5	3.7	4.6	2.5	2.9	3.4	2.5	2.9	6.1	6.1	3.7	4.6	2.5	2.5	6.1	6.1	2.9
Bio-composite Production2	3.5	2.2	2.1	2.5	2.6	3.1	1.1	3.4	1.7	4.6	4.8	1.7	4.6	4.8	3.4	6.7	1.8	3.4	6.7	1.8	0.5	1.2	1.7	0.4	4.6	4.8	3.4	6.7	1.8	1.7	4.6	4.8	0.4
Boiler Combustion1	0.0	0.0	2.7	0.0	0.0	2.5	3.1	4.7	2.9	4.7	5.6	2.9	4.7	5.6	4.6	3.2	2.8	4.6	3.2	2.8	3.3	3.9	2.9	3.3	4.7	5.6	4.6	3.2	2.8	2.9	4.7	5.6	3.3
Boiler Combustion2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	4.6	2.4	2.7	4.6	2.4	2.7	3.3	4.4	4.6	3.3	4.4	4.6	5.8	2.7	4.6	5.9	2.4	2.7	3.3	4.4	4.6	4.6	2.4	2.7	5.9
Boiler Combustion3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	4.0	4.2	0.7	4.0	4.2	5.5	5.9	0.6	5.5	5.9	0.6	1.7	3.2	0.7	1.7	4.0	4.2	5.5	5.9	0.6	0.7	4.0	4.2	1.7
Boiler Combustion4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	5.4	6.1	2.3	5.4	6.1	2.3	3.4	4.4	5.3	3.4	4.4	5.3	2.3	2.9	5.4	2.3	6.1	2.3	3.4	4.4	5.3	5.4	6.1	2.3	2.3
Boiler Combustion5	0.0	0.0	0.0	0.0	0.0	0.0	2.2	3.7	5.6	5.8	2.3	5.6	5.8	2.3	3.6	4.2	5.5	3.6	4.2	5.5	2.4	3.0	5.6	2.4	5.8	2.3	3.6	4.2	5.5	5.6	5.8	2.3	2.4
Boiler Combustion6	2.5	3.4	1.6	3.9	4.2	0.0	2.2	2.2	1.5	3.5	3.7	1.5	3.5	3.7	5.9	5.6	1.5	5.9	5.6	1.5	2.6	4.3	1.5	2.7	3.5	3.7	5.9	5.6	1.5	1.5	3.5	3.7	2.7
Boiler Combustion7	3.1	5.3	1.0	6.1	2.2	2.2	0.0	4.5	0.7	4.3	4.5	0.7	4.3	4.5	4.4	6.3	0.7	4.4	6.3	0.7	0.6	2.2	0.7	0.7	4.3	4.5	4.4	6.3	0.7	0.7	4.3	4.5	0.7
Boiler Combustion8	4.7	3.4	5.5	3.6	3.7	2.2	4.5	0.0	5.0	5.7	5.9	5.0	5.7	5.9	1.0	7.9	5.2	1.0	7.9	5.2	3.9	2.4	5.0	3.8	5.7	5.9	1.0	7.9	5.2	5.0	5.7	5.9	3.8
CMC Production	4.8	2.5	4.0	2.2	6.0	3.6	4.3	5.8	4.1	0.2	0.9	4.1	0.2	0.9	5.6	2.4	4.1	5.6	2.4	4.1	4.5	5.1	4.1	4.5	0.2	0.9	5.6	2.4	4.1	4.1	0.2	0.9	4.5
Enzymatic Hydrolysis1	4.6	3.3	5.5	3.4	3.6	5.9	4.4	1.0	4.9	5.6	5.7	4.9	5.6	5.7	0.0	7.7	5.0	0.0	7.7	5.0	3.8	2.7	4.9	3.8	5.6	5.7	0.0	7.7	5.0	4.9	5.6	5.7	3.8
Enzymatic Hydrolysis2	3.2	4.4	5.9	4.4	4.2	5.6	6.3	7.9	6.1	2.5	2.6	6.1	2.5	2.6	7.7	0.0	6.0	7.7	0.0	6.0	6.5	7.1	6.1	6.5	2.5	2.6	7.7	0.0	6.0	6.1	2.5	2.6	6.5
Enzymatic Hydrolysis3	2.8	4.6	0.6	5.3	5.5	1.5	0.7	5.2	0.1	4.0	4.2	0.1	4.0	4.2	5.0	6.0	0.0	5.0	6.0	0.0	1.3	2.9	0.1	1.4	4.0	4.2	5.0	6.0	0.0	0.1	4.0	4.2	1.4
Fast Pyrolysis1	3.3	5.8	1.7	2.3	2.4	2.6	0.6	3.9	1.2	4.5	4.6	1.2	4.5	4.6	3.8	6.5	1.3	3.8	6.5	1.3	0.0	1.7	1.2	0.1	4.5	4.6	3.8	6.5	1.3	1.2	4.5	4.6	0.1
Fast Pyrolysis2	3.9	2.7	3.2	2.9	3.0	4.3	2.2	2.4	2.8	5.1	5.2	2.8	5.1	5.2	2.7	7.1	2.9	2.7	7.1	2.9	1.7	0.0	2.8	1.6	5.1	5.2	2.7	7.1	2.9	2.8	5.1	5.2	1.6
Gasification1	3.0	4.9	1.0	5.6	5.8	1.7	0.6	4.7	0.0	0.0	0.0	0.0	0.0	0.0	4.6	6.2	0.5	4.6	6.2	0.5	0.9	2.6	0.3	1.0	4.1	4.3	4.6	6.2	0.5	0.0	0.0	0.0	0.0
Gasification2	2.7	4.2	0.2	5.1	5.2	1.4	1.1	5.6	0.0	0.0	0.0	0.0	0.0	0.0	5.4	5.9	0.5	5.4	5.9	0.5	1.7	3.3	0.6	1.7	3.9	4.1	5.4	5.9	0.5	0.0	0.0	0.0	0.0
Resin Production1	3.7	2.5	2.9	2.8	2.9	3.9	1.8	2.8	2.5	4.9	5.1	2.5	4.9	5.1	2.9	6.9	2.6	2.9	6.9	2.6	1.3	0.4	2.5	1.2	4.9	5.1	2.9	6.9	2.6	2.5	4.9	5.1	1.2
Resin Production2	4.6	1.5	3.1	3.0	2.7	2.7	4.1	3.0	3.5	3.0	3.2	3.5	3.0	3.2	3.0	4.8	3.4	3.0	4.8	3.4	4.7	2.2	3.5	4.8	3.0	3.2	3.0	4.8	3.4	3.5	3.0	3.2	4.8
Resin Production3	2.6	3.9	5.4	3.8	3.6	5.1	5.7	7.3	5.5	5.7	2.2	5.5	5.7	2.2	7.2	1.7	5.5	7.2	1.7	5.5	5.9	6.5	5.5	5.9	5.7	2.2	7.2	1.7	5.5	5.5	5.7	2.2	5.9
Slow Pyrolysis	3.3	5.8	1.7	2.3	2.4	2.6	0.6	3.9	1.2	4.5	4.6	1.2	4.5	4.6	3.8	6.5	1.3	3.8	6.5	1.3	0.0	1.7	1.2	0.1	4.5	4.6	3.8	6.5	1.3	1.2	4.5	4.6	0.1
Slow Pyrolysis2	3.9	2.7	3.2	2.9	3.0	4.3	2.2	2.4	2.8	5.1	5.2	2.8	5.1	5.2	2.7	7.1	2.9	2.7	7.1	2.9	1.7	0.0	2.8	1.6	5.1	5.2	2.7	7.1	2.9	2.8	5.1	5.2	1.6

Table A.11 Distance from further processing 1 facilities, l to further processing 2 facilities, n

	Formaldehyde Production1	Formaldehyde Production2	Bio-ethylene Production1	Bio-ethylene Production2	Ammonia Production1	Ammonia Production2
Anaerobic Digestion Plant1	258	65	260	319	79	260
Anaerobic Digestion Plant2	108	417	116	35	276	116
Anaerobic Digestion Plant3	187	144	193	241	2	192
Bio-oil upgrading1	207	124	212	262	19	212
Bio-oil upgrading2	234	101	239	288	46	239
Fermentation Plant1	258	65	260	319	79	260
Fermentation Plant2	108	417	116	35	276	116
Fermentation Plant3	187	144	193	241	2	192
FTL production 1	188	143	194	242	0	193
FTL production 2	4	317	18	87	184	17
FTL production 3	16	322	1	97	193	1
Methanol Production	188	143	194	242	0	193
Methanol Production2	4	317	18	87	184	17
Methanol Production3	16	322	1	97	193	1
Power Production1	79	272	92	112	131	91
Power Production2	116	215	123	168	75	123
Power Production3	185	151	191	236	11	191
Power Production4	102	220	107	166	87	107
Power Production5	99	228	105	156	90	105
Power Production6	165	161	170	223	25	170
Power Production7	199	134	204	252	11	204
Power Production8	266	62	269	324	81	269
Separation Plant	188	143	194	242	0	193
Separation Plant2	4	317	18	87	184	17
Separation Plant3	16	322	1	97	193	1
Separation Plant4	209	123	214	263	20	213
Steam reforming1	188	143	194	242	0	193
Steam reforming2	209	123	214	263	20	213
Steam reforming3	4	317	18	87	184	17
Steam reforming4	16	322	1	97	193	1
Xylitol Production	258	65	260	319	79	260

Xylitol Production2	108	417	116	35	276	116
Xylitol Production3	187	144	193	241	2	192

Table A.12 Approximated transportation cost from further processing 1 facilities, *l* to further processing 2 facilities, *n*

	Formaldehyde Production1	Formaldehyde Production2	Bio-ethylene Production1	Bio-ethylene Production2	Ammonia Production1	Ammonia Production2
Anaerobic Digestion Plant1	29	17	29	31	20	29
Anaerobic Digestion Plant2	24	34	24	13	30	24
Anaerobic Digestion Plant3	27	25	27	29	7	27
Bio-oil upgrading1	27	25	28	29	10	28
Bio-oil upgrading2	28	24	28	30	14	28
Fermentation Plant1	29	17	29	31	20	29
Fermentation Plant2	24	34	24	13	30	24
Fermentation Plant3	27	25	27	29	7	27
FTL production 1	27	25	27	29	0	27
FTL production 2	8	31	10	21	27	10
FTL production 3	9	31	7	23	27	0
Methanol Production	17	13	27	29	0	27
Methanol Production2	1	28	10	21	27	10
Methanol Production3	1	29	7	23	27	0
Power Production1	20	30	22	24	25	22
Power Production2	24	28	25	26	19	25
Power Production3	27	26	27	28	9	27
Power Production4	24	28	24	26	21	24
Power Production5	23	28	24	26	22	24
Power Production6	26	26	26	28	11	26
Power Production7	27	25	27	29	9	27
Power Production8	29	17	29	31	20	29
Separation Plant1	27	25	27	29	0	17
Separation Plant2	8	31	10	21	16	10
Separation Plant3	9	31	7	23	17	0
Separation Plant4	27	25	28	29	10	19
Steam reforming1	27	25	27	29	0	17
Steam reforming2	27	25	28	29	2	19
Steam reforming3	8	31	10	21	16	2
Steam reforming4	9	31	7	23	17	0
Xylitol Production	29	17	29	31	20	29
Xylitol Production2	24	34	24	13	30	24
Xylitol Production3	27	25	27	29	7	27

Table A.13 Approximated emission factor further processing 1 facilities, *l* to further processing 2 facilities, *n*

	Formaldehyde Production1	Formaldehyde Production2	Ammonia Production1	Ammonia Production2	Bio-ethylene Production1	Bio-ethylene Production2
Anaerobic Digestion Plant1	5.7	4.0	4.9	5.7	5.7	7.0
Anaerobic Digestion Plant2	2.4	9.2	6.1	2.6	2.6	2.2
Anaerobic Digestion Plant3	4.1	3.2	0.1	4.2	4.2	5.3
Bio-oil upgrading1	4.6	2.7	1.2	4.7	4.7	5.8
Bio-oil upgrading2	5.2	2.2	2.8	5.2	5.3	6.3
Fermentation Plant1	5.7	4.0	4.9	5.7	5.7	7.0
Fermentation Plant2	2.4	9.2	6.1	2.6	2.6	2.2
Fermentation Plant3	4.1	3.2	0.1	4.2	4.2	5.3
FTL production 1	4.1	3.1	0.0	4.3	4.3	5.3
FTL production 2	0.3	7.0	4.0	1.1	1.1	5.4
FTL production 3	1.0	7.1	4.2	0.0	0.1	6.0
Methanol Production1	0.0	0.0	0.0	4.3	4.3	5.3
Methanol Production2	0.0	0.0	4.0	1.1	1.1	5.4
Methanol Production3	0.0	0.0	4.2	0.0	0.1	6.0
Power Production1	4.9	6.0	2.9	5.7	5.7	2.5
Power Production2	2.5	4.7	4.6	2.7	2.7	3.7
Power Production3	4.1	3.3	0.7	4.2	4.2	5.2
Power Production4	2.3	4.8	5.4	2.3	2.4	3.7
Power Production5	6.1	5.0	5.6	2.3	2.3	3.4
Power Production6	3.6	3.5	1.5	3.7	3.7	4.9
Power Production7	4.4	3.0	0.7	4.5	4.5	5.5
Power Production8	5.8	3.9	5.0	5.9	5.9	7.1
Separation Plant1	4.1	3.1	0.0	0.0	4.3	5.3
Separation Plant2	0.3	7.0	0.0	1.1	1.1	5.4
Separation Plant3	1.0	7.1	0.0	0.0	0.1	6.0
Separation Plant4	4.6	2.7	1.3	0.0	4.7	5.8
Steam reforming1	4.1	3.1	0.0	0.0	4.3	5.3
Steam reforming2	4.6	2.7	0.0	0.0	4.7	5.8
Steam reforming3	0.3	7.0	0.0	0.0	1.1	5.4
Steam reforming4	1.0	7.1	0.0	0.0	0.1	6.0
Xylitol Production1	5.7	4.0	4.9	5.7	5.7	7.0
Xylitol Production2	2.4	9.2	6.1	2.6	2.6	2.2
Xylitol Production3	4.1	3.2	0.1	4.2	4.2	5.3

Table A.14 Estimated production cost factor, conversion factor and CO_2 emissions at *h*

Pre-processing, *h*	Pre-processed product, *i*	Production cost factor (USD $/tonne)	Conversion factor	CO_2 emission factor (ton CO_2eq /tonne of product)
DLF Production	Dry Long Fiber	85	0.37	0.0041
Aerobic Digestion	Bio-compost	10	0.95	0.0200
Alkaline Activation	Activated Carbon	144	0.50	0.0176
Briquetting	Briquette	50	0.38	0.0500
Pelletization	Pellet	60	0.38	0.0500
Torrefied Pelletization	Torrefied Pellet	70	0.38	0.0805
Extraction	Cellulose	125	0.63	0.0590
	Hemicellulose	130	0.18	0.0650
	Lignin	135	0.19	0.0620

Table A.15 Estimated production cost factor, conversion factor and CO_2 emissions at *j*

Pre-processed feedstock, *i*	Main processing, *j*	Intermediate product 1, *k*	Production cost factor (USD $/tonne)	Conversion factor	CO_2 emission factor (ton CO_2eq /tonne of product)
Dry Long Fiber	Bio-composite Production	Bio-composite	107.0	0.75	7.481
Cellulose	CMC Production	CMC	2500.0	0.86	0.097
	Acid Hydrolysis	Glucose	73.4	0.37	0.097
	Enzymatic Hydrolysis		85.7	0.47	0.085
Hemicellulose	Acid Hydrolysis	Xylose	168.7	0.91	0.075
	Enzymatic Hydrolysis		83.1	0.88	0.082
Lignin	Resin Production	Bio-resin	1900.0	0.95	2.500
Briquette	Boiler Combustion	HP Steam	20.7	0.20	0.750
Pellet	Boiler Combustion	HP Steam	20.7	0.25	0.750
	Gasification	Bio-syngas	300.0	0.70	0.680
	Fast pyrolysis	Bio-oil	1003	0.60	0.580
	Slow pyrolysis	Bio-char	111.5	0.50	0.580
Torrefied Pellet	Boiler Combustion	HP Steam	20.7	0.30	0.750
	Gasification	Bio-syngas	300.0	0.80	0.680
	Fast pyrolysis	Bio-oil	1003	0.60	0.600

Table A.16 Estimated production cost factor, conversion factor and CO_2 emissions at *l*

Intermediate product 1, *k*	Further processing 1, *l*	Intermediate product 2, *m*	Production cost factor (USD $/tonne or MWh)	Conversion Factor	CO_2 emission factor (ton CO_2eq /tonne of product)
Bio-oil	Steam Reforming	Bio-hydrogen	455.0	0.84	16.930
	Bio-oil Upgrading	Bio-gasoline	1089.0	0.40	13.000
Bio-oil	Bio-oil Upgrading	Bio-diesel	918.0	0.20	13.000
Glucose	Fermentation	Bio-ethanol	98.2	0.33	0.098
Xylose		Bio-ethanol	98.2	0.33	0.098
Glucose	Anaerobic Digestion	Bio-gas	199.0	0.70	0.250
Xylose	Anaerobic Digestion	Bio-gas	199.0	0.70	0.250
	Xylitol Production	Xylitol	2100.0	0.70	0.082
HP Steam	Power Production	Electricity	58.9/MWh	0.30 MWh/tonne of steam	0.050
	Power Production	MP Steam	12.0	0.35	0.050
	Power Production	LP Steam	7.0	0.35	0.050
Bio-syngas	Methanol Production	Bio-methanol	83.6	0.41	0.083
	Separation	Bio-hydrogen	112	0.46	0.090
	FTL Productions	Bio-diesel	167.3	0.71	0.067
	FTL Productions	Bio-gasoline	519.8	0.29	0.639

Table A.17 Estimated production cost factor, conversion factor and CO_2 emissions at *n*

Intermediate product 2, *m*	Further processing 2, *n*	Final product, *p*	Production cost factor(USD $/tonne)	Conversion factor	CO_2 emission factor (ton CO_2eq /tonne of product)
Bio-hydrogen	Ammonia Production	Ammonia	377	0.80	1.694
Bio-methanol	Formaldehyde Production	Formaldehyde	232	0.97	0.083
Bio-ethanol	Bio-ethylene Production	Bio-ethylene	1200	0.99	1.400

Table A.18 Biomass availability

EFB collection	Fresh fruit bunch production (tonne/hr)	Amount of EFB (tonne/year)*
TENGGAROH	40	63,360.00
TENGGAROH TIMUR	42	66,528.00
Kilang Sawit Risda Sg Ambat	60	95,040.00
Tunjuk Laut	60	95,040.00
ulu Sibol Oil mill	40	63,360.00
Sg kachur POM	30	47,520.00
Kilang sawit Wa ha	37	58,608.00
Kulai POM	60	95,040.00
YPJ POM	40	63,360.00
K.K.S Tai Tak	54	85,536.00
SEMENCHU POM	54	85,536.00
Adela POM	40	63,360.00
KILANG KELAPA SAWIT SIANG	42	66,528.00
Kilang Kelapa Sawit Sedenak	45	71,280.00
Masai Palm Oil Mill	45	71,280.00
Keck Seng POM	30	47,520.00
Pagoh Palm Oil Mill	30	47,520.00
Pamol Plantation	20	31,680.00
Muar oil mill	40	63,360.00
Pamol Klauang	54	85,536.00
Tereh Palm oil mill	60	95,040.00
Sindpra POM	60	95,040.00
Dara Lam Soon	35	55,440.00
Ayer Itam Oil Mill	30	47,520.00
Bukit Benut Oil Palm Mill	40	63,360.00
Bukit Benut POM	100	158,400.00
Bukit Lawiang POM	60	95,040.00
KKS Belitong	40	63,360.00
Ulu remis oil mill	60	95,040.00
Nam Heng Oil mill Co Sdn bhd	60	95,040.00
Gomali Oil Mill	60	95,040.00
Hadapan Palm Oil Mill	90	142,560.00
KKS Nitar	54	85,536.00
Wujud Waisan	30	47,520.00
Kota bahagia palm oil mill	60	95,040.00
KKS Keratong 9	45	71,280.00
Keratong 3 palm oil mill	54	85,536.00
Keratong 2 Palm oil mill	60	95,040.00
Palong Timor Palm oil mill	54	85,536.00
Pukin Palm Oil Mill	40	63,360.00
Palong cocoa pom	120	190,080.00
RISDA ulu keratong	40	63,360.00

Selancar 2b	40	63,360.00
Selancar 2A	60	95,040.00
Johor Labis POM	20	31,680.00
Kekayaan Palm oil mill	60	95,040.00
SOU 20 Chaah	60	95,040.00
SELENDANG POM	40	63,360.00
Seri Intan Palm Oil Mill	30	47,520.00
Lima Blas POM	30	47,520.00
SOU 13 Labu POM	30	47,520.00
SOU 14 Tanah Merah	40	63,360.00
Kilang Kelapa Sawit Ulu Kanchong	30	47,520.00
SOU 15 - Sua Betong POM	55	87,120.00
Pasoh Palm oil mill	10	15,840.00
KS SERTING HILIR-N. SEMBILAN	40	63,360.00
Kok Foh oil mill	60	95,040.00
Kilang Kelapa Sawit Serting	60	95,040.00
Pasir Besar Palm oil mill	60	95,040.00
Jeram Padang Mill	54	85,536.00
Nam bee oil mill	80	126,720.00
Kempas oil mill	60	95,040.00
Diamond Jubilee Oil mill	60	95,040.00
Dominion Square	30	47,520.00
SOU 8 East Mill	50	79,200.00
SOU 9 West Mill	60	95,040.00
Lepar Utara 4 POM	25	39,600.00
lepar utara 6 palm oil mill	54	85,536.00
Carotino POM	54	85,536.00
Jengka 8 POM	45	71,280.00
Kilang Kelapa Sawit Felcra Maran	40	63,360.00
Bukit kepayang palm oil mil	27	42,768.00
Tementi palm oil mill	35	55,440.00
Bukit Sagu POM	45	71,280.00
SOU 12 Jabor POM	60	95,040.00
Panching Palm oil mill	60	95,040.00
Ladang Cheong wing chan	40	63,360.00
Lepar hilir palm oil mill	40	63,360.00
Kilang Sawit LCSB Lepar	40	63,360.00
Sungai jernih mill	35	55,440.00
Bukit Lee Lau	54	85,536.00
CHINI 2 POM	54	85,536.00
Chini 3 Palm oil mill	40	63,360.00
KS KRAU-PAHANG	40	63,360.00
Kuantan Trading POM	90	142,560.00
Padang Piol POM	54	85,536.00
Kota Gelanggi palm oil mill	30	47,520.00

Jengka 21 POM	54	85,536.00
Jengka 3 POM	54	85,536.00
KS SEROJA (JENGKA 18)-PAHANG	40	63,360.00
Kerdau Palm Oil Mill	20	31,680.00
KKS Bukit Mendi	45	71,280.00
Kemasul POM	40	63,360.00
Syarikat penanaman bukti senorang	30	47,520.00
Selaba oil mill	45	71,280.00
Seri Pelangi POM	45	71,280.00
Flemington POM	60	95,040.00
Jendarata Palm Oil Mill (P01)	30	47,520.00
Southern Perak Plantation S/B	40	63,360.00
Ulu bernam POM	100	158,400.00
Trolak palm oil mill	55	87,120.00
Sungai Tengi palm oil mill	60	95,040.00
Kilang Kelapa Sawit Ulu Basir	30	47,520.00
Tanjung Malim palm oil mill	25	39,600.00
KS MEMPAGA-PAHANG	40	63,360.00
Tennamaram Palm Oil Mill	30	47,520.00
Tuan mee palm oil mill	30	47,520.00
SOU 7 Bukit Kerayong	30	47,520.00
Bukit Kerayong Palm Oil Mill	20	31,680.00
Kilang Kelapa Sawit Risda Durian Mas	25	39,600.00
K.K.S Rasau Kerteh	60	95,040.00
Kilang Kelapa Sawit Kemaman	54	85,536.00
Ladang rakyat mill	40	63,360.00
Neram palm oil mill	45	71,280.00
TDM kemaman palm oil mill	60	95,040.00
Temerloh Mill	54	85,536.00
Kechau	54	85,536.00
Bukit Puteri Palm Oil Mill	50	79,200.00
Tersang palm oil mill	40	63,360.00
Minsawi Industries (K. Kangsar)	60	95,040.00
SOU 3 Elphil Mill	60	95,040.00
Trong mill	20	31,680.00
United International Enterprises POM	45	71,280.00
Sungei Kahang Palm Oil	40	63,360.00
Changkat Chermin	27	42,768.00
Pinehill Plantations (Malaysia)	28	44,352.00
Syarikat Cahaya Muda Perak (Oil Mil) Sdn Bhd	54	85,536.00

Kilang Kelapa Sawit Felcra Seberang Perak	30	47,520.00
Felcra Processing & Engineering SB	60	95,040.00
Felcra Bidor Palm oil mill	50	79,200.00
KKS Besout	100	158,400.00
Chalok palm oil mill	60	95,040.00
Kilang Sungai Tong	60	95,040.00
K.K.S Jerangau Barat	60	95,040.00
K.K.S Maokil	30	47,520.00
Ladang Serasa	54	85,536.00
Kilang Kelapa Sawit Kemahang	40	63,360.00
Kuala Pertang POM	54	85,536.00
Kilang Kelapa Sawit Paloh 3	30	47,520.00
Kilang sawit Chiku	20	31,680.00
Solid Orient POM	25	39,600.00
Kilang Kelapa Sawit Sungai Dingin	60	95,040.00
Kilang Sawit Setia Kawan	80	126,720.00
Kilang Kelapa Sawit Batu Lintang	22	34,848.00
KKS Telok Sengat	40	63,360.00
Chersonese POM	20	31,680.00

* 23% of fresh fruit bunch will be assumedly to produce EFB as reported by Ng and Ng (2013) and MPOB (2019)

Table A.19 Annual demands for products in tonne/year

Product	World demands (Tonne/year) or (MWh/year)	Product demands (Tonne/year) or (MWh/year)
Dry Long Fiber	85.4×10^6	85.4
Bio-compost	0.4×10^6	0.4
Activated carbon	1.9×10^6	1.9
Cellulose	5.81×10^6	5.81
Hemicellulose	15×10^6	15
Lignin	0.6×10^6	0.6
Briquette	30×10^6	30
Pellet	37×10^6	37
Torrefied Pellet	70×10^6	70
Bio-composite	0.92×10^6	0.92
Carboxymethyl Cellulose (CMC)	0.4×10^6	0.4
Glucose	5.81×10^6	5.81
Xylose	15×10^6	15
Bio-resin	0.2×10^6	0.2
High pressure steam	2.0×10^6	2
Bio-syngas	100×10^6	100
Bio-oil	5×10^6	5
Bio-char	3000×10^6	3000
Bio-hydrogen	375.5×10^6	375.5
Xylitol	0.002×10^6	0.002
Bio-ethanol	3.6×10^6	3.6
Bio-gas	9×10^6	9
Bio-methanol	0.3×10^6	0.3
Electricity	20×10^6 MWh	20
Medium pressure steam	0.9×10^6	0.9
Low pressure steam	0.45×10^6	0.45
Bio-ethylene	140×10^6	140
Bio-diesel	0.8×10^6	0.8
Bio-gasoline	1.2×10^6	1.2
Ammonia	170.0×10^6	170
Formaldehyde	42×10^6	42

(Abdulrazik et al., 2017; Hanina and Asadullah, 2014)

Table A.20 Processing facilities location and capacities

Processing facilities	Owner	Coordinates		Capacity (tonne/year)	Reference for capacity
		X-Coordinate	Y-Coordinate		
Aerobic Digestion1	Green Global Synergy	100.80171	4.387612	48000	(Clean Development Mechanism (CDM), 2007)
Aerobic Digestion2	Kulim Nursery	103.740316	1.546216	1,380	(Hasanudin et al., 2015)
Aerobic Digestion3	Sawipac Sdn Bhd	103.360561	2.05843	30,000	(Sawipac Sdn Bhd, 2014)
DLF Production1	Green Global Synergy	100.80171	4.387612	14,880	(Lee et al., 2017)
DLF Production2	Sawipac Sdn Bhd	103.360561	2.05843	30,000	(Sawipac Sdn Bhd, 2014)
DLF Production3	Solid Orient Palm oil mill	100.699888	5.569942	95040	(FITTERS Diversified Berhad, 2019)
DLF Production4	Tian Siang Oil Mill (Air Kuning) Biomass Plant	101.145566	4.142549	14,880	(Lee et al., 2017)
DLF Production5	Tian Siang Oil Mill(Perak) Biomass Plant	100.781364	4.500621	14,880	(Lee et al., 2017)
DLF Production6	Biovision & Greenergy (Segamat Plant)	101.600474	3.056095	14,880	(Lee et al., 2017)
DLF Production7	HK Kitaran Sdn Bhd	100.529863	5.219133	58,968	(Heng Huat Resources Group Berhad, 2019)
Extraction Plant1	Detik Aturan Sdn Bhd	101.673899	2.997368	30,000	(Detik Aturan, 2010)
Extraction Plant2	Bionutricia Manufacturing Sdn.Bhd	101.568508	3.162611	930	(Mabrouk et al., 2017)
Extraction Plant3	Tropical Bioessence Sdn. Bhd	102.07895	2.330244	161	(Tropical Bioessence Sdn. Bhd., 2019)
Briquetting Plant1	Green Global Synergy	100.80171	4.387612	44,000	(Shahrukh et al., 2016)
Briquetting Plant2	Solid Orient Palm oil mill	100.699888	5.569942	95040	(FITTERS Diversified Berhad, 2019)
Pelletization Mill1	Green Global Synergy	100.80171	4.387612	44,000	(Shahrukh et al., 2016)
Pelletization Mill2	Sawipac Sdn Bhd	103.360561	2.05843	30,000	(Sawipac Sdn Bhd, 2014)
Pelletization Mill3	FNI Biofuel	104.105184	1.578967	44,000	(Shahrukh et al., 2016)
Pelletization Mill4	Detik Aturan Sdn Bhd	101.673899	2.997368	30,000	(Detik Aturan, 2010)
Pelletization Mill5	Solid Orient Palm oil mill	100.699888	5.569942	95040	(FITTERS Diversified Berhad, 2019)
Pelletization Mill6	Bac Biomass Plant	100.969491	4.243053	44,000	(Shahrukh et al., 2016)

Pelletization Mill7	Biomass Builder Sdn Bhd	103.701711	1.625176	44,000	(Shahrukh et al., 2016)
Torrefied Pelletization1	Green Global Synergy	100.80171	4.387612	44,000	(Shahrukh et al., 2016)
Torrefied Pelletization2	Sawipac Sdn Bhd Kluang Johor	103.360561	2.05843	30,000	(Sawipac Sdn Bhd, 2014)
Torrefied Pelletization3	FNI Biofuel	104.105184	1.578967	44,000	(Shahrukh et al., 2016)
Torrefied Pelletization4	Detik aturan sdn bhd kuala selangor	101.673899	2.997368	30,000	(Detik Aturan, 2010)
Torrefied Pelletization5	Solid Orient Palm oil mill	100.699888	5.569942	95040	(FITTERS Diversified Berhad, 2019)
Torrefied Pelletization6	Bac Biomass Plant	100.969491	4.243053	44,000	(Shahrukh et al., 2016)
Torrefied Pelletization7	Biomass Builder sdn bhd	103.701711	1.625176	44,000	(Shahrukh et al., 2016)
Alkaline Activation (Activated Carbon) Plant1	Green Global Synergy	100.80171	4.387612	6,000	(FEECO International, 2019)
Alkaline Activation (Activated Carbon) Plant2	Gaia Carbon Sdn. Bhd	103.843458	1.600208	6,000	(FEECO International, 2019)
Alkaline Activation (Activated Carbon) Plant3	Effigen Sdn Bhd	101.330597	3.174933	4,500	(Effigen Sdn Bhd, 2019)
CMC Production1	Waris Nove Sdn. Bhd	103.405	4.03345	39,600	(Abdul Rahman et al., 2013)
Acid Hydrolysis1	Chemical Industries (Malaya) Sdn. Bhd.	101.110573	4.642779	60,000	(Hafyan et al., 2019)
Acid Hydrolysis2	Bioalpha Johor Herbal Sdn. Bhd.	104.205372	1.574466	60,000	(Hafyan et al., 2019)
Acid Hydrolysis3	Bioalpha Holdings Berhad	101.754079	2.952926	60,000	(Hafyan et al., 2019)
Enzymatic Hydrolysis1	Chemical Industries (Malaya) Sdn. Bhd.	101.110573	4.642779	60,000	(Hafyan et al., 2019)
Enzymatic Hydrolysis2	Bioalpha Johor Herbal Sdn. Bhd.	104.205372	1.574466	60,000	(Hafyan et al., 2019)
Enzymatic Hydrolysis3	Bioalpha Holdings Berhad	101.754079	2.952926	60,000	(Hafyan et al., 2019)
Resin Production1	Norsechem Resins Sdn Berhad	101.382169	2.952963	24000	(Hexza Corporation Berhad, 2007)
Resin Production2	Luxchem Polymer Industries Sdn Bhd	102.230367	2.269764	30,000	(Luxchem Trading Sdn Bhd, 2017)abdul
Resin Production3	Lotte Chemical Titan	103.964339	1.459831	100,000	(Siehe Industry, 2014)
Bio-composite Production1	Pointray (M) Sdn Bhd	102.592126	5.756882	60,000	(Mifama Opa Carbo, 2019)
Bio-composite Production2	Millennium Composite Industries Sdn Bhd	101.495882	3.026285	60,000	(Mifama Opa Carbo, 2019)

Boiler Combustion1	Bell Eco(biomass) Power Plant	102.892901	1.916693	37,136	(BELL Group of Companies, 2019)be
Boiler Combustion2	Bandar Baru Serting Biomass Plant	102.414788	2.838828	216,000	(Clean Development Mechanism, 2007)
Boiler Combustion3	Sunquest Biomass Power Plant	101.789133	2.589025	123,499	(Clean Development Mechanism, 2010)
Boiler Combustion4	FTJ/TNB-Jengka biomass power plant	102.503739	3.818195	350,000	(FGV Holdings Berhad, 2019)
Boiler Combustion5	Agni-Bera Biomass power plant	102.5508	3.275	280,000	(Luk et al., 2013)
Boiler Combustion6	Bentong power plant	101.941227	3.484914	280,000	(Luk et al., 2013)
Boiler Combustion7	Tenaga Sulpom	101.649699	2.850873	280,000	(Luk et al., 2013)
Boiler Combustion8	Maju intan	101.03445	3.96949	280,000	(SMEC Malaysia, 2016)
Gasification1	Green Global Synergy	100.80171	4.387612	348,000	(Hanina and Asadullah, 2014)
Gasification2	MPOB Labu Experimental Palm Oil Mill (POMTEC).	101.804659	2.748974	1,825	(MPOB, 2017)
Fast Pyrolysis1	Lipochem (M) Sdn. Bhd	101.568024	3.066465	1,825	(Safana A.A et al., 2017)
Fast Pyrolysis2	Eco Power Synergy Sdn Bhd	101.328589	2.965363	8,760	(Beston (Henan) Machinery, 2019)
Slow Pyrolysis1	Lipochem (M) Sdn. Bhd	101.568024	3.066465	1,825	(Safana A.A et al., 2017)
Slow Pyrolysis2	Eco Power Synergy Sdn Bhd	101.328589	2.965363	8,760	(Beston (Henan) Machinery, 2019)
Fermentation Plant1	Chemical Industries (Malaya) Sdn. Bhd.	101.110573	4.642779	60,000	(Hafyan et al., 2019)
Fermentation Plant2	Bioalpha Johor Herbal Sdn. Bhd.	104.205372	1.574466	60,000	(Hafyan et al., 2019)
Fermentation Plant3	Bioalpha Holdings Berhad	101.754079	2.952926	60,000	(Hafyan et al., 2019)
Anaerobic Digestion Plant1	Chemical Industries (Malaya) Sdn. Bhd.	101.110573	4.642779	60,000	(Hafyan et al., 2019)
Anaerobic Digestion Plant2	Bioalpha Johor Herbal Sdn. Bhd.	104.205372	1.574466	60,000	(Hafyan et al., 2019)
Anaerobic Digestion Plant3	Bioalpha Holdings Berhad	101.754079	2.952926	60,000	(Hafyan et al., 2019)
Xylitol Production1	Chemical Industries (Malaya) Sdn. Bhd.	101.110573	4.642779		(Hafyan et al., 2019)

Xylitol Production2	Bioalpha Johor Herbal Sdn. Bhd.	104.205372	1.574466	60,000	(Hafyan et al., 2019)
Xylitol Production3	Bioalpha Holdings Berhad	101.754079	2.952926	60,000	(Hafyan et al., 2019)
Power Production1	Bell Eco(biomass) Power Plant	102.892901	1.916693	37,136	(BELL Group of Companies, 2019)be
Power Production2	Bandar Baru Serting Biomass Plant	102.414788	2.838828	216,000	(Clean Development Mechanism, 2007)
Power Production3	Sunquest Biomass Power Plant	101.789133	2.589025	123,499	(Clean Development Mechanism, 2010)
Power Production4	FTJ/TNB-Jengka biomass power plant	102.503739	3.818195	350,000	(FGV Holdings Berhad, 2019)
Power Production5	Agni-Bera Biomass power plant	102.5508	3.275	280,000	(Luk et al., 2013)
Power Production6	Bentong power plant	101.941227	3.484914	280,000	(Luk et al., 2013)
Power Production7	Tenaga Sulpom	101.649699	2.850873	280,000	(Luk et al., 2013)
Power Production8	Maju intan	101.03445	3.96949	280,000	(SMEC Malaysia, 2016)
Methanol Production1	Linde Group	101.741443	3.009099	36,500	(Linde Engineering, 2019)
Methanol Production2	Petronas Chemicals MTBE (M) Sdn Bhd	103.382989	3.975453	69,350	(Phoenix Equipment Corporation, 2019)
Methanol Production3	Petronas Chemical Derivatives	103.439353	4.575925	69,350	(Phoenix Equipment Corporation, 2019)
Separation Plant1	Linde Group	101.741443	3.009099	210,600	(Linde Engineering, 2019)
Separation Plant2	Petronas Chemicals MTBE (M) Sdn Bhd	103.382989	3.975453	73,000	(Perry Process Equipment, 2019)
Separation Plant3	Petronas Chemical Derivatives	103.439353	4.575925	73,000	(Perry Process Equipment, 2019)
Separation Plant4	Air Products Malaysia Sdn Bhd	101.557868	3.031701	73,000	(Perry Process Equipment, 2019)
FTL production 1	Linde Group	101.741443	3.009099	660,000	(P.L Spath and D.C Dayton, 2003)
FTL production 2	Petronas Chemicals MTBE (M) Sdn Bhd	103.382989	3.975453	660,000	(P.L Spath and D.C Dayton, 2003)
FTL production 3	Petronas Chemical Derivatives	103.439353	4.575925	660,000	(P.L Spath and D.C Dayton, 2003)
Steam Reforming1	Linde Group	101.741443	3.009099	60,000	(Linde Engineering, 2019)
Steam Reforming2	Petronas Chemicals MTBE (M) Sdn Bhd	103.382989	3.975453	100,800	(Air Liquide, 2019)

Steam Reforming3	Petronas Chemical Derivatives	103.439353	4.575925	100,800	(Air Liquide, 2019)
Steam Reforming4	Air Products Malaysia Sdn Bhd	,101.557868	3.031701	100,800	(Air Liquide, 2019)
Bio-oil upgrading1	Lipochem (M) Sdn. Bhd	101.568024	3.066465	1,825	(Safana A.A et al., 2017)
Bio-oil upgrading2	Eco Power Synergy Sdn Bhd	101.328589	2.965363	8,760	(Beston (Henan) Machinery, 2019)
Ammonia Production1	Linde Group	101.741443	3.009099	36,500	(Linde Engineering, 2019)
Ammonia Production2	PETRONAS Chemicals Ammonia Sdn Bhd	103.44653	4.586098	198,560	(Pattabathula and Richardson, 2016)
Formaldehyde Production1	CSA Chemical Sdn Bhd	103.423001	3.979065	60,000	(ChemStationAsia (CSA), 2019)
Formaldehyde Production2	Formal Chemical Sdn Bhd	100.548256	5.440619	15,000	(Phoenix Equipment Corporation, 2019)
Bio-ethylene Production1	Petronas Chemicals Ethylene Sdn Bhd	103.449522	4.591126	400,000	(NrgEdge Pte Ltd, 2019)
Bio-ethylene Production2	Lotte Chemical Titan	103.894305	1.445076	80,000	(McKechnie et al., 2015)
Transesterification1	Carotino Sdn Bhd	103.90273	1.45039	180,000	(Johari et al., 2015)
Transesterification2	YPJ Palm International Sdn. Bhd	103.985582	1.456825	120,000	(Johari et al., 2015)
Transesterification3	Malaysia Vegetable Oil Refinery Sdn. Bhd.	103.916472	1.447559	200,000	Assumed based on Carotech
Transesterification4	Nexsol (Malaysia) Sdn. Bhd	103.992035	1.453087	200,000	Assumed based on Carotech
Transesterification5	PGEO BioproductsSdn. Bhd	103.897318	1.45048	200,000	Assumed based on Carotech
Transesterification6	Vance Bioenergy Sdn. Bhd	103.923207	1.46022	150,000	(Johari et al., 2015)
Transesterification7	Felda Global Ventures Downstream Sdn Bhd	103.301325	3.834987	200,000	Assumed based on Carotech
Transesterification8	CarotechBerhad (Lumut Plant)	100.669976	4.253487	200,000	(Johari et al., 2015)
Transesterification9	CarotechBerhad (Chemor Plant)	101.124928	4.699218	200,000	(Johari et al., 2015)
Transesterification10	KL-Kepong OleomasSdn. Bhd.	101.334209	2.972925	150,000	(Johari et al., 2015)
Transesterification11	Sime Darby Biodiesel Sdn. Bhd.-Carey Island	101.432843	2.88184	90,000	(Johari et al., 2015)

Transesterification12	Sime Darby Biodiesel Sdn. Bhd.-Panglima Garang	101.474044	2.922036	90,000	(Johari et al., 2015)
Transesterification13	KLK Bioenergy Sdn. Bhd. (ZoopSdn. Bhd.)	101.529139	3.060749	200,000	Assumed based on Carotech
Transesterification14	Future Prelude Sdn. Bhd	101.332285	2.971149	200,000	Assumed based on Carotech
Anaerobic Digestion (Glycerol)1	Carotino Sdn Bhd	103.90273	1.45039	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)2	YPJ Palm International Sdn. Bhd	103.985582	1.456825	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)3	Malaysia Vegetable Oil Refinery Sdn. Bhd.	103.916472	1.447559	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)4	Nexsol (Malaysia) Sdn. Bhd	103.992035	1.453087	60,000	Assumed based on Carotech
Anaerobic Digestion (Glycerol)5	PGEO BioproductsSdn. Bhd	103.897318	1.45048	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)6	Vance Bioenergy Sdn. Bhd	103.923207	1.46022	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)7	Felda Global Ventures Downstream Sdn Bhd	103.301325	3.834987	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)8	CarotechBerhad (Lumut Plant)	100.669976	4.253487	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)9	CarotechBerhad (Chemor Plant)	101.124928	4.699218	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)10	KL-Kepong OleomasSdn. Bhd.	101.334209	2.972925	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)11	Sime Darby Biodiesel Sdn. Bhd.-Carey Island	101.432843	2.88184	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)12	Sime Darby Biodiesel Sdn. Bhd.-Panglima Garang	101.474044	2.922036	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)13	KLK Bioenergy Sdn. Bhd. (ZoopSdn. Bhd.)	101.529139	3.060749	60,000	(Hafyan et al., 2019)
Anaerobic Digestion (Glycerol)14	Future Prelude Sdn. Bhd	101.332285	2.971149	60,000	(Hafyan et al., 2019)

Table A.21 Products' selling prices derived for Case D

Product	Selling price (USD $/tonne or USD $/MWh*)	References
Crude palm oil (CPO)	594	(MPOB, 2019)
Bio-diesel	618	(Jaafar et al., 2010)
Glycerol	16.7	(Jaafar et al., 2010)

Table A.22 Distance CPO supplier, *g* to further processing 2 facilities, *n* for Case D

	Formaldehyde Production1	Formaldehyde Production2	Ammonia Production1	Ammonia Production2	Bio-ethylene Production1	Bio-ethylene Production2	Transesterififcation1	Transesterififcation2	Transesterififcation3	Transesterififcation4	Transesterififcation5	Transesterififcation6	Transesterififcation7	Transesterififcation8	Transesterififcation9	Transesterififcation10	Transesterififcation11	Transesterififcation12	Transesterififcation13	Transesterififcation14
TENGGAROH	70	378	238	81	81	17	17	21	18	22	17	18	78	360	312	283	272	267	262	283
TENGGAROH TIMUR	72	382	242	82	82	19	19	21	19	21	19	19	81	364	316	287	276	272	266	288
Kilang Sawit Risda Sg Ambat	69	377	238	80	80	19	19	22	19	23	19	19	77	359	311	283	272	267	261	283
Tunjuk Laut	80	389	249	90	90	16	16	14	15	14	16	14	89	370	323	294	283	278	272	294
ulu Sibol Oil mill	59	352	211	73	73	32	33	42	35	43	33	35	62	333	286	256	245	240	234	256
Sg kachur POM	69	368	227	81	81	17	18	26	19	27	17	20	74	349	302	272	261	256	251	272
Kilang sawit Wa ha	93	401	261	102	102	22	21	13	20	13	22	19	101	383	335	306	295	290	285	306
Kulai POM	64	355	214	78	78	28	29	38	31	39	29	31	67	337	289	259	248	244	238	259
YPJ POM	67	363	222	80	80	21	22	31	23	31	21	24	72	344	297	267	255	251	245	267
K.K.S Tai Tak	77	378	238	89	89	8	8	15	9	16	8	10	83	360	312	282	271	267	261	283
SEMENCHU POM	99	406	265	108	108	24	23	13	21	13	23	20	107	387	340	310	299	294	289	310
Adela POM	107	415	274	115	115	33	32	22	30	22	32	29	115	396	349	319	308	303	298	319
KILANG KELAPA SAWIT SIANG	109	417	277	117	117	35	34	25	33	24	35	32	118	399	351	322	310	306	300	322
Kilang Kelapa Sawit Sedenak	75	368	227	89	89	16	16	26	18	26	16	19	80	349	302	272	260	256	250	272
Masai Palm Oil Mill	88	391	250	99	99	8	7	3	6	4	8	5	95	372	325	295	283	279	273	295
Keck Seng POM	88	391	250	99	99	8	7	3	6	4	8	5	95	372	325	295	283	279	273	295
Pagoh Palm Oil Mill	88	257	115	99	99	127	128	137	130	138	128	130	75	237	191	160	149	144	139	160

Pamol Plantation	92	253	111	103	103	132	133	142	134	143	132	135	78	233	187	155	144	140	134	156
Muar oil mill	96	249	107	107	107	136	137	146	138	146	136	139	83	229	184	151	140	136	130	152
Pamol Klauang	48	325	185	64	64	58	59	68	61	69	59	61	45	307	259	230	219	214	208	230
Tereh Palm oil mill	46	320	180	62	62	64	64	73	66	74	64	66	42	302	254	225	214	210	204	225
Sindpra POM	52	317	177	67	68	66	67	76	69	77	66	69	46	299	251	221	210	206	200	222
Dara Lam Soon	53	312	171	69	69	71	72	81	74	82	72	74	46	293	246	216	205	201	195	216
Ayer Itam Oil Mill	59	304	163	74	74	80	81	90	82	91	80	83	50	285	238	207	196	192	186	208
Bukit Benut Oil Palm Mill	53	321	180	69	69	62	63	72	65	73	62	65	49	302	256	225	214	210	204	225
Bukit Benut POM	54	320	179	70	70	64	64	74	66	74	64	67	49	301	254	224	213	208	202	224
Bukit Lawiang POM	52	331	190	68	68	53	54	63	55	63	53	56	50	312	265	235	224	219	214	235
KKS Belitong	53	338	197	69	69	46	47	56	48	56	46	49	54	319	272	242	231	226	221	242
Ulu remis oil mill	56	334	193	71	71	49	50	59	52	60	49	52	54	315	268	238	227	223	217	238
Nam Heng Oil mill Co Sdn bhd	73	282	140	86	87	102	103	113	105	113	103	106	61	262	216	185	173	169	164	185
Gomali Oil Mill	57	322	180	73	73	62	63	72	65	73	62	65	52	302	256	225	214	209	204	225
Hadapan Palm Oil Mill	56	336	195	72	72	47	48	57	50	58	47	50	56	317	271	240	229	225	219	240
KKS Nitar	48	353	213	61	61	37	37	44	38	45	37	39	54	335	287	259	248	243	237	259
Wujud Wawasan	69	261	122	78	78	124	125	134	126	134	124	127	55	243	195	167	157	152	146	168
Kota bahagia palm oil mill	59	272	134	69	70	113	114	122	115	123	113	116	45	254	206	179	168	163	157	179
KKS Keratong 9	56	276	137	67	67	109	110	119	112	120	110	112	42	258	210	183	172	167	161	183
Keratong 3 palm oil mill	67	264	126	77	77	120	121	130	122	130	120	123	53	247	198	171	160	155	149	171
Keratong 2 Palm oil mill	58	274	135	68	68	111	112	121	114	121	112	114	44	256	208	181	170	165	159	181
Palong Timor Palm oil mill	86	247	107	95	95	136	137	146	139	147	137	139	72	229	181	152	141	137	131	153
Pukin Palm Oil Mill	65	270	130	76	76	114	115	124	117	125	114	117	52	252	204	175	164	160	154	176
Palong cocoa pom	75	260	120	85	86	124	125	134	126	134	124	127	61	241	194	165	154	149	143	165
RISDA ulu keratong	74	262	122	84	84	121	122	131	124	132	122	124	60	244	196	167	156	152	146	167
Selancar 2b	58	280	140	70	70	104	105	114	106	114	104	107	45	262	214	185	174	170	164	186
Selancar 2A	56	282	142	68	69	102	103	112	105	113	103	105	43	264	216	187	176	172	166	188
Johor Labis POM	60	287	147	74	74	96	97	106	99	107	96	99	49	269	222	192	180	176	170	192
Kekayaan Palm oil mill	52	304	163	68	68	80	81	90	82	91	80	83	44	285	238	208	197	192	187	208
SOU 20 Chaah	66	282	141	79	79	102	102	112	104	112	102	105	54	263	216	186	175	170	164	186
SELENDANG POM	33	328	189	49	49	60	61	69	62	70	61	63	33	310	262	234	223	219	213	234
Seri Intan Palm Oil Mill	45	339	200	60	60	47	47	56	49	56	47	49	47	321	273	245	234	229	223	245

Lima Blas POM	219	107	36	223	223	277	278	287	280	288	278	280	206	88	42	21	18	17	17	21
SOU 13 Labu POM	182	151	9	188	188	235	235	245	237	245	235	238	168	130	87	53	41	37	31	53
SOU 14 Tanah Merah	184	151	10	190	190	236	236	246	238	246	236	239	170	130	87	51	40	36	31	52
Kilang Kelapa Sawit Ulu Kanchong	162	173	30	168	169	213	214	223	215	224	213	216	148	152	108	74	63	59	53	75
SOU 15 - Sua Betong POM	174	162	20	180	180	224	225	234	226	235	224	227	160	141	98	63	52	48	42	63
Pasoh Palm oil mill	129	200	61	135	135	183	184	193	186	194	183	186	115	182	135	106	95	90	84	106
KS SERTING HILIR-N. SEMBILAN	108	221	82	115	115	162	163	172	165	173	163	165	94	203	155	127	116	112	106	127
Kok Foh oil mill	106	225	85	114	114	158	159	168	161	169	159	161	92	206	159	130	119	115	109	130
Kilang Kelapa Sawit Serting	112	218	78	119	119	165	166	175	168	176	165	168	98	200	152	124	113	108	102	124
Pasir Besar Palm oil mill	107	227	86	115	115	157	157	166	159	167	157	160	93	208	161	131	120	116	110	131
Jeram Padang Mill	118	214	74	125	126	169	170	179	172	180	170	172	104	195	149	119	108	103	97	119
Nam bee oil mill	110	226	84	118	119	158	159	168	161	169	159	161	96	206	160	129	118	113	108	129
Kempas oil mill	118	220	78	127	127	165	166	175	167	175	165	168	104	200	154	122	111	107	101	123
Diamond Jubilee Oil mill	112	226	84	121	121	158	159	169	161	169	159	162	98	206	160	129	117	113	107	129
Dominion Square	112	226	84	121	121	159	159	169	161	169	159	162	98	206	160	129	117	113	107	129
SOU 8 East Mill	222	113	34	227	228	276	276	286	278	286	276	279	209	90	53	12	0	4	11	12
SOU 9 West Mill	232	104	44	236	237	285	286	295	288	296	285	288	218	81	46	2	9	14	20	2
Lepar Utara 4 POM	68	255	121	72	73	135	136	144	137	145	135	138	54	239	189	166	155	151	144	166
lepar utara 6 palm oil mill	81	241	108	85	86	148	149	158	151	158	149	151	68	225	175	153	142	138	131	153
Carotino POM	67	255	121	73	73	134	135	143	136	144	135	137	54	239	189	166	156	151	144	166
Jengka 8 POM	92	232	97	97	97	155	155	164	157	165	155	157	78	215	166	142	131	127	120	142
Kilang Kelapa Sawit Felcra Maran	82	242	106	88	88	144	145	154	147	155	145	147	68	225	176	151	141	136	130	152
Bukit kepayang palm oil mil	93	232	95	100	100	152	153	162	155	163	153	155	79	215	166	141	130	125	119	141
Tementi palm oil mill	93	233	95	100	100	151	152	161	154	162	152	154	79	216	167	141	130	125	119	141
Bukit Sagu POM	31	291	158	37	37	106	106	114	108	114	106	108	17	276	226	203	193	188	181	203
SOU 12 Jabor POM	13	308	175	23	23	92	93	100	94	100	93	94	3	293	243	220	210	205	198	220
Panching Palm oil mill	29	294	160	37	37	102	102	110	104	111	102	104	15	278	228	205	194	189	183	205
Ladang Cheong wing chan	33	290	155	42	42	103	104	112	105	112	104	106	19	274	224	201	190	185	179	201
Lepar hilir palm oil mill	47	277	142	54	54	113	114	122	116	123	114	116	33	261	211	187	176	172	165	187
Kilang Sawit LCSB Lepar	39	285	150	48	48	106	107	115	108	115	106	109	25	269	219	195	184	180	173	195
Sungai jernih mill	39	288	151	50	50	101	102	110	103	111	101	104	26	271	222	197	186	181	175	197
Bukit Lee Lau	36	292	155	47	48	97	98	106	99	107	97	100	23	275	226	201	190	185	179	201

CHINI 2 POM	57	269	133	65	65	118	119	127	120	128	118	121	43	252	203	178	167	162	156	178
Chini 3 Palm oil mill	57	269	133	65	65	118	119	127	120	128	118	121	43	252	203	178	167	162	156	178
KS KRAU-PAHANG	161	163	30	165	165	220	221	230	223	231	220	223	147	146	98	73	63	58	51	73
Kuantan Trading POM	46	284	146	58	58	102	103	111	104	112	102	105	33	267	218	192	181	176	170	192
Padang Piol POM	104	218	86	108	108	168	169	178	171	178	169	171	90	202	153	130	120	115	109	131
Kota Gelanggi palm oil mill	104	218	86	108	108	168	169	178	171	178	169	171	90	202	153	130	120	115	109	131
Jengka 21 POM	105	218	84	109	110	167	168	177	170	178	168	170	91	202	153	129	118	114	107	129
Jengka 3 POM	99	223	90	104	104	163	164	173	166	173	163	166	86	207	158	134	124	119	113	135
KS SEROJA (JENGKA 18)-PAHANG	98	225	91	102	103	161	162	171	163	171	161	164	84	209	159	136	125	121	114	136
Kerdau Palm Oil Mill	113	210	75	118	118	174	175	184	177	185	175	177	100	194	145	120	110	105	98	120
KKS Bukit Mendi	126	201	63	132	132	182	183	192	185	193	183	185	112	183	135	108	97	92	86	108
Kemasul POM	123	204	66	129	129	179	180	189	182	190	180	182	109	186	138	111	100	95	89	111
Syarikat penanaman bukti senorang	119	209	70	125	125	175	176	184	177	185	175	178	105	191	143	115	104	100	94	116
Selaba oil mill	260	67	76	263	264	319	320	329	321	329	319	322	247	46	16	36	46	49	54	36
Seri Pelangi POM	255	72	71	258	258	313	314	323	315	324	313	316	241	52	15	31	41	44	48	31
Flemington POM	285	46	100	288	289	343	344	353	345	353	343	346	272	22	34	57	68	72	77	57
Jendarata Palm Oil Mill (P01)	268	62	83	271	271	325	326	335	328	336	325	328	254	39	21	40	51	55	60	40
Southern Perak Plantation S/B	267	62	82	271	271	325	326	335	327	335	325	328	254	40	22	40	50	54	59	39
Ulu bernam POM	257	72	71	260	260	314	315	324	316	324	314	317	243	51	20	29	40	44	48	29
Trolak palm oil mill	230	95	48	233	234	289	290	299	292	300	289	292	217	76	30	21	25	26	28	21
Sungai Tengi palm oil mill	223	104	38	227	227	280	281	290	283	291	281	284	210	84	40	16	16	16	17	16
Kilang Kelapa Sawit Ulu Basir	241	87	56	244	245	298	299	308	301	309	299	302	227	66	26	19	27	30	34	18
Tanjung Malim palm oil mill	232	95	47	235	235	289	290	299	292	300	289	292	218	75	32	17	21	23	26	17
KS MEMPAGA-PAHANG	205	123	20	210	210	262	263	272	264	272	262	265	192	103	58	29	20	16	9	29
Tennamaram Palm Oil Mill	229	101	43	233	234	285	286	295	287	296	285	288	215	80	39	9	13	16	19	10
Tuan mee palm oil mill	219	112	31	223	223	274	275	284	276	285	274	277	205	91	49	16	9	8	9	16
SOU 7 Bukit Kerayong	228	104	41	233	233	283	284	293	286	294	283	286	215	82	43	7	9	12	17	7
Bukit Kerayong Palm Oil Mill	229	103	42	233	234	284	285	294	286	295	284	287	215	81	43	6	10	13	18	6
Kilang Kelapa Sawit Risda Durian Mas	20	317	189	7	7	103	103	109	104	109	103	104	26	304	253	234	223	219	212	234
K.K.S Rasau Kerteh	19	309	179	14	15	104	104	110	105	111	104	106	19	295	244	224	213	209	202	224
Kilang Kelapa Sawit Kemaman	9	317	185	10	10	94	94	100	95	101	94	96	15	302	252	230	220	215	209	230
Ladang rakyat mill	23	298	167	28	28	103	103	110	105	111	103	105	12	283	233	211	201	196	190	212

Neram palm oil mill	15	307	174	23	23	95	95	102	97	103	95	97	5	291	241	219	208	203	197	219
TDM kemaman palm oil mill	22	301	171	23	23	105	106	113	107	113	106	107	16	287	236	215	205	200	194	216
Temerloh Mill	22	301	171	23	23	105	106	113	107	113	106	107	16	287	236	215	205	200	194	216
Kechau	150	172	48	152	153	214	215	224	217	224	214	217	137	156	106	88	78	74	67	88
Bukit Puteri Palm Oil Mill	183	139	27	186	186	245	246	255	248	256	246	248	170	123	73	56	48	44	38	56
Tersang palm oil mill	181	142	26	183	184	242	243	252	244	252	242	245	167	126	76	58	49	45	38	58
Minsawi Industries (K. Kangsar)	281	41	101	283	283	342	343	352	344	353	342	345	267	29	25	63	73	76	80	63
SOU 3 Elphil Mill	260	62	83	262	262	322	323	332	325	333	322	325	247	49	5	49	58	60	63	49
Trong mill	302	24	121	305	305	362	363	372	365	373	363	366	289	10	46	79	89	93	98	78
United International Enterprises POM	307	25	123	309	309	366	366	376	368	376	366	369	293	3	51	80	91	95	100	80
Sungei Kahang Palm Oil	288	38	105	290	291	347	348	357	350	358	348	350	274	19	33	63	74	78	82	63
Changkat Chermin	303	29	119	305	306	361	362	371	364	372	362	364	289	3	48	76	87	91	96	75
Pinehill Plantations (Malaysia)	306	28	122	309	309	364	365	374	367	375	365	367	293	0	51	79	90	94	99	78
Syarikat Cahaya Muda Perak (Oil Mil) Sdn Bhd	240	83	60	243	244	300	301	310	303	311	301	303	227	66	19	28	35	37	39	28
Kilang Kelapa Sawit Felcra Seberang Perak	275	52	92	278	278	334	335	344	336	345	334	337	262	31	23	50	61	65	69	50
Felcra Processing & Engineering SB	267	60	83	270	271	326	326	336	328	336	326	329	254	39	19	42	52	56	60	41
Felcra Bidor Palm oil mill	251	75	67	254	254	309	310	319	312	320	310	312	237	56	16	29	38	41	45	29
KKS Besout	235	90	53	238	238	294	295	304	296	305	294	297	221	71	26	23	28	30	32	23
Chalok palm oil mill	80	248	129	77	77	161	161	169	163	169	161	163	71	236	185	171	162	157	150	171
Kilang Sungai Tong	66	263	141	62	63	148	149	156	150	156	148	150	57	250	199	183	174	169	162	184
K.K.S Jerangau Barat	47	280	155	43	44	130	131	137	132	138	130	132	39	267	216	198	188	184	177	199
K.K.S Maokil	65	261	138	63	63	146	146	153	147	154	146	148	55	248	197	181	171	166	160	181
Ladang Serasa	141	181	68	142	142	212	213	221	214	222	212	215	129	168	117	105	97	92	86	105
Kilang Kelapa Sawit Kemahang	148	178	79	147	147	222	223	231	225	232	223	225	137	168	117	111	104	100	93	111
Kuala Pertang POM	138	188	82	137	137	212	213	221	214	222	212	215	126	177	125	117	109	105	98	117
Kilang Kelapa Sawit Paloh 3	130	192	75	131	131	201	202	210	203	211	201	204	118	179	128	114	105	101	94	114
Kilang sawit Chiku	138	184	68	139	139	208	208	217	210	217	208	210	125	171	120	106	98	93	86	107
Solid Orient POM	305	17	128	306	307	368	369	378	371	379	368	371	292	27	51	90	100	103	107	89
Kilang Kelapa Sawit Sungai Dingin	313	9	135	314	314	375	376	385	378	386	376	378	300	26	58	95	105	109	113	95
Kilang Sawit Setia Kawan	313	9	134	314	314	375	376	385	377	386	375	378	299	25	57	94	105	108	112	94
Kilang Kelapa Sawit Batu Lintang	312	10	132	314	314	374	374	383	376	384	374	377	299	20	56	91	102	106	110	91
KKS Telok Sengat	302	19	123	304	304	364	365	374	366	375	364	367	289	20	47	83	94	97	101	83
Chersonese POM	331	14	149	333	333	391	392	401	394	402	392	394	318	28	75	107	118	122	126	107

Table A.23 Approximated transportation cost from CPO supplier, *g* to further processing 2 facilities, *n*

	Formaldehyde Production1	Formaldehyde Production2	Ammonia Production1	Ammonia Production2	Bio-ethylene Production1	Bio-ethylene Production2	Transesterification1	Transesterification2	Transesterification3	Transesterification4	Transesterification5	Transesterification6	Transesterification7	Transesterification8	Transesterification9	Transesterification10	Transesterification11	Transesterification12	Transesterification13	Transesterification14
TENGGAROH	18	33	28	20	20	10	10	10	10	10	10	10	20	32	31	30	30	29	29	30
TENGGAROH TIMUR	19	33	29	20	20	10	10	10	10	10	10	10	20	33	31	30	30	30	29	30
Kilang Sawit Risda Sg Ambat	18	33	28	20	20	10	10	10	10	11	10	10	20	32	31	30	30	29	29	30
Tunjuk Laut	20	33	29	22	22	9	9	9	9	9	9	9	21	33	31	30	30	30	30	30
ulu Sibol Oil mill	16	32	28	19	19	12	12	14	13	14	12	13	17	32	30	29	29	29	28	29
Sg kachur POM	18	33	28	20	20	10	10	11	10	11	10	10	19	32	31	30	29	29	29	30
Kilang sawit Wa ha	22	34	29	24	24	10	10	9	10	9	10	10	24	33	32	31	30	30	30	31
Kulai POM	17	32	28	20	20	11	12	13	12	13	12	12	18	32	30	29	29	29	28	29
YPJ POM	18	33	28	20	20	10	10	12	11	12	10	11	19	32	30	29	29	29	29	29
K.K.S Tai Tak	19	33	28	21	21	8	8	9	8	9	8	8	21	32	31	30	30	29	29	30
SEMENCHU POM	23	34	29	24	24	11	11	9	10	9	11	10	24	33	32	31	30	30	30	31
Adela POM	24	34	30	24	24	12	12	11	12	10	12	12	24	34	32	31	31	31	30	31
KILANG KELAPA SAWIT SIANG	24	34	30	24	24	13	12	11	12	11	13	12	24	34	32	31	31	31	31	31
Kilang Kelapa Sawit Sedenak	19	33	28	21	21	9	10	11	10	11	9	10	20	32	31	30	29	29	29	30
Masai Palm Oil Mill	21	34	29	23	23	8	8	7	8	7	8	8	22	33	31	30	30	30	30	30
Keck Seng POM	21	34	29	23	23	8	8	7	8	7	8	8	22	33	31	30	30	30	30	30
Pagoh Palm Oil Mill	21	29	24	23	23	25	25	25	25	25	25	25	19	28	27	26	25	25	25	26
Pamol Plantation	22	29	24	24	24	25	25	25	25	25	25	25	20	28	27	26	25	25	25	26
Muar oil mill	23	29	24	24	24	25	25	25	25	25	25	25	20	28	27	26	25	25	25	26
Pamol Klauang	15	31	27	17	17	16	17	18	17	18	16	17	14	31	29	28	28	28	27	28
Tereh Palm oil mill	14	31	27	17	17	17	17	19	18	19	17	18	14	31	29	28	28	27	27	28

Sindpra POM	15	31	26	18	18	18	18	19	18	19	18	18	14	30	29	28	28	27	27	28
Dara Lam Soon	16	31	26	18	18	19	19	20	19	20	19	19	14	30	29	28	27	27	27	28
Ayer Itam Oil Mill	16	31	26	19	19	20	20	22	20	22	20	20	15	30	28	27	27	27	27	27
Bukit Benut Oil Palm Mill	16	31	27	18	18	17	17	19	17	19	17	18	15	31	29	28	28	28	27	28
Bukit Benut POM	16	31	26	18	18	17	17	19	18	19	17	18	15	31	29	28	28	27	27	28
Bukit Lawiang POM	15	32	27	18	18	16	16	17	16	17	16	16	15	31	29	28	28	28	28	28
KKS Belitong	16	32	27	18	18	14	15	16	15	16	14	15	16	31	30	29	28	28	28	29
Ulu remis oil mill	16	32	27	19	19	15	15	17	15	17	15	15	16	31	29	28	28	28	28	28
Nam Heng Oil mill Co Sdn bhd	19	30	25	21	21	24	24	24	24	24	24	24	17	29	28	27	26	26	26	27
Gomali Oil Mill	16	31	27	19	19	17	17	19	17	19	17	18	15	31	29	28	28	27	27	28
Hadapan Palm Oil Mill	16	32	27	19	19	15	15	16	15	16	15	15	16	31	30	29	28	28	28	29
KKS Nitar	15	32	28	17	17	13	13	14	13	14	13	13	16	32	30	29	29	29	28	29
Wujud Wawasan	18	29	25	20	20	25	25	25	25	25	25	25	16	29	27	26	26	26	25	26
Kota bahagia palm oil mill	17	30	25	18	18	24	24	25	24	25	24	24	14	29	27	26	26	26	26	26
KKS Keratong 9	16	30	25	18	18	24	24	24	24	25	24	24	14	29	28	27	26	26	26	27
Keratong 3 palm oil mill	18	29	25	19	19	25	25	25	25	25	25	25	16	29	27	26	26	26	25	26
Keratong 2 Palm oil mill	16	30	25	18	18	24	24	25	24	25	24	24	14	29	27	27	26	26	26	27
Palong Timor Palm oil mill	21	29	24	22	22	25	25	25	25	25	25	25	19	28	27	26	25	25	25	26
Pukin Palm Oil Mill	18	30	25	19	19	24	24	25	24	25	24	24	15	29	27	26	26	26	26	26
Palong cocoa pom	19	29	25	21	21	25	25	25	25	25	25	25	17	29	27	26	26	25	25	26
RISDA ulu keratong	19	29	25	21	21	25	25	25	25	25	25	25	17	29	27	26	26	26	25	26
Selancar 2b	16	30	25	18	18	24	24	24	24	24	24	24	14	29	28	27	26	26	26	27
Selancar 2A	16	30	25	18	18	24	24	24	24	24	24	24	14	29	28	27	26	26	26	27
Johor Labis POM	17	30	25	19	19	23	23	24	23	24	23	23	15	29	28	27	27	26	26	27
Kekayaan Palm oil mill	15	31	26	18	18	20	20	22	20	22	20	20	14	30	28	27	27	27	27	27
SOU 20 Chaah	18	30	25	20	20	24	24	24	24	24	24	24	16	29	28	27	26	26	26	27
SELENDANG POM	12	31	27	15	15	17	17	18	17	18	17	17	12	31	29	28	28	28	28	28
Seri Intan Palm Oil Mill	14	32	27	17	17	14	15	16	15	16	15	15	15	31	30	29	28	28	28	29
Lima Blas POM	28	24	13	28	28	30	30	30	30	30	30	30	27	21	14	10	10	10	10	10
SOU 13 Labu POM	27	26	8	27	27	28	28	29	28	29	28	28	26	25	21	15	14	13	12	15
SOU 14 Tanah Merah	27	26	8	27	27	28	28	29	28	29	28	28	26	25	21	15	13	13	12	15
Kilang Kelapa Sawit Ulu Kanchong	26	26	12	26	26	28	28	28	28	28	28	28	25	26	24	19	17	16	16	19
SOU 15 - Sua Betong POM	26	26	10	27	27	28	28	28	28	28	28	28	26	25	23	17	15	15	14	17

Pasoh Palm oil mill	25	27	17	25	25	27	27	27	27	27	27	27	24	27	25	24	22	22	21	24
KS SERTING HILIR-N. SEMBILAN	24	28	20	24	24	26	26	26	26	26	26	26	22	27	26	25	24	24	24	25
Kok Foh oil mill	24	28	21	24	24	26	26	26	26	26	26	26	22	27	26	25	24	24	24	25
Kilang Kelapa Sawit Serting	24	28	20	24	24	26	26	26	26	26	26	26	23	27	26	25	24	24	24	25
Pasir Besar Palm oil mill	24	28	21	24	24	26	26	26	26	26	26	26	22	27	26	25	25	24	24	25
Jeram Padang Mill	24	28	19	25	25	26	26	26	26	27	26	26	24	27	25	24	24	24	23	24
Nam bee oil mill	24	28	21	24	24	26	26	26	26	26	26	26	23	27	26	25	24	24	24	25
Kempas oil mill	24	28	20	25	25	26	26	26	26	26	26	26	24	27	26	25	24	24	24	25
Diamond Jubilee Oil mill	24	28	21	25	25	26	26	26	26	26	26	26	23	27	26	25	24	24	24	25
Dominion Square	24	28	21	25	25	26	26	26	26	26	26	26	23	27	26	25	24	24	24	25
SOU 8 East Mill	28	24	12	28	28	30	30	30	30	30	30	30	27	22	15	9		8	9	9
SOU 9 West Mill	28	24	14	28	28	30	30	30	30	30	30	30	28	20	14	7	8	9	10	7
Lepar Utara 4 POM	18	29	25	19	19	25	25	25	25	25	25	25	16	28	27	26	26	26	25	26
lepar utara 6 palm oil mill	20	29	24	21	21	25	25	26	26	26	25	26	18	28	26	26	25	25	25	26
Carotino POM	18	29	25	19	19	25	25	25	25	25	25	25	16	28	27	26	26	26	25	26
Jengka 8 POM	22	28	23	23	23	26	26	26	26	26	26	26	20	28	26	25	25	25	25	25
Kilang Kelapa Sawit Felcra Maran	20	29	24	21	21	25	25	26	25	26	25	25	18	28	26	26	25	25	25	26
Bukit kepayang palm oil mil	22	28	22	23	23	26	26	26	26	26	26	26	20	28	26	25	25	25	24	25
Tementi palm oil mill	22	28	23	23	24	26	26	26	26	26	26	26	20	28	26	25	25	25	24	25
Bukit Sagu POM	12	30	26	13	13	24	24	24	24	24	24	24	10	30	28	27	27	27	27	27
SOU 12 Jabor POM	9	31	26	11	11	22	22	23	22	24	22	22	7	30	29	28	27	27	27	28
Panching Palm oil mill	12	30	26	13	13	24	24	24	24	24	24	24	9	30	28	27	27	27	27	27
Ladang Cheong wing chan	12	30	26	14	14	24	24	24	24	24	24	24	10	30	28	27	27	27	26	27
Lepar hilir palm oil mill	14	30	25	16	16	24	24	25	24	25	24	24	12	29	28	27	26	26	26	27
Kilang Sawit LCSB Lepar	13	30	26	15	15	24	24	24	24	24	24	24	11	29	28	27	27	27	26	27
Sungai jernih mill	13	30	26	15	15	24	24	24	24	24	24	24	11	30	28	27	27	27	26	27
Bukit Lee Lau	13	30	26	15	15	23	23	24	23	24	23	23	11	30	28	27	27	27	26	27
CHINI 2 POM	16	29	25	18	18	24	24	25	25	25	24	25	14	29	27	26	26	26	26	26
Chini 3 Palm oil mill	16	29	25	18	18	24	24	25	25	25	24	25	14	29	27	26	26	26	26	26
KS KRAU-PAHANG	26	26	12	26	26	28	28	28	28	28	28	28	25	25	23	19	17	16	15	19
Kuantan Trading POM	14	30	25	16	16	24	24	24	24	24	24	24	12	29	28	27	27	26	26	27
Padang Piol POM	24	28	21	24	24	26	26	26	26	26	26	26	22	27	26	25	25	24	24	25
Kota Gelanggi palm oil mill	24	28	21	24	24	26	26	26	26	26	26	26	22	27	26	25	25	24	24	25

Jengka 21 POM	24	28	21	24	24	26	26	26	26	26	26	26	22	27	26	25	24	24	24	25
Jengka 3 POM	23	28	22	24	24	26	26	26	26	26	26	26	21	27	26	25	25	24	24	25
KS SEROJA (JENGKA 18)-PAHANG	23	28	22	24	24	26	26	26	26	26	26	26	21	27	26	25	25	25	24	25
Kerdau Palm Oil Mill	24	28	19	24	24	26	26	27	26	27	26	26	23	27	25	25	24	24	23	25
KKS Bukit Mendi	25	27	17	25	25	27	27	27	27	27	27	27	24	27	25	24	23	22	21	24
Kemasul POM	25	27	18	25	25	26	27	27	27	27	27	27	24	27	25	24	23	22	21	24
Syarikat penanaman bukti senorang	24	27	18	25	25	26	26	27	26	27	26	26	24	27	25	24	24	23	22	24
Selaba oil mill	29	18	19	29	29	31	31	31	31	31	31	31	29	14	9	13	14	15	16	13
Seri Pelangi POM	29	19	18	29	29	31	31	31	31	31	31	31	29	15	9	12	14	14	15	12
Flemington POM	30	14	24	30	30	32	32	32	32	32	32	32	30	10	12	16	18	19	19	16
Jendarata Palm Oil Mill (P01)	29	17	20	30	30	31	31	32	31	32	31	31	29	13	10	13	15	16	17	13
Southern Perak Plantation S/B	29	17	20	30	30	31	31	32	31	32	31	31	29	13	11	13	15	16	17	13
Ulu bernam POM	29	19	19	29	29	31	31	31	31	31	31	31	29	15	10	12	13	14	15	12
Trolak palm oil mill	28	22	15	28	28	30	30	30	30	31	30	30	28	19	12	10	11	11	11	10
Sungai Tengi palm oil mill	28	24	13	28	28	30	30	30	30	30	30	30	28	21	13	10	9	9	10	10
Kilang Kelapa Sawit Ulu Basir	29	21	16	29	29	30	30	31	31	31	30	31	28	18	11	10	11	12	12	10
Tanjung Malim palm oil mill	28	22	15	28	28	30	30	30	30	31	30	30	28	19	12	10	10	11	11	10
KS MEMPAGA-PAHANG	27	25	10	27	28	29	29	30	29	30	29	29	27	24	16	12	10	9	8	12
Tennamaram Palm Oil Mill	28	24	14	28	28	30	30	30	30	30	30	30	28	20	13	8	9	9	10	8
Tuan mee palm oil mill	28	24	12	28	28	30	30	30	30	30	30	30	27	22	15	9	8	8	8	9
SOU 7 Bukit Kerayong	28	24	14	28	28	30	30	30	30	30	30	30	28	20	14	8	8	9	10	8
Bukit Kerayong Palm Oil Mill	28	24	14	28	28	30	30	30	30	30	30	30	28	20	14	8	8	9	10	8
Kilang Kelapa Sawit Risda Durian Mas	10	31	27	8	8	24	24	24	24	24	24	24	11	31	29	28	28	28	28	28
K.K.S Rasau Kerteh	10	31	26	9	9	24	24	24	24	24	24	24	10	30	29	28	28	27	27	28
Kilang Kelapa Sawit Kemaman	8	31	27	8	9	22	22	24	22	24	22	23	9	31	29	28	28	28	27	28
Ladang rakyat mill	11	30	26	11	11	24	24	24	24	24	24	24	9	30	28	28	27	27	27	28
Neram palm oil mill	9	31	26	11	11	22	23	24	23	24	22	23	8	30	29	28	27	27	27	28
TDM kemaman palm oil mill	10	31	26	11	11	24	24	24	24	24	24	24	9	30	28	28	27	27	27	28
Temerloh Mill	10	31	26	11	11	24	24	24	24	24	24	24	9	30	28	28	27	27	27	28
Kechau	26	26	15	26	26	28	28	28	28	28	28	28	25	26	24	21	20	19	18	21
Bukit Puteri Palm Oil Mill	27	25	11	27	27	29	29	29	29	29	29	29	26	25	19	16	15	14	13	16
Tersang palm oil mill	27	25	11	27	27	29	29	29	29	29	29	29	26	25	19	16	15	14	13	16
Minsawi Industries (K. Kangsar)	30	14	24	30	30	32	32	32	32	32	32	32	29	12	11	17	19	19	20	17

SOU 3 Elphil Mill	29	17	20	29	29	31	31	32	31	32	31	31	29	15	8	15	16	17	17	15
Trong mill	31	11	25	31	31	33	33	33	33	33	33	33	30	8	14	20	21	22	23	20
United International Enterprises POM	31	11	25	31	31	33	33	33	33	33	33	33	30	7	15	20	22	22	24	20
Sungei Kahang Palm Oil	30	13	24	30	30	32	32	32	32	32	32	32	30	10	12	17	19	20	20	17
Changkat Chermin	31	12	24	31	31	33	33	33	33	33	33	33	30	7	15	19	21	22	23	19
Pinehill Plantations (Malaysia)	31	11	25	31	31	33	33	33	33	33	33	33	30		15	20	22	22	23	20
Syarikat Cahaya Muda Perak (Oil Mil) Sdn Bhd	29	21	17	29	29	31	31	31	31	31	31	31	28	18	10	11	13	13	13	11
Kilang Kelapa Sawit Felcra Seberang Perak	30	15	22	30	30	32	32	32	32	32	32	32	29	12	11	15	17	17	18	15
Felcra Processing & Engineering SB	29	17	21	30	30	31	31	32	31	32	31	31	29	13	10	14	15	16	17	14
Felcra Bidor Palm oil mill	29	19	18	29	29	31	31	31	31	31	31	31	28	16	9	12	13	14	14	12
KKS Besout	28	22	16	28	28	30	30	31	30	31	30	30	28	19	11	11	11	12	12	11
Chalok palm oil mill	20	29	25	19	20	26	26	26	26	26	26	26	18	28	27	26	26	26	26	26
Kilang Sungai Tong	18	29	25	17	17	25	25	26	26	26	25	26	16	29	27	27	26	26	26	27
K.K.S Jerangau Barat	15	30	26	14	14	25	25	25	25	25	25	25	13	29	28	27	27	27	26	27
K.K.S Maokil	18	29	25	17	17	25	25	26	25	26	25	25	16	29	27	27	26	26	26	27
Ladang Serasa	25	27	18	25	25	28	28	28	28	28	28	28	25	26	24	24	23	22	21	24
Kilang Kelapa Sawit Kemahang	25	26	20	25	25	28	28	28	28	28	28	28	25	26	24	24	24	23	22	24
Kuala Pertang POM	25	27	20	25	25	28	28	28	28	28	28	28	25	26	25	24	24	24	23	24
Kilang Kelapa Sawit Paloh 3	25	27	19	25	25	27	27	28	27	28	27	27	24	26	25	24	24	24	22	24
Kilang sawit Chiku	25	27	18	25	25	27	27	28	28	28	27	28	25	26	25	24	23	22	21	24
Solid Orient POM	31	10	25	31	31	33	33	33	33	33	33	33	30	11	15	22	23	24	24	22
Kilang Kelapa Sawit Sungai Dingin	31	8	25	31	31	33	33	33	33	33	33	33	30	11	16	22	24	24	24	22
Kilang Sawit Setia Kawan	31	8	25	31	31	33	33	33	33	33	33	33	30	11	16	22	24	24	24	22
Kilang Kelapa Sawit Batu Lintang	31	9	25	31	31	33	33	33	33	33	33	33	30	10	16	22	24	24	24	22
KKS Telok Sengat	31	10	25	31	31	33	33	33	33	33	33	33	30	10	14	20	22	23	24	20
Chersonese POM	32	9	25	32	32	34	34	34	34	34	34	34	31	11	19	24	24	25	25	24

Table A.24 Approximated emission factor (10^{-3}) CPO supplier, *g* to further processing 2 facilities, *n*

	Formaldehyde Production1	Formaldehyde Production2	Ammonia Production1	Ammonia Production2	Bio-ethylene Production1	Bio-ethylene Production2	Transesterififcation1	Transesterififcation2	Transesterififcation3	Transesterififcation4	Transesterififcation5	Transesterififcation6	Transesterififcation7	Transesterififcation8	Transesterififcation9	Transesterififcation10	Transesterififcation11	Transesterififcation12	Transesterififcation13	Transesterififcation14
TENGGAROH	4.4	8.3	5.2	5.0	5.0	1.1	1.1	1.3	1.1	1.3	1.1	1.1	4.8	7.9	6.9	6.2	6.0	5.9	5.8	6.2
TENGGAROH TIMUR	4.5	8.4	5.3	5.1	5.1	1.2	1.2	1.3	1.2	1.3	1.2	1.2	5.0	8.0	6.9	6.3	6.1	6.0	5.8	6.3
Kilang Sawit Risda Sg Ambat	4.3	8.3	5.2	4.9	4.9	1.2	1.2	1.4	1.2	1.4	1.2	1.2	4.8	7.9	6.9	6.2	6.0	5.9	5.8	6.2
Tunjuk Laut	5.0	8.6	5.5	5.6	5.6	1.0	1.0	0.9	0.9	0.9	1.0	0.9	5.5	8.2	7.1	6.5	6.2	6.1	6.0	6.5
ulu Sibol Oil mill	3.6	7.7	4.6	4.5	4.5	2.0	2.1	2.6	2.2	2.6	2.0	2.2	3.8	7.3	6.3	5.6	5.4	5.3	5.2	5.6
Sg kachur POM	4.3	8.1	5.0	5.1	5.0	1.0	1.1	1.6	1.2	1.7	1.1	1.2	4.6	7.7	6.6	6.0	5.7	5.6	5.5	6.0
Kilang sawit Wa ha	5.7	8.8	5.7	2.2	2.2	1.4	1.3	0.8	1.2	0.8	1.3	1.2	2.2	8.4	7.4	6.7	6.5	6.4	6.3	6.7
Kulai POM	3.9	7.8	4.7	4.8	4.8	1.7	1.8	2.4	1.9	2.4	1.8	1.9	4.1	7.4	6.4	5.7	5.5	5.4	5.2	5.7
YPJ POM	4.2	8.0	4.9	5.0	5.0	1.3	1.4	1.9	1.5	2.0	1.3	1.5	4.4	7.6	6.5	5.9	5.6	5.5	5.4	5.9
K.K.S Tai Tak	4.8	8.3	5.2	5.5	5.5	0.5	0.5	1.0	0.6	1.0	0.5	0.6	5.2	7.9	6.9	6.2	6.0	5.9	5.7	6.2
SEMENCHU POM	6.1	8.9	5.8	2.4	2.4	1.5	1.4	0.8	1.3	0.8	1.4	1.3	2.4	8.5	7.5	6.8	6.6	6.5	6.3	6.8
Adela POM	2.3	9.1	6.0	2.5	2.5	2.0	2.0	1.4	1.9	1.3	2.0	1.8	2.5	8.7	7.7	7.0	6.8	6.7	6.6	7.0
KILANG KELAPA SAWIT SIANG	2.4	9.2	6.1	2.6	2.6	2.2	2.1	1.5	2.0	1.5	2.2	2.0	2.6	8.8	7.7	7.1	6.8	6.7	6.6	7.1
Kilang Kelapa Sawit Sedenak	4.7	8.1	5.0	5.5	5.5	1.0	1.0	1.6	1.1	1.6	1.0	1.2	4.9	7.7	6.7	6.0	5.7	5.6	5.5	6.0
Masai Palm Oil Mill	5.5	8.6	5.5	6.1	6.1	0.5	0.5	0.2	0.4	0.2	0.5	0.3	5.9	8.2	7.1	6.5	6.2	6.1	6.0	6.5
Keck Seng POM	5.5	8.6	5.5	6.1	6.1	0.5	0.5	0.2	0.4	0.2	0.5	0.3	5.9	8.2	7.1	6.5	6.2	6.1	6.0	6.5
Pagoh Palm Oil Mill	5.5	5.7	2.5	6.1	6.2	2.8	2.8	3.0	2.9	3.0	2.8	2.9	4.6	5.2	4.2	3.5	3.3	3.2	3.1	3.5
Pamol Plantation	5.7	5.6	2.4	2.3	2.3	2.9	2.9	3.1	3.0	3.1	2.9	3.0	4.9	5.1	4.1	3.4	3.2	3.1	3.0	3.4
Muar oil mill	6.0	5.5	2.4	2.4	2.4	3.0	3.0	3.2	3.0	3.2	3.0	3.1	5.1	5.0	4.0	3.3	3.1	3.0	2.9	3.3
Pamol Klauang	3.0	7.2	4.1	4.0	4.0	3.6	3.7	4.2	3.8	4.3	3.6	3.8	2.8	6.7	5.7	5.1	4.8	4.7	4.6	5.1
Tereh Palm oil mill	2.9	7.0	4.0	3.8	3.9	3.9	4.0	4.5	4.1	4.6	4.0	4.1	2.6	6.6	5.6	5.0	4.7	4.6	4.5	5.0
Sindpra POM	3.2	7.0	3.9	4.2	4.2	4.1	4.2	4.7	4.2	4.8	4.1	4.3	2.9	6.6	5.5	4.9	4.6	4.5	4.4	4.9
Dara Lam Soon	3.3	6.9	3.8	4.3	4.3	4.4	4.5	5.0	4.6	5.1	4.4	4.6	2.9	6.5	5.4	4.8	4.5	4.4	4.3	4.8

Ayer Itam Oil Mill	3.6	6.7	3.6	4.6	4.6	4.9	5.0	5.6	5.1	5.6	5.0	5.1	3.1	6.3	5.2	4.6	4.3	4.2	4.1	4.6
Bukit Benut Oil Palm Mill	3.3	7.1	4.0	4.3	4.3	3.9	3.9	4.5	4.0	4.5	3.9	4.0	3.0	6.7	5.6	5.0	4.7	4.6	4.5	5.0
Bukit Benut POM	3.4	7.0	3.9	4.3	4.4	3.9	4.0	4.6	4.1	4.6	4.0	4.1	3.1	6.6	5.6	4.9	4.7	4.6	4.5	4.9
Bukit Lawiang POM	3.2	7.3	4.2	4.2	4.2	3.3	3.3	3.9	3.4	3.9	3.3	3.5	3.1	6.9	5.8	5.2	4.9	4.8	4.7	5.2
KKS Belitong	3.3	7.4	4.3	4.3	4.3	2.8	2.9	3.5	3.0	3.5	2.9	3.0	3.3	7.0	6.0	5.3	5.1	5.0	4.9	5.3
Ulu remis oil mill	3.4	7.4	4.3	4.4	4.4	3.0	3.1	3.7	3.2	3.7	3.1	3.2	3.4	6.9	5.9	5.2	5.0	4.9	4.8	5.2
Nam Heng Oil mill Co Sdn bhd	4.5	6.2	3.1	5.4	5.4	2.3	2.3	2.5	2.3	2.5	2.3	2.3	3.8	5.8	4.8	4.1	3.8	3.7	3.6	4.1
Gomali Oil Mill	3.5	7.1	4.0	4.5	4.5	3.8	3.9	4.5	4.0	4.5	3.9	4.0	3.2	6.7	5.6	5.0	4.7	4.6	4.5	5.0
Hadapan Palm Oil Mill	3.5	7.4	4.3	4.5	4.5	2.9	3.0	3.5	3.1	3.6	2.9	3.1	3.5	7.0	6.0	5.3	5.0	4.9	4.8	5.3
KKS Nitar	3.0	7.8	4.7	3.8	3.8	2.3	2.3	2.8	2.4	2.8	2.3	2.4	3.4	7.4	6.3	5.7	5.4	5.3	5.2	5.7
Wujud Wawasan	4.3	5.7	2.7	4.8	4.9	2.7	2.7	2.9	2.8	3.0	2.7	2.8	3.4	5.3	4.3	3.7	3.4	3.3	3.2	3.7
Kota bahagia palm oil mill	3.7	6.0	2.9	4.3	4.3	2.5	2.5	2.7	2.5	2.7	2.5	2.5	2.8	5.6	4.5	3.9	3.7	3.6	3.5	3.9
KKS Keratong 9	3.5	6.1	3.0	4.1	4.2	2.4	2.4	2.6	2.5	2.6	2.4	2.5	2.6	5.7	4.6	4.0	3.8	3.7	3.5	4.0
Keratong 3 palm oil mill	4.2	5.8	2.8	4.8	4.8	2.6	2.7	2.9	2.7	2.9	2.6	2.7	3.3	5.4	4.4	3.8	3.5	3.4	3.3	3.8
Keratong 2 Palm oil mill	3.6	6.0	3.0	4.2	4.2	2.4	2.5	2.7	2.5	2.7	2.5	2.5	2.7	5.6	4.6	4.0	3.7	3.6	3.5	4.0
Palong Timor Palm oil mill	5.3	5.4	2.4	5.9	5.9	3.0	3.0	3.2	3.1	3.2	3.0	3.1	4.5	5.0	4.0	3.4	3.1	3.0	2.9	3.4
Pukin Palm Oil Mill	4.0	5.9	2.9	4.7	4.7	2.5	2.5	2.7	2.6	2.7	2.5	2.6	3.2	5.5	4.5	3.9	3.6	3.5	3.4	3.9
Palong cocoa pom	4.7	5.7	2.6	5.3	5.3	2.7	2.7	2.9	2.8	3.0	2.7	2.8	3.8	5.3	4.3	3.6	3.4	3.3	3.2	3.6
RISDA ulu keratong	4.6	5.8	2.7	5.2	5.2	2.7	2.7	2.9	2.7	2.9	2.7	2.7	3.7	5.4	4.3	3.7	3.4	3.3	3.2	3.7
Selancar 2b	3.6	6.2	3.1	4.3	4.4	2.3	2.3	2.5	2.3	2.5	2.3	2.4	2.8	5.8	4.7	4.1	3.8	3.7	3.6	4.1
Selancar 2A	3.5	6.2	3.1	4.2	4.3	2.3	2.3	2.5	2.3	2.5	2.3	2.3	2.7	5.8	4.7	4.1	3.9	3.8	3.6	4.1
Johor Labis POM	3.7	6.3	3.2	4.6	4.6	6.0	6.0	2.3	6.1	2.3	6.0	6.1	3.0	5.9	4.9	4.2	4.0	3.9	3.7	4.2
Kekayaan Palm oil mill	3.2	6.7	3.6	4.2	4.2	5.0	5.0	5.6	5.1	5.6	5.0	5.1	2.7	6.3	5.2	4.6	4.3	4.2	4.1	4.6
SOU 20 Chaah	4.1	6.2	3.1	4.9	4.9	2.2	2.3	2.5	2.3	2.5	2.2	2.3	3.3	5.8	4.8	4.1	3.8	3.7	3.6	4.1
SELENDANG POM	2.0	7.2	4.2	3.0	3.0	3.7	3.8	4.3	3.9	4.3	3.8	3.9	2.0	6.8	5.8	5.2	4.9	4.8	4.7	5.2
Seri Intan Palm Oil Mill	2.8	7.5	4.4	3.7	3.7	2.9	2.9	3.4	3.0	3.5	2.9	3.1	2.9	7.1	6.0	5.4	5.1	5.0	4.9	5.4
Lima Blas POM	4.8	2.4	2.2	4.9	4.9	6.1	6.1	6.3	6.2	6.3	6.1	6.2	4.5	5.4	2.6	1.3	1.1	1.1	1.0	1.3
SOU 13 Labu POM	4.0	3.3	0.6	4.1	4.1	5.2	5.2	5.4	5.2	5.4	5.2	5.2	3.7	2.9	5.4	3.3	2.6	2.3	1.9	3.3
SOU 14 Tanah Merah	4.0	3.3	0.6	4.2	4.2	5.2	5.2	5.4	5.2	5.4	5.2	5.3	3.7	2.9	5.4	3.2	2.5	2.2	1.9	3.2
Kilang Kelapa Sawit Ulu Kanchong	3.6	3.8	1.9	3.7	3.7	4.7	4.7	4.9	4.7	4.9	4.7	4.7	3.3	3.3	2.4	4.6	3.9	3.6	3.3	4.6
SOU 15 - Sua Betong POM	3.8	3.6	1.3	4.0	4.0	4.9	4.9	5.1	5.0	5.2	4.9	5.0	3.5	3.1	6.1	3.9	3.2	3.0	2.6	3.9

Pasoh Palm oil mill	2.8	4.4	3.8	3.0	3.0	4.0	4.0	4.2	4.1	4.3	4.0	4.1	2.5	4.0	3.0	2.3	5.9	5.6	5.2	2.3
KS SERTING HILIR-N. SEMBILAN	2.4	4.9	5.1	2.5	2.5	3.6	3.6	3.8	3.6	3.8	3.6	3.6	5.8	4.5	3.4	2.8	2.6	2.5	2.3	2.8
Kok Foh oil mill	2.3	5.0	5.3	2.5	2.5	3.5	3.5	3.7	3.5	3.7	3.5	3.6	5.7	4.5	3.5	2.9	2.6	2.5	2.4	2.9
Kilang Kelapa Sawit Serting	2.5	4.8	4.9	2.6	2.6	3.6	3.7	3.9	3.7	3.9	3.6	3.7	6.1	4.4	3.4	2.7	2.5	2.4	2.2	2.7
Pasir Besar Palm oil mill	2.3	5.0	5.3	2.5	2.5	3.4	3.5	3.7	3.5	3.7	3.5	3.5	5.8	4.6	3.5	2.9	2.6	2.5	2.4	2.9
Jeram Padang Mill	2.6	4.7	4.6	2.8	2.8	3.7	3.7	3.9	3.8	4.0	3.7	3.8	2.3	4.3	3.3	2.6	2.4	2.3	6.0	2.6
Nam bee oil mill	2.4	5.0	5.2	2.6	2.6	3.5	3.5	3.7	3.5	3.7	3.5	3.6	6.0	4.5	3.5	2.8	2.6	2.5	2.4	2.8
Kempas oil mill	2.6	4.8	4.8	2.8	2.8	3.6	3.6	3.8	3.7	3.9	3.6	3.7	2.3	4.4	3.4	2.7	2.4	2.4	2.2	2.7
Diamond Jubilee Oil mill	2.5	5.0	5.2	2.7	2.7	3.5	3.5	3.7	3.5	3.7	3.5	3.6	6.1	4.5	3.5	2.8	2.6	2.5	2.4	2.8
Dominion Square	2.5	5.0	5.2	2.7	2.7	3.5	3.5	3.7	3.5	3.7	3.5	3.6	6.1	4.5	3.5	2.8	2.6	2.5	2.4	2.8
SOU 8 East Mill	4.9	2.5	2.1	5.0	5.0	6.1	6.1	6.3	6.1	6.3	6.1	6.1	4.6	5.6	3.3	0.7	0.0	0.3	0.7	0.7
SOU 9 West Mill	5.1	2.3	2.7	5.2	5.2	6.3	6.3	6.5	6.3	6.5	6.3	6.3	4.8	5.0	2.9	0.1	0.6	0.9	1.3	0.1
Lepar Utara 4 POM	4.2	5.6	2.7	4.5	4.5	3.0	3.0	3.2	3.0	3.2	3.0	3.0	3.4	5.3	4.2	3.7	3.4	3.3	3.2	3.7
lepar utara 6 palm oil mill	5.0	5.3	2.4	5.3	5.3	3.3	3.3	3.5	3.3	3.5	3.3	3.3	4.2	4.9	3.9	3.4	3.1	3.0	2.9	3.4
Carotino POM	4.2	5.6	2.7	4.5	4.5	3.0	3.0	3.2	3.0	3.2	3.0	3.0	3.3	5.3	4.2	3.7	3.4	3.3	3.2	3.7
Jengka 8 POM	5.7	5.1	6.0	6.0	6.0	3.4	3.4	3.6	3.5	3.6	3.4	3.5	4.8	4.7	3.6	3.1	2.9	2.8	2.6	3.1
Kilang Kelapa Sawit Felcra Maran	5.1	5.3	2.3	5.5	5.5	3.2	3.2	3.4	3.2	3.4	3.2	3.2	4.2	5.0	3.9	3.3	3.1	3.0	2.9	3.3
Bukit kepayang palm oil mil	5.8	5.1	5.9	6.2	6.2	3.3	3.4	3.6	3.4	3.6	3.4	3.4	4.9	4.7	3.7	3.1	2.9	2.8	2.6	3.1
Tementi palm oil mill	5.8	5.1	5.9	6.2	2.2	3.3	3.3	3.5	3.4	3.6	3.3	3.4	4.9	4.7	3.7	3.1	2.9	2.8	2.6	3.1
Bukit Sagu POM	1.9	6.4	3.5	2.3	2.3	2.3	2.3	2.5	2.4	2.5	2.3	2.4	1.1	6.1	5.0	4.5	4.2	4.1	4.0	4.5
SOU 12 Jabor POM	0.8	6.8	3.9	1.4	1.5	5.7	5.8	6.2	5.8	2.2	5.7	5.9	0.2	6.4	5.3	4.8	4.6	4.5	4.4	4.8
Panching Palm oil mill	1.8	6.5	3.5	2.3	2.3	2.2	2.3	2.4	2.3	2.4	2.2	2.3	0.9	6.1	5.0	4.5	4.3	4.2	4.0	4.5
Ladang Cheong wing chan	2.1	6.4	3.4	2.6	2.6	2.3	2.3	2.5	2.3	2.5	2.3	2.3	1.2	6.0	4.9	4.4	4.2	4.1	3.9	4.4
Lepar hilir palm oil mill	2.9	6.1	3.1	3.3	3.4	2.5	2.5	2.7	2.5	2.7	2.5	2.6	2.0	5.7	4.6	4.1	3.9	3.8	3.6	4.1
Kilang Sawit LCSB Lepar	2.4	6.3	3.3	3.0	3.0	2.3	2.3	2.5	2.4	2.5	2.3	2.4	1.6	5.9	4.8	4.3	4.1	4.0	3.8	4.3
Sungai jernih mill	2.4	6.3	3.3	3.1	3.1	2.2	2.2	2.4	2.3	2.4	2.2	2.3	1.6	6.0	4.9	4.3	4.1	4.0	3.8	4.3
Bukit Lee Lau	2.2	6.4	3.4	2.9	3.0	6.0	6.1	2.3	6.1	2.3	6.0	6.2	1.4	6.1	5.0	4.4	4.2	4.1	3.9	4.4
CHINI 2 POM	3.5	5.9	2.9	4.0	4.1	2.6	2.6	2.8	2.6	2.8	2.6	2.7	2.7	5.5	4.5	3.9	3.7	3.6	3.4	3.9
Chini 3 Palm oil mill	3.5	5.9	2.9	4.0	4.1	2.6	2.6	2.8	2.6	2.8	2.6	2.7	2.7	5.5	4.5	3.9	3.7	3.6	3.4	3.9
KS KRAU-PAHANG	3.5	3.6	1.9	3.6	3.6	4.8	4.9	5.1	4.9	5.1	4.8	4.9	3.2	3.2	6.0	4.5	3.9	3.6	3.2	4.5
Kuantan Trading POM	2.9	6.3	3.2	3.6	3.6	2.2	2.3	2.5	2.3	2.5	2.3	2.3	2.0	5.9	4.8	4.2	4.0	3.9	3.7	4.2
Padang Piol POM	2.3	4.8	5.3	2.4	2.4	3.7	3.7	3.9	3.8	3.9	3.7	3.8	5.6	4.5	3.4	2.9	2.6	2.5	2.4	2.9
Kota Gelanggi palm oil mill	2.3	4.8	5.3	2.4	2.4	3.7	3.7	3.9	3.8	3.9	3.7	3.8	5.6	4.5	3.4	2.9	2.6	2.5	2.4	2.9

Jengka 21 POM	2.3	4.8	5.2	2.4	2.4	3.7	3.7	3.9	3.7	3.9	3.7	3.7	5.6	4.4	3.4	2.8	2.6	2.5	2.4	2.8
Jengka 3 POM	6.2	4.9	5.6	2.3	2.3	3.6	3.6	3.8	3.6	3.8	3.6	3.7	5.3	4.6	3.5	3.0	2.7	2.6	2.5	3.0
KS SEROJA (JENGKA 18)-PAHANG	6.1	5.0	5.7	2.2	2.3	3.5	3.6	3.8	3.6	3.8	3.6	3.6	5.2	4.6	3.5	3.0	2.8	2.7	2.5	3.0
Kerdau Palm Oil Mill	2.5	4.6	4.7	2.6	2.6	3.8	3.9	4.0	3.9	4.1	3.8	3.9	6.2	4.3	3.2	2.6	2.4	2.3	6.1	2.6
KKS Bukit Mendi	2.8	4.4	3.9	2.9	2.9	4.0	4.0	4.2	4.1	4.2	4.0	4.1	2.5	4.0	3.0	2.4	6.0	5.7	5.3	2.4
Kemasul POM	2.7	4.5	4.1	2.8	2.8	3.9	4.0	4.2	4.0	4.2	4.0	4.0	2.4	4.1	3.0	2.4	6.2	5.9	5.5	2.4
Syarikat penanaman bukti senorang	2.6	4.6	4.3	2.7	2.8	3.8	3.9	4.1	3.9	4.1	3.8	3.9	2.3	4.2	3.1	2.5	2.3	6.2	5.8	2.5
Selaba oil mill	5.7	4.1	4.7	5.8	5.8	7.0	7.0	7.2	7.1	7.2	7.0	7.1	5.4	2.9	1.0	2.2	2.8	3.1	3.3	2.2
Seri Pelangi POM	5.6	4.5	4.4	5.7	5.7	6.9	6.9	7.1	6.9	7.1	6.9	7.0	5.3	3.2	1.0	1.9	2.5	2.8	3.0	1.9
Flemington POM	6.3	2.9	2.2	6.3	6.4	7.5	7.6	7.8	7.6	7.8	7.5	7.6	6.0	1.4	2.1	3.5	4.2	4.5	4.8	3.5
Jendarata Palm Oil Mill (P01)	5.9	3.8	5.1	6.0	6.0	7.2	7.2	7.4	7.2	7.4	7.2	7.2	5.6	2.4	1.3	2.5	3.2	3.4	3.7	2.5
Southern Perak Plantation S/B	5.9	3.9	5.1	6.0	6.0	7.1	7.2	7.4	7.2	7.4	7.2	7.2	5.6	2.5	1.4	2.5	3.1	3.4	3.7	2.4
Ulu bernam POM	5.6	4.5	4.4	5.7	5.7	6.9	6.9	7.1	7.0	7.1	6.9	7.0	5.3	3.1	1.3	1.8	2.5	2.7	3.0	1.8
Trolak palm oil mill	5.1	5.9	3.0	5.1	5.1	6.4	6.4	6.6	6.4	6.6	6.4	6.4	4.8	4.7	1.9	1.3	1.5	1.6	1.7	1.3
Sungai Tengi palm oil mill	4.9	2.3	2.4	5.0	5.0	6.2	6.2	6.4	6.2	6.4	6.2	6.2	4.6	5.2	2.5	1.0	1.0	1.0	1.1	1.0
Kilang Kelapa Sawit Ulu Basir	5.3	5.4	3.5	5.4	5.4	6.6	6.6	6.8	6.6	6.8	6.6	6.6	5.0	4.1	1.6	1.1	1.7	1.9	2.1	1.1
Tanjung Malim palm oil mill	5.1	5.9	2.9	5.2	5.2	6.4	6.4	6.6	6.4	6.6	6.4	6.4	4.8	4.7	2.0	1.0	1.3	1.4	1.6	1.0
KS MEMPAGA-PAHANG	4.5	2.7	1.2	4.6	4.6	5.8	5.8	6.0	5.8	6.0	5.8	5.8	4.2	2.3	3.6	1.8	1.2	1.0	0.6	1.8
Tennamaram Palm Oil Mill	5.0	2.2	2.6	5.1	5.1	6.3	6.3	6.5	6.3	6.5	6.3	6.3	4.7	4.9	2.4	0.6	0.8	1.0	1.2	0.6
Tuan mee palm oil mill	4.8	2.5	1.9	4.9	4.9	6.0	6.0	6.2	6.1	6.3	6.0	6.1	4.5	5.6	3.0	1.0	0.6	0.5	0.5	1.0
SOU 7 Bukit Kerayong	5.0	2.3	2.5	5.1	5.1	6.2	6.2	6.4	6.3	6.5	6.2	6.3	4.7	5.1	2.7	0.4	0.6	0.8	1.1	0.4
Bukit Kerayong Palm Oil Mill	5.0	2.3	2.6	5.1	5.1	6.2	6.3	6.5	6.3	6.5	6.3	6.3	4.7	5.0	2.6	0.4	0.6	0.8	1.1	0.4
Kilang Kelapa Sawit Risda Durian Mas	1.3	7.0	4.2	0.4	0.4	2.3	2.3	2.4	2.3	2.4	2.3	2.3	1.6	6.7	5.6	5.1	4.9	4.8	4.7	5.1
K.K.S Rasau Kerteh	1.2	6.8	3.9	0.9	0.9	2.3	2.3	2.4	2.3	2.4	2.3	2.3	1.2	6.5	5.4	4.9	4.7	4.6	4.4	4.9
Kilang Kelapa Sawit Kemaman	0.6	7.0	4.1	0.6	0.6	5.8	5.8	2.2	5.9	2.2	5.8	5.9	0.9	6.6	5.5	5.1	4.8	4.7	4.6	5.1
Ladang rakyat mill	1.4	6.6	3.7	1.7	1.7	2.3	2.3	2.4	2.3	2.4	2.3	2.3	0.7	6.2	5.1	4.7	4.4	4.3	4.2	4.7
Neram palm oil mill	0.9	6.7	3.8	1.4	1.4	5.9	5.9	2.2	6.0	2.3	5.9	6.0	0.3	6.4	5.3	4.8	4.6	4.5	4.3	4.8
TDM kemaman palm oil mill	1.4	6.6	3.8	1.4	1.4	2.3	2.3	2.5	2.4	2.5	2.3	2.4	1.0	6.3	5.2	4.7	4.5	4.4	4.3	4.7
Temerloh Mill	1.4	6.6	3.8	1.4	1.4	2.3	2.3	2.5	2.4	2.5	2.3	2.4	1.0	6.3	5.2	4.7	4.5	4.4	4.3	4.7
Kechau	3.3	3.8	2.9	3.4	3.4	4.7	4.7	4.9	4.8	4.9	4.7	4.8	3.0	3.4	2.3	5.4	4.9	4.6	4.2	5.5
Bukit Puteri Palm Oil Mill	4.0	3.1	1.7	4.1	4.1	5.4	5.4	5.6	5.4	5.6	5.4	5.5	3.7	2.7	4.5	3.5	3.0	2.7	2.3	3.5
Tersang palm oil mill	4.0	3.1	1.6	4.0	4.0	5.3	5.3	5.5	5.4	5.6	5.3	5.4	3.7	2.8	4.7	3.6	3.0	2.8	2.4	3.6

Minsawi Industries (K. Kangsar)	6.2	2.6	2.2	6.2	6.2	7.5	7.5	7.7	7.6	7.8	7.5	7.6	5.9	1.8	1.5	3.9	4.5	4.7	4.9	3.9
SOU 3 Elphil Mill	5.7	3.8	5.2	5.8	5.8	7.1	7.1	7.3	7.1	7.3	7.1	7.2	5.4	3.0	0.3	3.1	3.6	3.7	3.9	3.1
Trong mill	6.7	1.5	2.7	6.7	6.7	8.0	8.0	8.2	8.0	8.2	8.0	8.0	6.4	0.6	2.9	4.9	5.5	5.8	6.1	4.9
United International Enterprises POM	6.7	1.5	2.7	6.8	6.8	8.0	8.1	8.3	8.1	8.3	8.0	8.1	6.5	0.2	3.2	5.0	5.7	5.9	2.2	5.0
Sungei Kahang Palm Oil	6.3	2.4	2.3	6.4	6.4	7.6	7.7	7.9	7.7	7.9	7.6	7.7	6.0	1.2	2.0	3.9	4.6	4.8	5.1	3.9
Changkat Chermin	6.7	1.8	2.6	6.7	6.7	7.9	8.0	8.2	8.0	8.2	8.0	8.0	6.4	0.2	3.0	4.7	5.4	5.6	5.9	4.7
Pinehill Plantations (Malaysia)	6.7	1.7	2.7	6.8	6.8	8.0	8.0	8.2	8.1	8.3	8.0	8.1	6.4	0.0	3.2	4.9	5.6	5.8	6.1	4.9
Syarikat Cahaya Muda Perak (Oil Mil) Sdn Bhd	5.3	5.2	3.7	5.4	5.4	6.6	6.6	6.8	6.7	6.8	6.6	6.7	5.0	4.1	1.1	1.7	2.1	2.3	2.4	1.7
Kilang Kelapa Sawit Felcra Seberang Perak	6.1	3.2	5.7	6.1	6.1	7.3	7.4	7.6	7.4	7.6	7.4	7.4	5.8	1.9	1.4	3.1	3.8	4.0	4.3	3.1
Felcra Processing & Engineering SB	5.9	3.7	5.2	5.9	6.0	7.2	7.2	7.4	7.2	7.4	7.2	7.2	5.6	2.4	1.2	2.6	3.2	3.5	3.7	2.6
Felcra Bidor Palm oil mill	5.5	4.7	4.2	5.6	5.6	6.8	6.8	7.0	6.9	7.0	6.8	6.9	5.2	3.4	1.0	1.8	2.4	2.6	2.8	1.8
KKS Besout	5.2	5.6	3.3	5.2	5.2	6.5	6.5	6.7	6.5	6.7	6.5	6.5	4.9	4.4	1.6	1.4	1.7	1.9	2.0	1.4
Chalok palm oil mill	5.0	5.5	2.8	4.8	4.8	3.5	3.6	3.7	3.6	3.7	3.5	3.6	4.4	5.2	4.1	3.8	3.6	3.5	3.3	3.8
Kilang Sungai Tong	4.1	5.8	3.1	3.9	3.9	3.3	3.3	3.4	3.3	3.4	3.3	3.3	3.6	5.5	4.4	4.0	3.8	3.7	3.6	4.0
K.K.S Jerangau Barat	2.9	6.2	3.4	2.7	2.7	2.9	2.9	3.0	2.9	3.0	2.9	2.9	2.4	5.9	4.8	4.4	4.1	4.0	3.9	4.4
K.K.S Maokil	4.0	5.7	3.0	3.9	3.9	3.2	3.2	3.4	3.2	3.4	3.2	3.3	3.4	5.5	4.3	4.0	3.8	3.7	3.5	4.0
Ladang Serasa	3.1	4.0	4.2	3.1	3.1	4.7	4.7	4.9	4.7	4.9	4.7	4.7	2.8	3.7	2.6	2.3	6.0	5.7	5.3	2.3
Kilang Kelapa Sawit Kemahang	3.3	3.9	4.9	3.2	3.2	4.9	4.9	5.1	4.9	5.1	4.9	5.0	3.0	3.7	2.6	2.4	2.3	6.2	5.8	2.4
Kuala Pertang POM	3.0	4.1	5.1	3.0	3.0	4.7	4.7	4.9	4.7	4.9	4.7	4.7	2.8	3.9	2.8	2.6	2.4	2.3	6.1	2.6
Kilang Kelapa Sawit Paloh 3	2.9	4.2	4.7	2.9	2.9	4.4	4.4	4.6	4.5	4.6	4.4	4.5	2.6	3.9	2.8	2.5	2.3	2.2	5.8	2.5
Kilang sawit Chiku	3.0	4.1	4.2	3.0	3.1	4.6	4.6	4.8	4.6	4.8	4.6	4.6	2.8	3.8	2.6	2.3	6.1	5.8	5.4	2.3
Solid Orient POM	6.7	1.1	2.8	6.7	6.7	8.1	8.1	8.3	8.2	8.3	8.1	8.2	6.4	1.7	3.1	5.6	6.2	2.3	2.3	5.5
Kilang Kelapa Sawit Sungai Dingin	6.9	0.6	3.0	6.9	6.9	8.3	8.3	8.5	8.3	8.5	8.3	8.3	6.6	1.6	3.6	5.9	2.3	2.4	2.5	5.9
Kilang Sawit Setia Kawan	6.9	0.6	3.0	6.9	6.9	8.3	8.3	8.5	8.3	8.5	8.3	8.3	6.6	1.5	3.6	5.8	2.3	2.4	2.5	5.8
Kilang Kelapa Sawit Batu Lintang	6.9	0.6	2.9	6.9	6.9	8.2	8.2	8.4	8.3	8.5	8.2	8.3	6.6	1.2	3.5	5.7	2.2	2.3	2.4	5.7
KKS Telok Sengat	6.6	1.2	2.7	6.7	6.7	8.0	8.0	8.2	8.1	8.2	8.0	8.1	6.4	1.2	2.9	5.2	5.8	6.0	2.2	5.1
Chersonese POM	7.3	0.9	3.3	7.3	7.3	8.6	8.6	8.8	8.7	8.8	8.6	8.7	7.0	1.8	4.6	2.3	2.6	2.7	2.8	2.3

Table A.25 Distance from further processing 2 facilities, *n* to further processing 3 facilities, *o*

	Anaerobic Digestion(Glycerol)1	Anaerobic Digestion(Glycerol)2	Anaerobic Digestion(Glycerol)3	Anaerobic Digestion(Glycerol)4	Anaerobic Digestion(Glycerol)5	Anaerobic Digestion(Glycerol)6	Anaerobic Digestion(Glycerol)7	Anaerobic Digestion(Glycerol)8	Anaerobic Digestion(Glycerol)9	Anaerobic Digestion(Glycerol)10	Anaerobic Digestion(Glycerol)11	Anaerobic Digestion(Glycerol)12	Anaerobic Digestion(Glycerol)13	Anaerobic Digestion(Glycerol)14
Formaldehyde Production1	85	91	86	92	85	86	14	306	256	233	223	218	212	234
Formaldehyde Production2	384	393	386	394	384	387	308	28	66	102	112	116	120	102
Ammonia Production1	243	252	245	253	243	246	175	122	78	45	34	30	24	46
Ammonia Production2	97	102	98	102	96	98	25	309	258	238	228	223	216	238
Bio-ethylene Production1	97	102	98	102	96	98	25	309	258	238	228	223	217	239
Bio-ethylene Production2	1	10	2	11	0	3	91	365	318	287	276	272	266	287
Transesterififcation1	0	9	2	10	1	2	91	365	319	288	277	272	267	288
Transesterififcation2	9	0	8	1	10	7	98	375	327	297	286	282	276	297
Transesterififcation3	2	8	0	8	2	1	93	367	320	289	278	274	268	290
Transesterififcation4	10	1	8	0	11	8	99	375	328	298	287	282	277	298
Transesterififcation5	1	10	2	11	0	3	91	365	318	287	276	272	266	288
Transesterififcation6	2	7	1	8	3	0	93	368	321	290	279	275	269	290
Transesterififcation7	91	98	93	99	91	93	0	293	243	220	209	204	198	220
Transesterififcation8	365	375	367	375	365	368	293	0	51	79	90	94	99	79
Transesterififcation9	319	327	320	328	318	321	243	51	0	44	52	55	57	44
Transesterififcation10	288	297	289	298	287	290	220	79	44	0	11	16	22	0
Transesterififcation11	277	286	278	287	276	279	209	90	52	11	0	5	11	11
Transesterififcation12	272	282	274	282	272	275	204	94	55	16	5	0	7	16
Transesterififcation13	267	276	268	277	266	269	198	99	57	22	11	7	0	22
Transesterififcation14	288	297	290	298	288	290	220	79	44	0	11	16	22	0

Table A.26 Approximated transportation cost further processing 2 facilities, *n* to further processing 3 facilities, *o*

	Anaerobic Digestion(Glycerol)1	Anaerobic Digestion(Glycerol)2	Anaerobic Digestion(Glycerol)3	Anaerobic Digestion(Glycerol)4	Anaerobic Digestion(Glycerol)5	Anaerobic Digestion(Glycerol)6	Anaerobic Digestion(Glycerol)7	Anaerobic Digestion(Glycerol)8	Anaerobic Digestion(Glycerol)9	Anaerobic Digestion(Glycerol)10	Anaerobic Digestion(Glycerol)11	Anaerobic Digestion(Glycerol)12	Anaerobic Digestion(Glycerol)13	Anaerobic Digestion(Glycerol)14
Formaldehyde Production1	21	22	21	22	21	21	9	31	29	28	28	28	28	28
Formaldehyde Production2	33	34	33	34	33	33	31	11	18	24	24	24	25	24
Ammonia Production1	29	29	29	29	29	29	26	25	20	14	12	12	11	14

Ammonia Production2	23	24	23	24	23	23	11	31	29	28	28	28	28	28
Bio-ethylene Production1	23	24	23	24	23	23	11	31	29	28	28	28	28	28
Bio-ethylene Production2	0	9	7	9	0	7	22	33	31	30	30	30	29	30
Transesterififcation1	0	8	7	8	0	7	22	33	31	30	30	30	29	30
Transesterififcation2	8	0	8	0	8	8	23	33	31	30	30	30	30	30
Transesterififcation3	7	8	0	8	7	0	22	33	31	30	30	30	29	30
Transesterififcation4	8	0	8	0	9	8	23	33	31	30	30	30	30	30
Transesterififcation5	0	8	7	9	0	7	22	33	31	30	30	30	29	30
Transesterififcation6	7	8	0	8	7	0	22	33	31	30	30	30	29	30
Transesterififcation7	22	23	22	23	22	22	0	30	29	28	27	27	27	28
Transesterififcation8	33	33	33	33	33	33	30	0	15	20	22	22	23	20
Transesterififcation9	31	31	31	31	31	31	29	15	0	14	15	16	16	14
Transesterififcation10	30	30	30	30	30	30	28	20	14	0	9	9	10	0
Transesterififcation11	30	30	30	30	30	30	27	22	15	9	0	8	9	9
Transesterififcation12	30	30	30	30	30	30	27	22	16	9	8	0	8	9
Transesterififcation13	29	30	29	30	29	29	27	23	16	10	9	8	0	10
Transesterififcation14	30	30	30	30	30	30	28	20	14	0	9	9	10	0

Table A.27 Approximated emission factor (10^{-3}) further processing 2 facilities, *n* to further processing 3 facilities, *o*

	Anaerobic Digestion(Glycerol)1	Anaerobic Digestion(Glycerol)2	Anaerobic Digestion(Glycerol)3	Anaerobic Digestion(Glycerol)4	Anaerobic Digestion(Glycerol)5	Anaerobic Digestion(Glycerol)6	Anaerobic Digestion(Glycerol)7	Anaerobic Digestion(Glycerol)8	Anaerobic Digestion(Glycerol)9	Anaerobic Digestion(Glycerol)10	Anaerobic Digestion(Glycerol)11	Anaerobic Digestion(Glycerol)12	Anaerobic Digestion(Glycerol)13	Anaerobic Digestion(Glycerol)14
Formaldehyde Production1	5.3	5.7	5.3	5.7	5.3	5.4	0.9	6.7	5.6	5.1	4.9	4.8	4.7	5.1
Formaldehyde Production2	8.5	8.7	8.5	8.7	8.4	8.5	6.8	1.7	4.1	2.2	2.5	2.6	2.6	2.2
Ammonia Production1	5.4	5.6	5.4	5.6	5.3	5.4	3.8	2.7	4.8	2.8	2.1	1.8	1.5	2.8
Ammonia Production2	6.0	2.2	6.1	2.3	6.0	6.1	1.6	6.8	5.7	5.2	5.0	4.9	4.8	5.2
Bio-ethylene Production1	6.0	2.2	6.1	2.3	6.0	6.1	1.6	6.8	5.7	5.2	5.0	4.9	4.8	5.2
Bio-ethylene Production2	0.0	0.6	0.2	0.7	0.0	0.2	5.6	8.0	7.0	6.3	6.1	6.0	5.9	6.3
Transesterififcation1	0.0	0.6	0.1	0.6	0.0	0.1	5.7	8.0	7.0	6.3	6.1	6.0	5.9	6.3
Transesterififcation2	0.6	0.0	0.5	0.0	0.6	0.4	6.1	8.2	7.2	6.5	6.3	6.2	6.1	6.5
Transesterififcation3	0.1	0.5	0.0	0.5	0.1	0.0	5.7	8.1	7.0	6.4	6.1	6.0	5.9	6.4
Transesterififcation4	0.6	0.0	0.5	0.0	0.7	0.5	6.1	8.3	7.2	6.6	6.3	6.2	6.1	6.6
Transesterififcation5	0.0	0.6	0.1	0.7	0.0	0.2	5.6	8.0	7.0	6.3	6.1	6.0	5.9	6.3
Transesterififcation6	0.1	0.4	0.0	0.5	0.2	0.0	5.8	8.1	7.1	6.4	6.1	6.0	5.9	6.4
Transesterififcation7	5.7	6.1	5.7	6.1	5.6	5.8	0.0	6.4	5.3	4.8	4.6	4.5	4.4	4.8
Transesterififcation8	8.0	8.2	8.1	8.3	8.0	8.1	6.4	0.0	3.2	4.9	5.6	5.8	6.1	4.9
Transesterififcation9	7.0	7.2	7.0	7.2	7.0	7.1	5.3	3.2	0.0	2.7	3.2	3.4	3.6	2.7
Transesterififcation10	6.3	6.5	6.4	6.6	6.3	6.4	4.8	4.9	2.7	0.0	0.7	1.0	1.3	0.0

Transesterififcation11	6.1	6.3	6.1	6.3	6.1	6.1	4.6	5.6	3.2	0.7	0.0	0.3	0.7	0.7
Transesterififcation12	6.0	6.2	6.0	6.2	6.0	6.0	4.5	5.8	3.4	1.0	0.3	0.0	0.4	1.0
Transesterififcation13	5.9	6.1	5.9	6.1	5.9	5.9	4.4	6.1	3.6	1.3	0.7	0.4	0.0	1.4
Transesterififcation14	6.3	6.5	6.4	6.6	6.3	6.4	4.8	4.9	2.7	0.0	0.7	1.0	1.4	0.0

Table A.28 Estimated production cost factor, conversion factor and CO_2 emissions at *n* for Case D

CPO supplier, g	Intermediate product 2, *m*	Further processing 2, *n*	Intermediate product 3, *o*	Production cost factor(USD $/tonne)	Conversion factor	CO_2 emission factor (ton CO_2eq/tonne of product)
Crude palm oil (CPO)	Bio-methanol	Transesterification	Bio-diesel	280	0.98	1.19
		Transesterification	Glycerol	280	0.098	1.19

(Noulkamol, 2014; Ong et al., 2012)

Table A.29 Estimated production cost factor, conversion factor and CO_2 emissions at *s* for Case D

Intermediate product 3, *o*	Further processing 3, *s*	Final product, *t*	Production cost factor(USD $/tonne)	Conversion factor	CO_2 emission factor (ton CO_2eq /tonne of product)
Glycerol	Anaerobic-digestion	Bio-ethanol	98.2	0.33	0.098

(Abdulrazik et al., 2017)

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