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Supporting a Sustainable European Bioenergy Trade Strategy

Intelligent Energy Europe
IEE/13/577/SI2.675534

Assessment of sustainable lignocellulosic biomass export potentials from Indonesia to the European Union

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The BioTrade2020plus Project

Objectives

The main aim of BioTrade2020plus is to provide guidelines for the development of a **European Bioenergy Trade Strategy for 2020 and beyond** ensuring that imported biomass feedstock is sustainably sourced and used in an efficient way, while avoiding distortion of other (non-energy) markets. This will be accomplished by analyzing the potentials (technical, economical and sustainable) and assessing key sustainability risks of current and future lignocellulosic biomass and bioenergy carriers. Focus will be placed on wood chips, pellets, torrefied biomass and pyrolysis oil from current and potential future major sourcing regions of the world (US-SE, Ukraine, South America, Asia and Sub-Saharan Africa).

BioTrade2020plus will thus provide support to the use of stable, sustainable, competitively priced and resource-efficient flows of imported biomass feedstock to the EU – a necessary pre-requisite for the development of the bio-based economy in Europe.

In order to achieve this objective close cooperation will be ensured with current international initiatives such as IEA Bioenergy Task 40 on "Sustainable International Bioenergy Trade - Securing Supply and Demand" and European projects such as Biomass Policies, S2BIOM, Biomass Trade Centers, DIA-CORE, and PELLCERT.

Activities

The following main activities are implemented in the framework of the BioTrade2020plus project:

- Assessment of **sustainable potentials of lignocellulosic biomass** in the main sourcing regions outside the EU
- Definition and application of sustainability criteria and indicators
- Analysis of the **main economic and market issues of biomass/bioenergy imports** to the EU from the target regions
- Development of a dedicated and **user friendly web-based GIS-tool** on lignocellulosic biomass resources from target regions
- **Information to European industries** to identify, quantify and mobilize sustainable lignocellulosic biomass resources from export regions
- **Policy advice on long-term strategies** to include sustainable biomass imports in European bioenergy markets
- **Involvement of stakeholders** through consultations and dedicated workshops

More information is available at the BioTrade2020plus website: **www.biotrade2020plus.eu**

About this document

This report is a progress update of one of the six case studies to be developed udner WP3 of the BioTrade2020+ project

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List of Abbreviations

APL	Lands that can be used for development (e.g. palm plantation
CMS	Carbon molecular sieve
CPO	Crude palm oil
CSR	Corporate social responsibility
EFB	Empty fruit bunches
EU	European Union
FFB	Fresh fruit bunches
Ha	Hectare
HP	Non forested land of possible production porest
HPK	Convertible production forest
MDF	Medium density fiberboard
PKS	Palm kernel shell
PO	Palm oil
POR	Palm oil residues
RPR	Residue to product ratio

List of Figures

List of Tables

Table of Contents

Introduction

1.1 General Introduction

The main objective of WP3 is to analyse the main economic and market issues concerning biomass/bioenergy imports to the EU from six different country case studies (Brazil, Colombia, Kenya, Indonesia, Ukraine and the USA-SE).. Main elements are the analysis of current and future production and consumption volumes of biomass, identification of on-going and possible future trade routes and delivered costs, and potential risks of competition with other industries (both local and not) utilizing the investigated feedstocks per region.

In this work package, methodology to determine a net sustainable export potential of biomass and related cost and GHG supply curves will be applied and tested for the six selected case studies. For these sourcing regions, various potentials (technical, sustainable, market etc.) will be determined.

The aim of this progress report is to highlight the status of the data collection and analysis until June 2015. In section 2, a summary of the methodology is presented. In section 3, the general case study description is presented (based on Deliverable 2.1). In section 4, a summary of the data collected and thus far and an overview of preliminary results are presented. Finally, in section 5, a short outlook on the further work and completion of the case study is given.

1.2 General BioTrade2020plus methodological approach

The methodology chosen for the selection of the regions followed the overall general methodology [23]. This methodology is divided in three main areas: the selection of the regions, the considerations for the theoretical potential in each region according to selected feedstock and the overall background information of the regions.

As indicated before, the focus regions include the US-SE, Ukraine, Brazil, Colombia, Indonesia and Kenya. The feedstocks that will be considered are those which can produce different carriers such as wood chips, pellets, and torrefied biomass and pyrolysis oil.

The theoretical potential was calculated according to the availability of the selected feedstock and the residue production ratio identified in literatures as well as already calculated ratios and residues available.

The overall methodologyand their assessment includes the estimation of technological, sustainable and market potential for each feedstock (see report on methodology [23]).

The background information for the selected countries helped to identify the regions in each country that were more promising for the availability of the feedstock but also that included some of the technological facilities (including transportation and other logistics). The information provided from the Advisory Board (AB) also contributed to better select the particular regions. **Error! Reference source not found.** shows the methodology and information followed in this report.

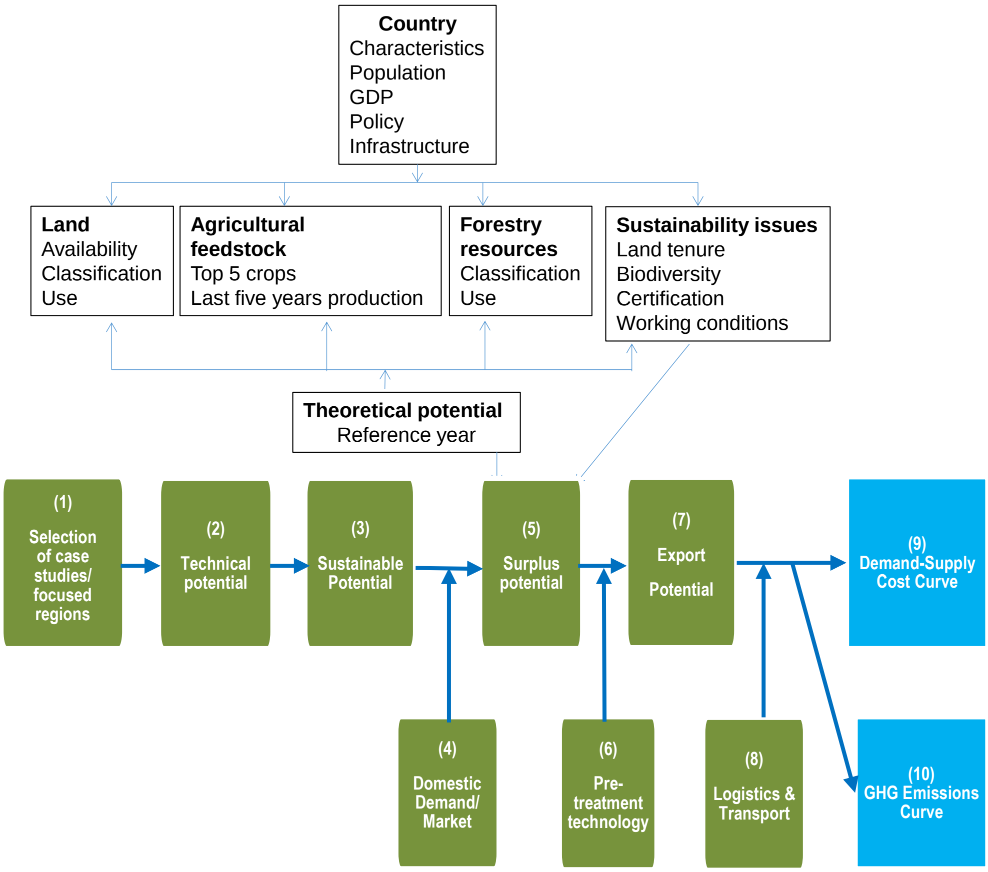


Figure 0-1 Methodology for selected countries and regions

The following section presents the information collected for the selected countries and regions. This was based in literature review, partners' previous work in the selected countries and information provided by the Advisory board members.
The detailed information and technical, sustainability and market potentials along with scenarios, is included in the specific case studies as the information needed requires more detail and in some cases field work provided mainly by students working in the regions.
Additional socio-economic issues such as the willingness to harvest and the management of the forests, in terms of the use of the resources (e.g. recreational, conservation, market) are not discussed in this report but considered in the specific case studies.

The summary of the countries and feedstock potential presented in this report is shown inTable 0-1.

Country	Feedstock				
	Forest residues	*Agricultural residues*	*Forest plantations*	*Biomass crops*	*New forest plantations*
Brazil		√		√	√
Colombia		√		√	
Kenya		√	√	√	
Indonesia		√			
United States	√		√		√
Ukraine	√	√		√	

Table 0-1 Overview of countries and feedstock potential

2. Case study: Indonesia[1]

The Biotrade 2020+ project consortium has identified several international sourcing regions for biomass imports, including Southeast Asia. Within this region Indonesia has been selected as case study due to its large agricultural and forestry sector. Biomass feedstocks can also be derived from dedicated energy crops. Due to limited time and resources, the focus however is only on residues from oil palm industry it is by far the largest agricultural commodity in Indonesia. The residues from this sector have been investigated for the current situation, Business As Usual (BAU) and High Export (HE) scenarios by 2020 and 2030 to assure the sustainability of feedstock supply chain.

Currently, palm residues including frond, trunk, empty fruit bunch (EFB), shell and fibre are locally used. Frond, trunk and EFBs are mostly left or abandoned on field whislt shell, fibre are burnt for electricity and energy generation at oil mills but with low efficiency, and. This indicates a potential for export of residues to the EU.

2.1 Introduction

2.1.1 Population and economy

Indonesia has a total population of 254 million (July 2014 est.) made of different ethnic groups including: Javanese 40.1%, Sundanese 15.5%, Malay 3.7%, Batak 3.6%, Madurese 3%, Betawi 2.9%, Minangkabau 2.7%, Buginese 2.7%, Bantenese 2%, Banjarese 1.7%, Balinese 1.7%, Acehnese 1.4%, Dayak 1.4%, Sasak 1.3%, Chinese 1.2%, other 15% (2010 est.) (CIA, 2015).

The country has a gross GDP of $856.1 billion (2014 est.) with an estimated GDP pp of $10,200 USD. GDP is divided over the following main sectors:

- agriculture: 14.2%
- industry: 45.5%
- services: 40.3% (2014 est.)

The main agricultural products are: rubber and similar products, palm oil, rice, sugar cane, poultry, beef, forest products, shrimp, cocoa, coffee, medicinal herbs. The industrial sector is dominated by: petroleum and natural gas, textiles, automotive, electrical appliances, apparel, footwear, mining, cement, medical instruments and appliances, handicrafts, chemical fertilizers, plywood, rubber, processed food, jewellery, and tourism.

[1] This section is based on Deliverable 2.1

Land use

Figure 2-1 Indonesia's archipelago (nations online)

Indonesia is a 189 million ha land area extended over an archipelago of over 17,000 islands, of which around 6,000 are inhabited (Figure 2-1). Two thirds of Indonesia's land area (127 million ha) is designated as "forest zone", although it is estimated that up to 30% of this land has no forest cover. Most land in this zone lies on Indonesia's outer islands. The government categorises forest zone land, allocating various functions to different areas. Of the total forest zone, 55 million ha is designated as protection and conservation forest, which is afforded varying degrees of protection, while production and conversion forest, allocated to economic activity, account for 72 million ha (Ministry of Forestry 2006).

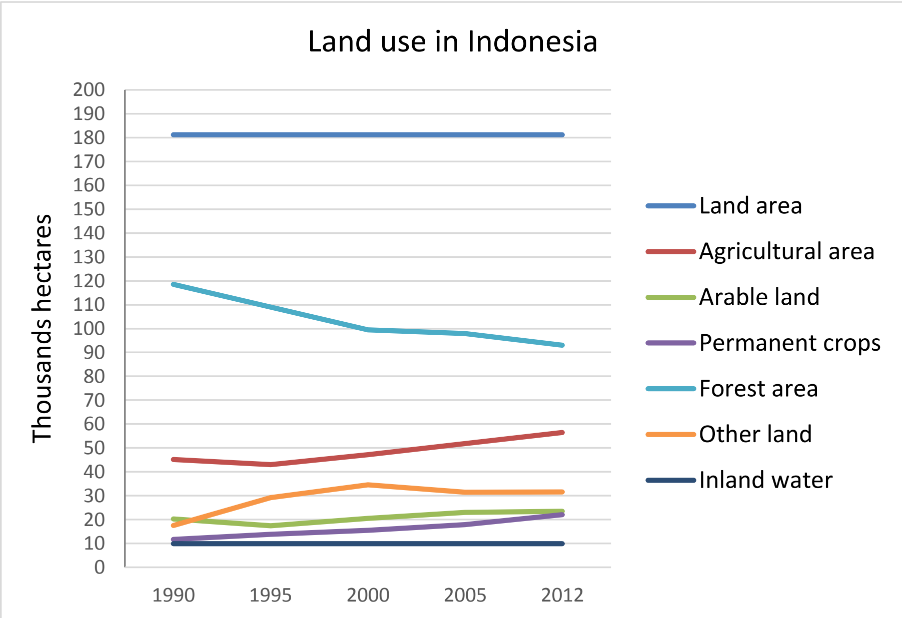


Figure 2-2 Land use in Indonesia (FAOstat, 2015)

Deforestation is one of the major environmental problems in Indonesia. Agricultural area has increased while forest area has decreased in the last 20 years. Most of it is attributed to the cultivation of oil palm (see Figure 2-2).

The main commodities of Indonesia reported by FAO in 2012 are presented in Table 2.1.

Top Ten commodities/ Production quantity 2012

	Commodity	Quantity [t]
1	Rice, paddy	69,056,126
2	Sugar cane	28,700,000
3	Oil, palm	26,900,000

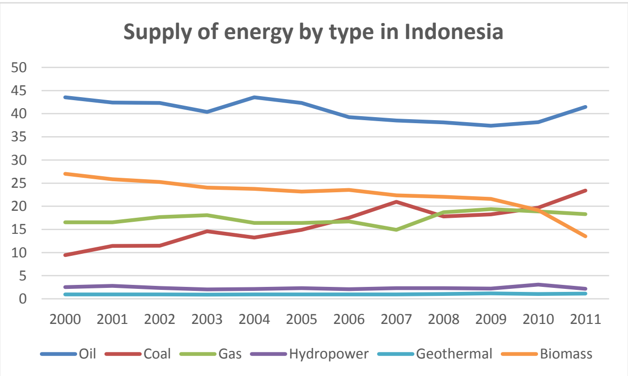
4	Cassava	24,177,372
5	Coconuts	19,400,000
6	Maize	19,387,022
7	Palm kernels	6,560,000
8	Bananas	6,189,052
9	Fruit, tropical fresh nes	3,147,488
10	Rubber, natural	3,040,400

Table 2-1 Main commodities produced in Indonesia (FAOstat, 2015).

Energy Sector

The Government elected in 2014 has emphasized domestic economic growth in its first few months in office, and in November 2014 reduced fuel subsidies, a move which could help the government increase spending on its development priorities. This will have an impact on demand and supply of renewables although it is not yet clear what the exact consequences will be.

Oil, coal and gas are the main sources of energy in Indonesia and although there seems to be a significant share of biomass based energy supply, this is mainly in the form of traditional use of biomass (EDSM, 2012) (Figure 2-3).



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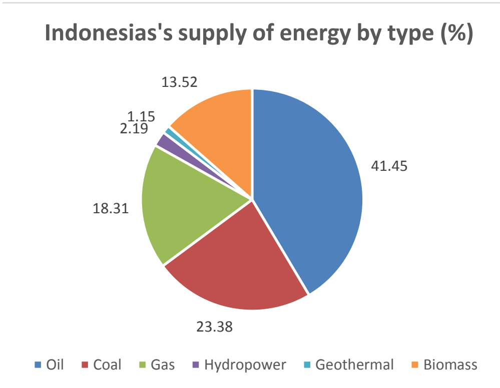

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Figure 2-3 Supply of Energy in Indonesia by type, historic (A) and in 2012 (B). EDSM, 2012.

Indonesia has implemented important changes since the IEA published its first review of the country’s energy policies in 2008. Key milestones include the 2007 Law on Energy, the 2009 Law on Electricity, the 2009 Law on Mineral and Coal Mining, and the 2014 National Energy Policy (IEA, 2015)

Indonesia has a 5 percent biodiesel mandate which had been in place and removed and it is now heading for B10 (diesel blend with 10% of biodiesel), the country also adopted an E3 ethanol (third generation biodiesel) mandate in 2010 to have 1.2 million kiloliters blended. Nevertheless, due to the decrease of oil prices, Indonesian biomass consumption grew 0.33 percent from 2000 until 2012 but its contribution to the Indonesian energy mix has declined during the same time period (Figure 2-4 A). Indonesia’s largest biomass user for energy is households (Figure 2-4 B), with approximately 84 percent of total biomass consumption. Firewood, forest and agricultural waste are the most common type of biomass used by Indonesian households.

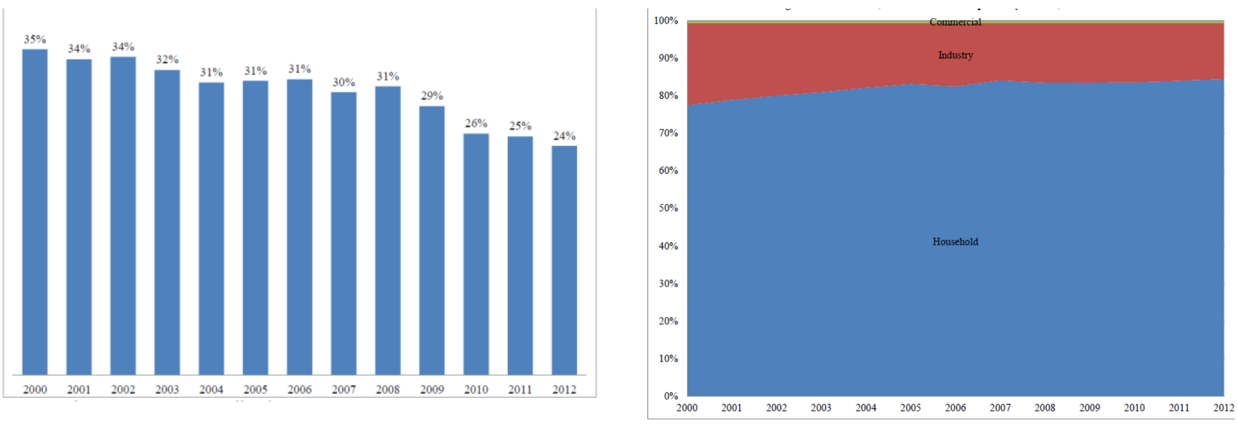

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Figure 2-4 Biomass use in Indonesia by year (A) and by user (B)

2.1.2 Bioenergy and biomass

Feedstocks

The promising biofuel crops/products identified for the case of Indonesia which could be used to produce biofuels are sugar cane, palm oil and molasses. The production of palm oil has been growing in the last years as shown in the figure below.

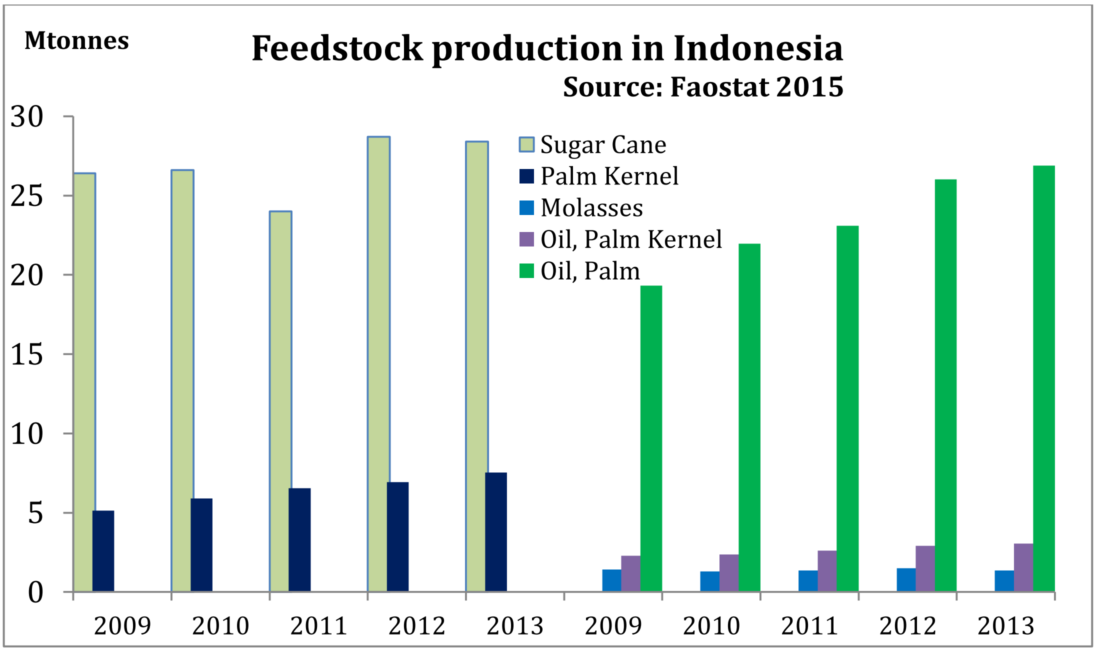


Figure 2-5 Production of feedstocks in Indonesia

The major crop residues considered for power generation in Indonesia are palm oil, sugar processing and rice processing residues. According to Bioenergy Consult (2014)[2] there are 67 sugar mills in operation in Indonesia and eight more are under construction or planned. The mills range in size of milling capacity from less than 1,000 tons of cane per day to 12,000 tons of cane per day. Current

[2] http://www.bioenergyconsult.com/biomass-energy-resources-in-indonesia/

sugar processing in Indonesia produces 8 millions MT bagasse and 11.5 millions MT canes top and leaves.

There are 39 palm oil plantations and mills currently operating in Indonesia, and at least eight new plantations are under construction. Most palm oil mills generate combined heat and power from fibres and shells, making the operations energy self sufficient. However, the use of palm oil residues can still be optimized in more energy efficient systems.

The types of residue generated by the palm oil industry include Empty Fruit Bunches (EFB), Palm Mesocarp Fiber (PMF) and Palm Kernel Shell (PKS) as a potential source of solid fuel. EFB, mesocarp fiber and kernel shell are generated at palm oil mills. EFB is the residue generated at the thresher, where fruits are removed from fresh fruit bunches. Mesocarp fiber is generated at the nut/fiber separator while kernel shell is generated from the shell/kernel separator (Fauzianto, 2015)

Table 2-2 Estimated residues for main crops in Indonesia

Feedstock	Type of residue	RPR min	tons	RPR max	tons
Sugarcane	Bagasse	0.10	0.05	0.33	0.15
	Tops	0.10	0.05	0.30	0.15
Rice	Straw	0.42	5.81	3.96	54.79
	Husk	0.20	2.77	0.35	4.84
	Fibres	0.14	0.99	0.15	0.99
Oil palm*	Kernel shells	0.06	0.42	0.07	0.42
	Empty bunches	0.23	1.63		

References: RPR FAO and Ma et al 1986
* Koopmans and Jaap Koppejan (1997)

There are other residues estimates found in the literature. For instance for South Sumatra, Bustan et al. (2011) estimated the following amount of residues from palm oil (Table 2-3) and the following characteristics of the residues (Table 2-4).

Table 2-3 Characteristics of solid residues of oil palm (Bustan et al, 2011)

Parameter	Fiber	Shell	EFB
RPR	0.12	0.07	0.24
Moisture content	23.00	20.00	60.00
Energy use factor	0.85	0.65	0.03
Oil content %	7.00		1.20
LHV (MJ/kg)	10.11	15.23	3.00

Table 2-4 Palm oil residue potential (Bustan et al, 2011)

Regency	Production (Ton/year)	Energy potential (GJ Thermal /yr)	Technical Potential (MWh/yr)
Lahat	151,708	330,708	22,965.8
Pagaralam	10.1	22	1.5
Empat Lawang	0	0	0
Musi Banyuasin	486,846	1,061,274	74,699.6
Banyuasin	253,449	552,493	38,367.6
Musi Rawas	332,548	724,921	50,341.7
Lubuk Linggau	63	137	9.5
OKU	111,783	243,675	16,921.9
OKU Timur	80,843	176,229	12,238.2
OKU Selatan	36	79	5.5
OKI	376,081	819,818	56,931.8
Ogan Ilir	22,935	49,996	3,471.9
Muara Enim	216,992	473,020	32,848.6
Prabumulih	3,258	7,102	493.2
Total	2,036,553	4,439,476	308,297

The production in Indonesia may vary from one island to another but major production is in Sumatra (Figure 2-6). Kalimantan (the Indonesian part of the island Borneo) is also increasing in terms of production levels.

Figure 2-6 Regional distribution of palm oil in Indonesia

2.1.3 Sustainability issues

Land rights

Indonesia faces a number of issues related to land ownership mainly because of the large number of people in rural areas of Indonesia who have little or no land (an average of 0.5 ha of land); also because of the high levels of inequality in the distribution of agricultural land ownership, and the large number of land disputes and conflicts recorded, covering almost 608,000 ha of land (Wright, 2011). Many such conflicts have resulted from the allocation of land for plantation estate development (Wakker, 2005 in Wright, 2011).

These issues are attributed to a number of problems and weaknesses in Indonesia's system of land governance such as the inherited system from colonial times, the lack of transparency, complexity and confusion surrounding the legal framework governing land rights and more recently the palm oil concessions. There is a lack of adequate legal recognition of customary rights to land (Wright, 2010).

Land rights are partially recognised by the Indonesian constitution, but are legally subordinated to the needs of national development and government agencies have discretionary power in deciding whether to respect them (Colchester et al, 2006).

Food security

A long term trend since the 1970s has been a decline in food insecurity in Indonesia. The country produces potentially high-value crops such as cocoa and spices but according to IFPRI (2015) further investment is needed to improve the systems needed to take full advantage of such high-value products. Food insecurity and under-nutrition are persistent challenges, and the country's stunting levels are alarmingly high. In 2007, an estimated 7.7 million children under 5 (36.8%) were stunted (2007). The stunting rate is higher than 30% in most districts (ranging from 23-58%) (WFP 2012).

For the above reasons, the government of Indonesia has formulated a development plan spanning 2005-2025. The overall plan includes 5-year medium-term plans, each with different development priorities. The current medium-term development plan covering 2009-2014 is the second phase and focuses on:

- promoting quality of human resources
- development of science and technology
- strengthening economic competitiveness (IFPRI, 2015)

FAO's country data also shows an improvement in food security reducing the undernutrition value and improved per capita food supply (Figure 1-7)

Indonesia: Per capita food supply

	Quantity [kcal/capita/day]			
	1996	2001	2006	2011
Food Supply	2548	2424	2484	2713

Source: FAOSTAT, FAO of the UN, Accessed on May 26, 2014.
http://faostat.fao.org/site/368/default.aspx#ancor

A

Indonesia: Prevalence of undernutrition

	Prevalence [%]			
	1999-01	2004-06	2007-09	2010-12
Undernutrition	18	15	12	9

Source: ESS, FAO of the UN, Accessed on October 9, 2012.
http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/

B

Figure 2-7 Indonesia's food security indicators (FAO, 2015)

Socio-economic

Despite Indonesia having committed to the main ILO standards, there are some that still need to be enforced specially those related to child labor.
Companies need to comply with workers right and the payment of minimum wage.

Table 2-5 ILO conventions signed in Indonesia

ILO Convention	Ratified	In force
Convention concerning Forced or Compulsory Labour (No 29)	1969	√

Convention concerning Freedom of Association and Protection of the Right to Organise (No 87)	1976	√
Convention concerning the Application of the Principles of the Right to Organise and to Bargain Collectively (No 98)	1976	√
Convention concerning Equal Remuneration of Men and Women Workers for Work of Equal Value (No 100)	1963	√
Convention concerning the Abolition of Forced Labour (No 105)	1963	√
Convention concerning Discrimination in Respect of Employment and Occupation (No 111)	1969	√
Convention concerning Minimum Age for Admission to Employment (No 138)	2001	√
Convention concerning the Prohibition and Immediate Action for the Elimination of the Worst Forms of Child Labour (No 182).	2005	√

Certification

The standards used in Indonesia for palm oil are the Round Table for Sustainable Palm Oil (RSPO) and there is one set up by the Government, the Indonesian Sustainable Palm Oil (ISPO). The Rainforest Alliance operates a sustainable palm oil training and certification programme in Indonesia that is complementary to RSPO, and one palm oil operation is currently certified to the Sustainable Agriculture Network (SAN) standards in the country (Rainforest Alliance, 2016)[3] (SAN, 2016)[4]. Utz Certified also provides traceability services to the sector for the RSPO system (Utz, 2016)[5]. For forestry FSC and PEFC are used.

Biodiversity

There is a wealth of information related to biodiversity and natural resources conservation in Indonesia. The geographic breadth of the country and complex habitats and the richness of its biological resources also make it difficult to monitor in general terms. Policy and scientific/technical jurisdiction is spread across several line ministries; this makes data collection and monitoring a gargantuan (and often politically charged) task. Terrestrial, fresh water aquatic, marine/coastal and atmospheric environment issues are governed by no less than seven ministries, plus an additional ministry for planning. The basic law(s) governing land use and land use changes that require EIAs have been recently re-established in Environmental management law No. 32 of 2009. This is overseen by the Ministry of the Environment and provincial environmental assessment agencies (BPLHD).

Indonesia is party to all of the major international environment treaties/conventions/protocols – generally seen as a good indicator of environmental awareness and activity. The Fourth Report to the Convention on Biological Diversity was prepared by the Ministry of the Environment in 2009. In addition the country has a National Environmental Action Plan, the Agenda 21, developed in 1997/98. This plan, although by now becoming out of date, helped to shape thinking and national and regional priorities important to current activities and plans. Biodiversity issues are carefully taken into account to assess the potential of palm residues (chapter 2 and 3).

[3] http://www.rainforest-alliance.org/work/agriculture/palm-oil

[4] http://san.ag/web/wp-content/uploads/2014/11/List-of-Certified-Farms-and-Operations-February-2016.pdf (page 74)

[5] https://www.utz.org/what-we-offer/traceability-system/traceability-service/palm-oil/

2.1.4 Policy

The government enacted Indonesia's National Energy Policy (Presidential Regulation No. 5/2006 (regulation 5) in early 2006. Regulation 5 formalized the development of biofuels in Indonesia, (ethanol and biodiesel), and established a five percent biofuel mandate by 2025. According to regulation 5, biofuel development will help diversify and secure energy supplies and support sustainable economic development. MEMR also issued Regulation No. 32/2008 in conjunction with regulation 5. Regulation 32 establishes a progressive set of targeted biofuel mandates during the 2008-2025 timeframe (USDA, 2014).

Other policies by topic (NCIV, 2013) relevant are:

- The 1999 Forestry Law (FL) no 41/1999 which states that the management of state forest located within the jurisdiction of customary law communities (*Masyarakat Hukum Adat*) may be classified as *Adat* Forest.
- The Plantation Estate Law 18/2004 (PEL) which is the main regulation that encourages the expansion of the palm oil estates .
- The Basic Agrarian Law (BAL, 1960) determines that *ulayat* rights and other similar rights of customary law community (M*asyarakat Hukum Adat*) applies to the earth, water and air and should be recognized, as long as these communities really exist, and as long as it does not contradict national and State interests.
- National Land Bureau issued Regulation no 5/1999 on Registration of *Adat* Land which regulates *Adat* Land as Non State Domain.
- The Regulation of the Minister of Agriculture No. 26/2007 (Spatial Planning Law) provides Guidance of Estate Business Permits and determines that the individual ownership of land for palm oil is at least 20% of the total area of the community which is developed for palm oil

2.2 Methodology to assess sustainable biomass potentials

A consistent methodology has been designed and applied to assess the sustainable biomass potentials in international sourcing countries. With the Indonesian case study, the methodology has been fully applied. The methodology covers ten steps.

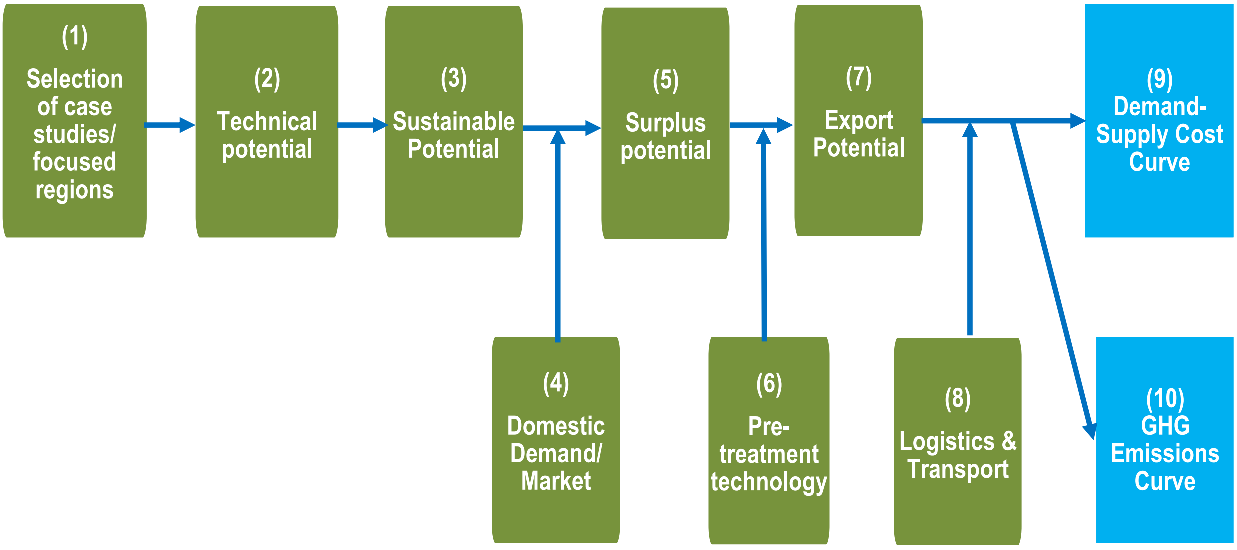


Figure 2-8 Assessment of Sustainable Lignocellulosic Biomass Value Chains

Step 1 – is based on national production palm sector, trade patterns, political situation and data availability (international & national databases , communication with local experts and consultation from external stakeholders, other projects and reports)

Step 2 - determines the total technical potential of palm residue in Indonesia taking into account current production of fresh bunches and land availability. Information is used related to the selection of the relevant provinces/states, specific spreadsheet for data collection (incl. results of other studies), application of GIS (if appropriate) based on the data of national or international statistics, other studies about potentials and communication with local experts.

Step 3 – evaluates with similar data of step 2 but also looks into the sustainable potential in consideration with a number of economic, environmental, social and institutional criteria developed by Wp2

Step 4 – finds out local demands and market of palm residues for energy & various uses in those Indonesia by consultation with expert opinion and based on socio-economic development (living standards, GDP, etc.), policies in energy, environment & climate, international & national databases (e.g. FAOSTAT, national statistics), communication with local experts as well as results from other projects/studies.

Step 5 – estimates surplus potentials after deducting local demands and market of feedstocks for energy & various uses in Indonesia.

Step 6 - Key factors for biomass transport are identified with the aim of reducing cost of delivering palm residue pellets. Different pre-treatment technologies and corresponding biomass carriers are considered. Physical & chemical characteristics of palm residues as well as the level of development of technologies are factors that determine whether a technology is deemed applicable. Technologies for pretreatment considers literature research, identify current and anticipate treatments based on physical & chemical characteristics of biomass feedstocks to achieve biomass pre-treatment in the scenarios

Step 7 – This step indicates the potential of pellets to be exported to EU-28 that meets sustainability criteria whilst considering the market requirements in step 4 and subtracting lignocellulosic feedstock for local use as identified in step 5 and

Step 8 - calculates transport requirement, the Biomass Intermodal Transport (BIT-UU) model is used, available at Utrecht University. The BIT-UU model is used to calculate the optimal route from various sourcing regions to the final destination. It also can evaluate different pathways to reduce cost and greenhouse gas emissions in the whole supply chain of lignocellulosic biomass, e.g. the effects of using larger vessels.

Step 9 – covers the demand-supply cost curve that uses cost balance equations based on cost in the biomass supply chains,

Step 10 - GHG emissions that considers GHG emissions equation in RED Annex V + iLUC, literature reviews and external sources.

2.3 Assessment of sustainable palm residues in Indonesia

2.3.1 Selection of studied region and biomass types

The oil palm plantation and processing industry is a key sector in the Indonesian economy. The Indonesian Statistics provide data on palm oil production at national, provincial and district/city level.

Based on the size of production and productivity as indicated in Figure 2-9, palm oil is largely produced in Sumatera (Sumatra) and Kalimantan regions, however the plantation and production in Sumatera is rather mature and palm biomass is planned to be used mainly for mulching and local electricity production[6].

Figure 2-9 Palm plantation in Indonesia

Kalimantan was therefore chosen as the investigated area due to its expanding plantation and logistic of palm trees. It also has an increasing capacity of biodiesel manufacturing (PASPI 2014) and governmental policies aimto increase the productivity of palm plantation. Details of this information are provided in the Appendix 1.

[6] http://www.sciencedirect.com/science/article/pii/S1876610214002264#

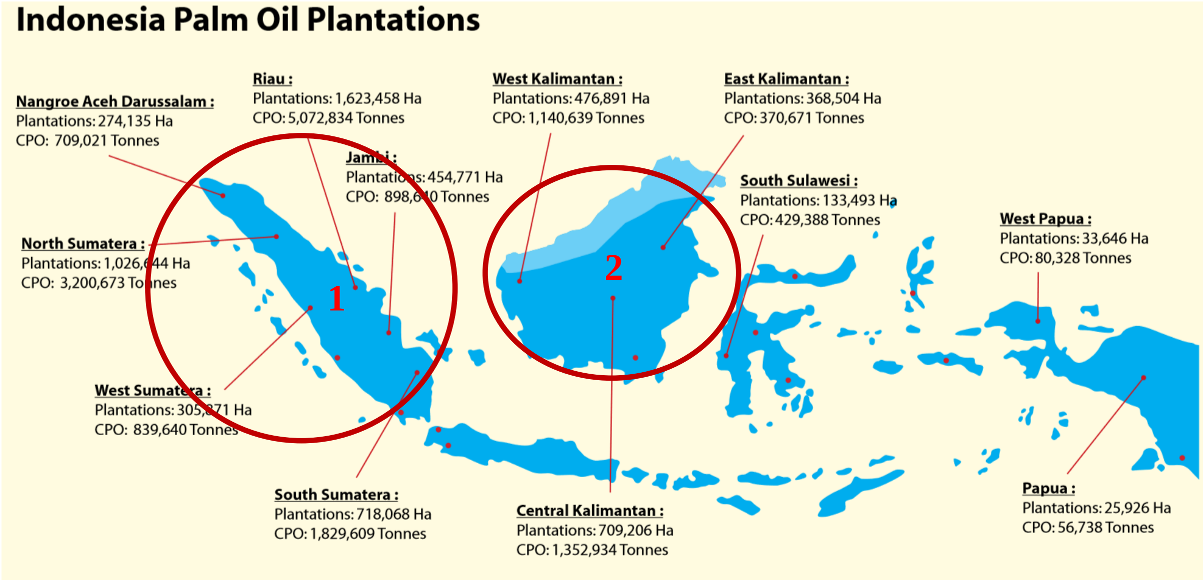


Figure 2-10 The two main regions of palm oil production, Sumatera (1) and Kalimantan (2)[7]

Overview of palm production in the last ten years in Kalimantan is drawn in Figure 2-10. It can be noted that production has steadily increased especially in Central Kalimantan from 0.17 Mt tonnes to 2.1 Mt. West Kalimantan also indicates a strong growth while in South and East Kalimantan, the production rise is less vigorous.

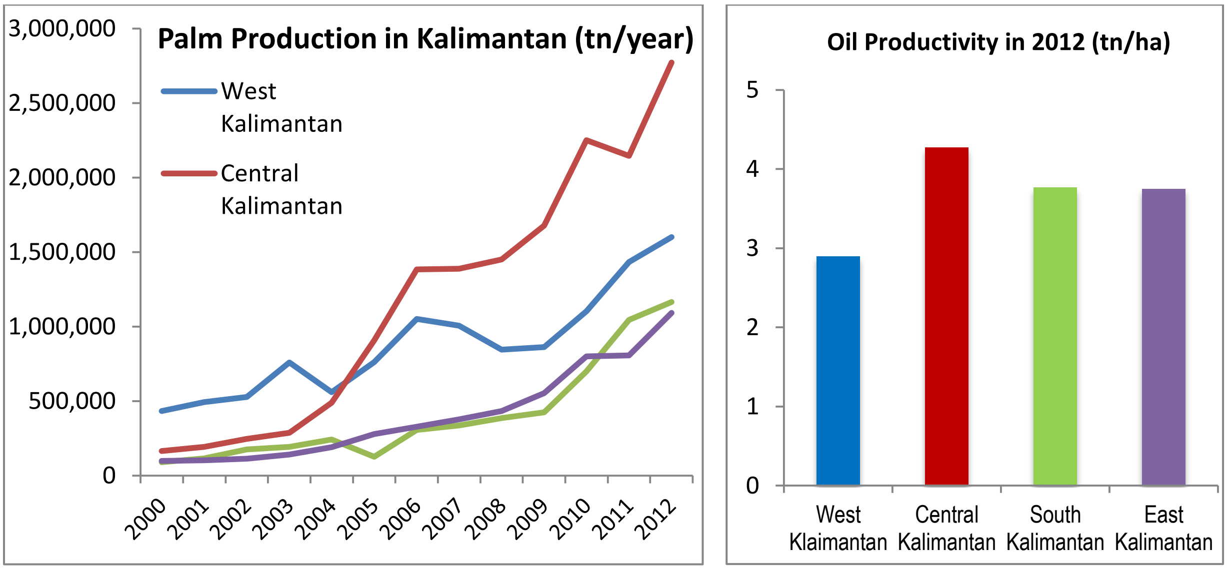


Figure 2-11 Evolution of palm production and Palm Productivity in 2012 in Kalimantan (tn/ha)[8]

[7] http://www.indonesia-dhaka.org/palm-oil/
[8] http://www.bps.go.id/linkTabelStatis/view/id/1666

Taking into account yield increase and palm production, as well as proximity to Pangkalanbuun and Sampit ports at the south of the region (where bulk commodities are traded), we have focussed our study in Central Kalimantan. In fact this region indicates the highest production and yields, while at the same time a potential for expanding palm plantation remains.

Figure 2-12 Ports of Pangkalanbuun and Sampit

In this report, three types of producers have been identified due to their different level of capacity and average yield of palm production: independent smallholders; plasma farmers and private companies. This classification is based on the Country Report. Indonesian Palm Oil Statistics [11].

Independent smallholder	Independent smallholder or "petani mandiri" meaning a farmer who manages, finances, and operates his/her own farm by himself/herself. Consequently, the productivity of the farm is usually low due to the lack of capital, knowledge, and facilities.
Plasma famer	A plasma farmer is supervised and supported by a partner company in managing, financing, and operating his/her farm under the partnership scheme of "nucleus-plasma" or "pola plasma-inti". Plasma farmers are also called "petani plasma".
Private company	Private company refers to an oil-palm estate company that is practicing good agricultural principles but is currently not certified under RSPO[9] (Roundtable Sustainable Palm Oil). Private company are alsod estate operations certified by third party, have compliance with RSPO standards.

2.3.2 Technical potential

The production of palm oil in the last decades has shown a revolutary expansion from manual harvesting and processing to large-scale industrial production which has also shown an increase in productivity. In this report the technical potential is defined as the lignocellulosic biomass potential that is available under current and future technological possibilities, taking into account spatial restrictions due to competition with other land uses (food, feed and fibre production) [23].

Modern palm oil production typically consists of the following eight steps:

1. Harvesting of fresh fruit bunches[10] (FFB)

[9] Initiative to ensure the credibility of palm oil sustainability claims
[10] The bunch harvested from the oil palm tree

2. Transportation of FFB to oil mill
3. Sterilization of FFB
4. Stripping of FFB
5. Transfer to digester where the fruit is meshed
6. Pressing of the meshed fruit from the digester to extract oil
7. Separation of oil and fruit debris of by screens and settling tanks
8. Clarification of oil by centrifuge

A simplified overview of this production method is showed in Figure 2-13.

The production of crude palm oil (CPO) generates residues in mainly two places: on the plantation and at milling facilities. Residues produced at the plantation consist of fronds and tree trunks.

Fronds and Trunks

Fronds and trunks are available throughout the production of fruit bunches. Tree trunks however only become available during replanting every 30 years.

Both fronds and trunks are barely used and, if used, it is under low efficiencies. Fronds are currently used as mulching agent and fertilizer, although this is limited due to labour and pest concerns (Sulaiman, Abdullah, Gerhauser, & Shariff, 2011). Currently fronds receive increasing attention since they show a large potential for use as renewable energy, feedstock in the paper industry and as animal feed. Trunks could be used as plywood or lumber or wood pellets and wood chips, but field study found out that they are currently burned in the field since the demand for wood is generally low in plantation areas.

Empty fruit bunches (EFB)

After harvesting, the fresh fruit bunches are transported to milling facilities to be processed into palm oil. Figure 2-11 shows a simplified overview of the milling process and the occurring residues.

In Indonesia, a high quantity of EFB is disposed of to an unmanaged, deep landfill located next to the palm oil mill. The disposal of EFB not only causes environmental problems in the surrounding areas but contributes to global warming as well. The anaerobic digestion of the EFB in disposal sites gives rise to undesired odour and at the same time, takes up land spaces [27].

EFBs are abundantly available in a typical palm oil mill as fibrous material of purely biological origin. EFB contains neither chemical nor mineral additives, and depending on proper handling operations at the mill, it is free from foreign elements such as gravel, nails, wood residues, waste etc. However, it is saturated with water due to the biological growth combined with the steam sterilization at the mill. Since the moisture content in EFB is around 67%, pre-processing is necessary before EFB can be considered as an useful fuel and by-product[11].

Fiber

Fibers are generally burned in the mill for power generation but efficiency is estimated very low, while a small fraction is sometimes sold as fuel. Similar to empty fruit bunches fiber can be used as feedstock in medium-density fibreboard and blackboards. The chemical industry also has applications for fiber as it can be used as filler in thermoplastics and thermoset composites, which are used in furniture and in the automotive industry.

Oil palm shell

Currently oil palm shells are mostly used as fuel for the mill and as fibres, they are used with low efficiency and normally to cover the roads in the plantation. Palm shell seems promising to be a source of fuel since it is already bought by cement companies as boiler fuel.

[11] http://www.bioenergyconsult.com/tag/uses-of-empty-fruit-bunch/

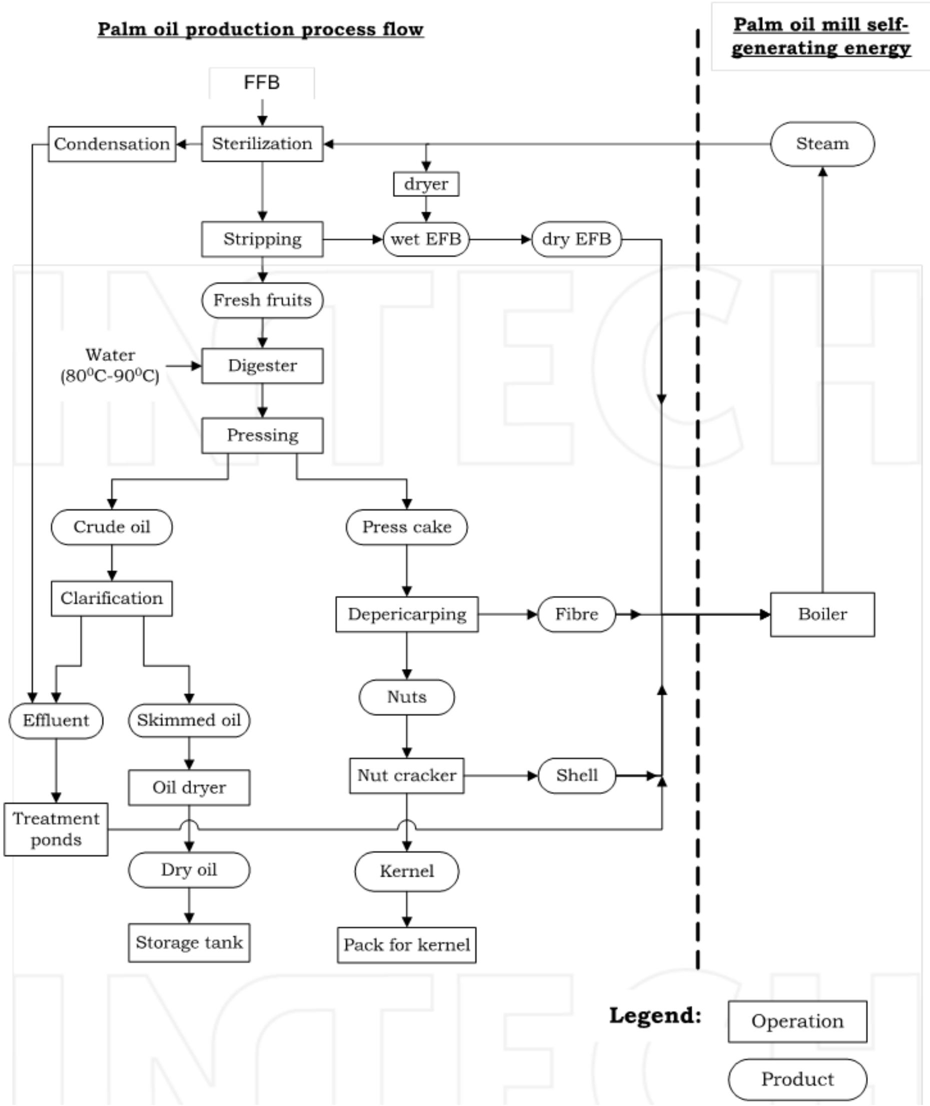


Figure 2-13 Overview of a palm oil mill (source: Sulaiman et al, 2011)

Other wastes

Different kinds of wastes can also be compacted into palm oil briquettes, which can be used as fuel for household- or industrial heating. To achieve better quality briquettes sawdust is added in the blend. Although these briquettes have good burning qualities, they cannot compete with charcoal or wood, which are still commonly used. Another promising application for palm oil wastes is as feedstock for the production of carbon molecular sieves (CMS). CMS can be used as an absorbent to separate gasses. These wastes are not investigated further due to project limited resources. The study focused mainly to discover the biomass potentials of trunks, fronds, EFBs, fibre and shell to be potentially used for heat and power generation.

Palm residues	Moisture content (%)[12]	Calorific value (MJ/kg)[13]
Frond	70.23	15.72
Trunk	75.60	17.47
EFB	67.00	18.88
Shell	12.00	20.09
Fibre	6.31	19.06

Table 2-6 Moisture content and calorific value of palm residues [15]

Estimation of trunks and fronds at the palm fields is achieved by using the RPR ratios. These ratios are obtained from Loh et al. [15]. When the total amount of residues is calculated, energy potentials of residues will also be generated. More details are provided on the appendix 2.

Data used for the assessment of palm biomass residues are heavily relied on the report of Rizaldi Boer et al. [18] and details of palm planted areas for current and future timelines have already been investigated. Yield productivity by effective fertiliser use and better management practices in the BAU and improved scenarios has also been identified.

Producers	Planted area (ha)	FFB yield (kg/ha)	EFB produced (t)
Independent small holders	144,619	7,250	209,698
Plasma holders	254,196	11,325	575,753
Private estates (ordinary + RSPO)	872,163	17,700	3,087,458

Table 2-7 Overview of palm plantation in Central Kalimantan in 2011

Trunks are normally collected before the replantation period which happens about every 30 years, the quantity depends on the plantation areas and is therefore separated from the palm productivity [16]. Fronds are sorted through annual pruning and also during replanting time as for trunks. The potential of these residues are calculated on an annual basis.

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
RPR (%)			**21.07**	**4.29**	**15.42**		
Dry quantity t/ha	**10.88**	**2.48**					
Moisture content (fresh) (%)	**0.75**	**0.706**	**0.67**	**0.12**	**0.37**		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**	**Kt**	**PJ**
Independent small holders (tonnes)	1,573,455	359,041	50,410	27,370	70,431	2,081	33.9
Plasma holders (tonnes)	2,765,648	631,083	78,744	42,754	110,018	3,628	58.9

[12] Moisture content of residues right after harvested

[13] Calorific value of dry residues

Private estates (ordinary + RSPO) (tonnes)	9,489,138	2,165,291	123,070	66,821	171,948	12,016	193.9
Total Techical MT	13.83	3.16	0.25	0.14	0.35	**17.73**	**286.73**

Table 2-8 Total technical potential of palm residues in Central Kalimantan (CK)

2.3.3 Sustainable potential

The sustainable amount of palm residues is calculated based on the first sustainability criterion S1 which takes into consideration soil criteria numbers 4.2 and 4.3 of Deliverable D2.4 [24]). These criteria were chosen to represent relevant Indonesian sustainability requirements for palm industry:

S1. There are certain amounts of residues that need to be left on field for maintaining soil quality and used as fertilisers for palm growth. These amounts might be reduced in the future depending on soil management and additional fertilisers to be used.

Regarding the land expansion for future scenarios, two additional sustainability criteria are applied (relevant to biodiversity criteria 3.1 and 3.2, participation criteria 7.1 of Deliverable 2.4 of BioTrade2020plus project) :

S2. Land expansion does not take into consideration of deforestation

S3. Additional lands and support for small holders who are currently least effective producers of palm oil

Site survey and the study about the oil palm wastes carried out by N. Abdullah and F. Sulaiman [13] have indicated that due to the unfertile soil quality in Central Kalimantan, fronds and EFBs are currently used as fertilisers. Sustainable potential of palm residues shows a very small quantity indicating almost no potentials for export. Disposal of EFB into oil palm plantation without recovering remnant oil in the EFB contributes to oil spills and therefore sustainability consideration does not count for the EFB disposal. EFB is considered as a resource that has huge potential to be used for power generation and currently not being efficiently mobilised.

2.3.4 Domestic demand/ Market segment analysis

Results from site surveys and communication with palm holders shows that EFB is currently burnt and thrown on the palm fields, therefore wasting a renewable energy sourcewhich could be used in boilers in the palm oil mills. At present, shell and fibre wastes are used extensively as fuel for steam production in palm-oil mills but with low efficiency.

Palm residues	Current status
Frond	Left on field
Trunk	Left on field
EFB	Left on field/ burnt at oil mills
Shell	Burnt for energy production (low efficiency)
Fibre	Burnt for energy production (low efficiency)

2.4 Scenario development

Rizaldi Boer et al (2012; [18]) mentioned that the government of Central Kalimantan has established a target to increase its area of palm oil plantations from 1 million hectares to 3.5 million hectares by 2020, mainly on sites owned by private plantations and smallholders (Ditjenbun, 2008), through:

(i) expansion of palm oil plantations on low-carbon land

(ii) increase of productivity

(iii) expansion on degraded land

In this report, the current development of palm plantation is considered following the national statistics for palm industry [11]. The development of palm plantation in the report of Rizaldi Boer et al (2012; [18]) is applied for timeline of 2020 and 2030.

CURRENT SITUATION

The planted areas in Central Kalimantan have slightly increased from the previous years including immature, mature and damaged lands. Planted palms are still at young ages. 44% of Central Kalimantan's population relies directly on palm oil for their livelihoods. Most of the palm oil production in Central Kalimantan is dominated by plantation companies but the areas under palm oil production cultivated by smallholders are being increased by the government.
Estimation of current palm plantation planted areas, harvesting and residues to be possibly collected is mainly based on the national statistics. Data on land use, palm yield and palm management are used as background information to compare with future development of palm industry, domestic use in the country.

Producers (anual)	Planted area (ha)	FFB yield (kg/ha)	EFB produced (t)
Independent small holders	144,619	7,250	209,698
Plasma holders	254,196	11,325	575,753
Private estates (ordinary + RSPO)	872,163	17,700	3,087,458

TIMELINE 2020 and 2030

Land expansion

With the governmental target, it was estimated that the palm oil production by 2020 will be over three times of the current production [18]. Under this plan, about 1 million ha of forested land will be deforested. Rizaldi et al. recommends that Central Kalimantan could revise its current target of 3.5 million hectares' oil palm to 2.9 million ha to avoid the deforestation without a significant reduction of the production level.

This report follows their recommendation regarding land expansion for 2020 and 2030. In order to save the 1 million hectare of the "forested land", two principal mechanisms are important:

(i) the undertaking of a 'land swap' between 'forested' and 'non-forested' areas, coupled with a broader spatial planning exercise, and
(ii) improvement of smallholder yields

The government of Central Kalimantan Province has allocated land for palm oil plantations. Aboutabout 3.21 million hectare of the 3.5 million hectare target is allocated, to 272 companies. Of the 3.21 million ha, currently only about 25% has been planted with palm oil which is considered sustainable, while the remaining land is still covered by forest, therefore avoid deforestation issues (28% mostly secondary forest), shrubs/grassland (29%), agriculture (9%) and others (mining, rice field, ponds, transmigration area, etc) [18]. About 11% of the areas are located in peatland.

BAU Scenario

About 656,000 ha of the unplanted land is not suitable for palm oil cultivation (Figure 3-1). Therefore in the BAU case, the total land to be potentially exploited is 2,844,000 ha (in comparison with 3,500,000 ha planned to be used for palm plantation).

The Indonesian Sustainable Palm Oil standard (ISPO) obliges all oil palm companies including the existing ones to establish plasma plantation on at least 30% of their concession areas. The total of palm oil plantations in Central Kalimantan already reached 1.5 million ha and most of the companies have not met their obligation in establishing plasma plantations. Thus targeting the communities who used the non-forested lands in HP[14] that will be changed to HPK for plasma plantation will create good synergy between these two policies. Smallholder farmers are an important part of the picture. In Central Kalimantan, they currently manage an estimated 15% of the planted palm oil area. However, given the ambitious sectoral growth targets, coupled with the regulatory requirement [18] that 20% of oil palm should be smallholder managed, the plantation area managed by smallholder farmers is expected to expand rapidly between now and 2020.

High Export scenario

The total area which has not been granted with permits (unlicensed lands) and is suitable for palm oil production and is located in convertible production forest and APL is about 963,000 hectares in size, including degraded lands [18]. Degraded land suitable for palm oil expansion was identified through using a number of criteria including land cover, topography, rainfall, and soil type. It was assumed that 70% of suitable degraded land would be allocated to palm oil, reflecting the current proportion of palm oil to other commodities and crops. To avoid the conversion of forested land in HPK and APL[15], it is recommended to the Ministry of Forestry to change the status of forest functions under a land swap mechanism. Sustainability criteria S1 and S2 are also applied in the High Export scenarioHigh Export. The total area for land swap is about 315,000 ha, i.e. non-forested land of production forest (HP) to convertible production forest (HPK) about 240,000 ha and forested land of convertible production forest (HPK) to production forest about 75,000 ha (Figure 2-12). Therefore in the High Export scenarios, the total area which could be accessed in the future is 3,159,000 ha.

Improvement of yield productivity

The assumptions in the analysis were that independent smallholders' production of fresh fruit bunches increased from 8 to 10 t/ha, and from 12.5 to 15.7 t/ha for plasma smallholders [18]. For companies, there is no increase in productivity due to the fact that they already achieve maximum

[14] HP refers to non-forested land of production forest
[15] HPK and APL are lands that can be used for development (e.g. plam oil plantation)

yields of EFB. From existing plantations that currently stands at 1 million hectares, Central Kalimantan province could double oil palm production by 2020 from the current level as most of their existing plantations are still at very young age [18]. Increases in productivity are achieved through investments in soil health, and uptake of better management practices. The independent smallholders bear the greatest opportunity to increase yields. Implementation of improved yield scenario for small farmers and plasma farmers will have a positive impact on the environment as it will reduce the demand for lands from 2.62 to 2.39 million ha or about 232,000 ha and this could avoid the conversion of forested land. In combination with land swap, forested land that can be saved will increase to 473,024 ha. This is equivalent to a reduction of emissions from deforestation of about 480 million ton of CO_2. With this reduction, the potential earnings received from carbon credit for those saved forests could not cover the additional cost required for yield improvement program. However, the additional benefit from yield improvement will result in significant increase in income.

SCENARIO BAU 2020

Under this scenario, land increase has been anticipated due to the government policy target. Even in the BAU perspective, the study does not consider the deforestation or forest conversion for palm plantation. Palm yield is assumed to increase for all the palm holders. Data for this scenario are taken from [18].

Producers (anual)	Planted area (ha)	FFB yield (kg/ha)	EFB produced (t)
Independent small holders	568,800	9,575	2,178,504
Plasma holders	682,560	14,958	4,083,756
Private estates (ordinary + RSPO)	1,592,640	23,375	14,891,184

SCENARIO High Export 2020

Different to the BAU 2020 perspective, a survey of [18] has indicated that a land swap mechanism if implemented could provide an addition of 315,000 ha for palm oil plantation. Nevertheless, palm yield is assumed to further increase for independent small holders and plasma holders due to better management and more fertilisers use. There is no yield increase for private estates because they already implement good agricultural practices. Data for this scenario is also taken from [18].

Producers (anual)	Planted area (ha)	FFB yield (kg/ha)	EFB produced (t)
Independent small holders	631,800	11,973	2,723,983
Plasma holders	758,160	18,550	5,064,595
Private estates (ordinary + RSPO)	1,769,040	23,375	16,540,524

SCENARIO BAU 2030

Under the BAU 2030, there are additional improvements in palm yield but land areas are kept as BAU 2020 due to no further investment in appropriate land use changes. Palm yield is assumed to continue increasing for all the palm holders, especially for private estates, yield would attain the maximum level of 29,050 kg/ha (investigated by [18]). Data for this scenario is taken from [18].

Producers (anual)	Planted area (ha)	FFB yield (kg/ha)	EFB produced (t)
Independent small holders	568,800	11,970	4,765,975
Plasma holders	682,560	18,590	8,882,153
Private estates (ordinary + RSPO)	1,592,640	29,050	32,386,334

SCENARIO High Export 2030

Similar to the High Export 2020, an addition of 315,000 ha for palm oil plantation could be possible attained. Palm yields achieve their highest productivity due to maximum fertiliseruse and good agricultural practices. Data for this scenario is also taken from [18].

Producers (anual)	Planted area (ha)	FFB yield (kg/ha)	EFB produced (t)
Independent small holders	631,800	14,880	6,580,829
Plasma holders	758,160	23,040	12,227,604
Private estates (ordinary + RSPO)	1,769,040	29,050	35,973,428

2.5 Treatment technology for palm residues

There is a large potential of transforming palm residues into renewable energy resource that could meet the existing energy demand of palm oil mills or other industries. Pre-treatment steps such as shredding/chipping and dewatering (screw pressing or drying) are necessary in order to improve the fuel property of palm residues. Pre-processing of palm residues will greatly improve its handling properties and reduce the transportation cost to the end user i.e. power plant. Under such scenario, shells and fibres which are currently utilized for providing heat for mills can be relieved for other uses off-site with higher economic returns for palm oil millers.

Unprocessed EFB is available as very wet whole empty fruit bunches each weighing several kilograms while processed (dry) EFB is a fibrous material with fibre length of 10-20 cm and reduced moisture content of 30-50%. Additional processing steps can reduce fibre length to around 5 cm and the material can also be processed into bales, pellets or pulverized form after drying.

Centralized palm residues collection and pre-processing systems could be considered as a component in the residues supply chain. It is evident that the mapping of available palm residues resources would be useful for palm residues resource supply chain improvement. This is particularly important as there are many different competitive usages. With proper mapping, assessment of better logistics and EFB resource planning can lead to better cost effectiveness for both supplier and user of the palm residues.

A covered yard is necessary to supply a constant amount of this biomass resource to the energy sector. Storage time should however be short, e.g. 5 days, as the product, even with 45% moisture, is vulnerable to natural decay through fungi or bacterial processes. This gives handling and health problems due to fungi spores, but it also contributes to a loss of dry matter trough biological degradation. Transportation of palm residues is recommended in open trucks with high sides which can be capable of carrying an acceptable tonnage of this low-density biomass waste.

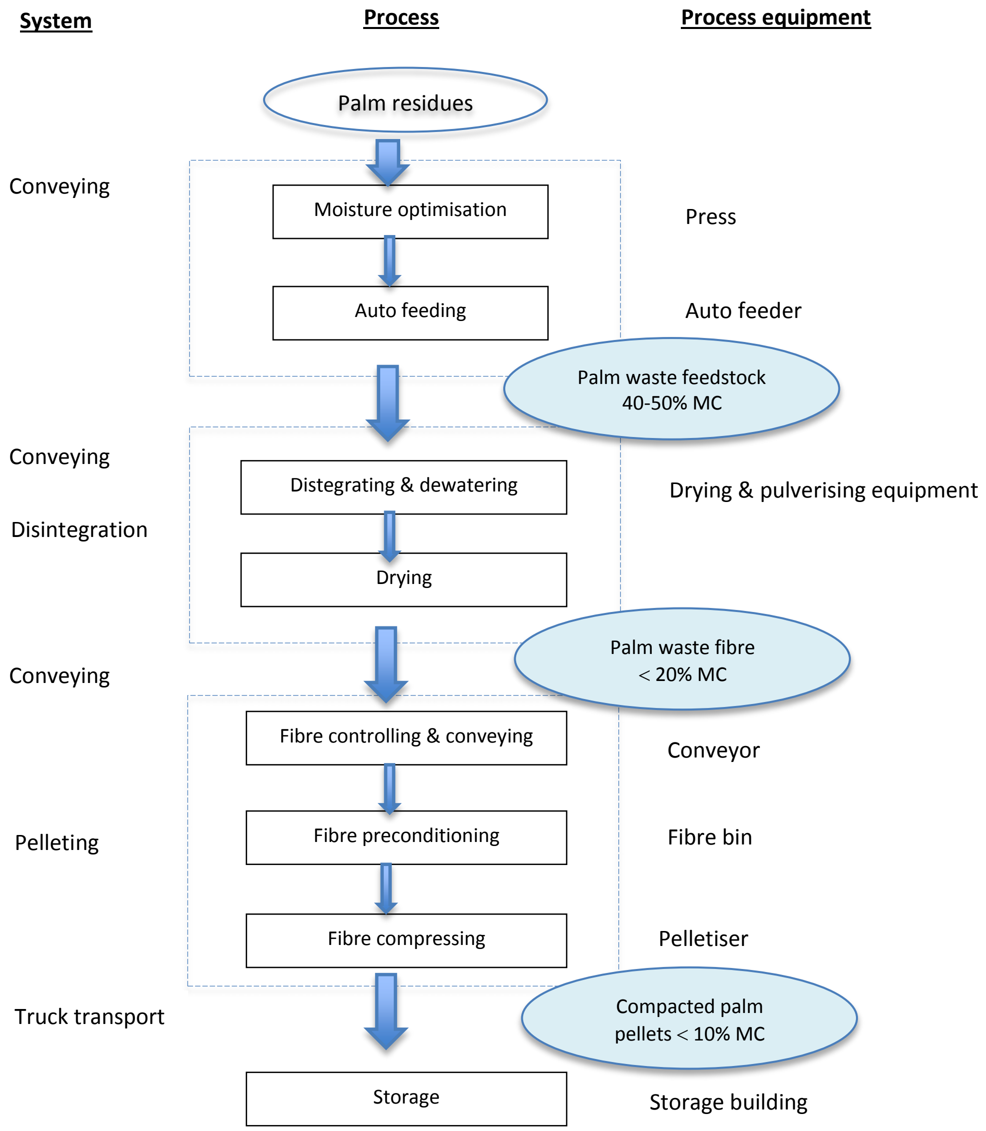


Figure 2-14 Process flow diagram of pellet production

For palm residues utilization in power stations, the supply chain is characterized by size reduction, drying and pressing into bales. This may result in significantly higher processing costs but transport costs are reduced. For use in co-firing in power plants this would be the best solution, as equipment for fuel handling in the power plant could operate with very high reliability having eliminated all problems associated with the handling of a moist, fibrous fuel in bulk.

Sub-system	Description	Assumption
Chopping	Particle size reduction to 5 cm long of palm residues	Incoming palm residues is in the form of bunch weighted 6 kg
Drying	Palm residues drying to 7 % moisture	Drying at 100ºC at atmospheric pressure

Grinding	Particle size reduction to 0.5 mm	Incoming palm residues average size is as described in Chopping Description
Torrefaction/ Pelletisation	Palm residues conversion to palm pellets	200-300ºC and mass yield is about 80% with energy density 20-24 MJ/kg
Storage	Storage of bio-oil and char	4 weeks storage capacity

In this research only pelletization of biomass is considered as pre-treatment technology which is also applied in the other case studies of the BioTrade2020plus project. This becauseother technologies have not matured yet and are still in a state of development. Pelletization is currently mainly applied for woody residues, agricultural residues are mostly just dried and baled and used locally. It is however possibly to use pelletization technology also on agricultural residues or on mixtures of agricultural and forestry residues (Nunes, Matias, & Catalão, 2014).

Following the Ukraine case study report developed by Visser et al. [28], the capacity in existing pellet plants is considered a limiting factor for the transport of pre-treated biomass to the EU. Data about the total installed capacity is not available; instead the most recent data about pellet production from literature review was considered. Business as Usual increase of pellet plant production. In the High Export scenario the capacity is assumed to increase at a maximum rate. This maximum rate is determined by comparing to that in the South-East of the US. The pellet market in this region is the most developed in the world and has experienced an impressive increase in the last decade (Southern Environmental Law Center, 2015). Mimicking the South-East US growth rate is considered realistic considering it is based on actual realized growth rates, but High Export considering the more favorable conditions in the US compared to Indonesia.

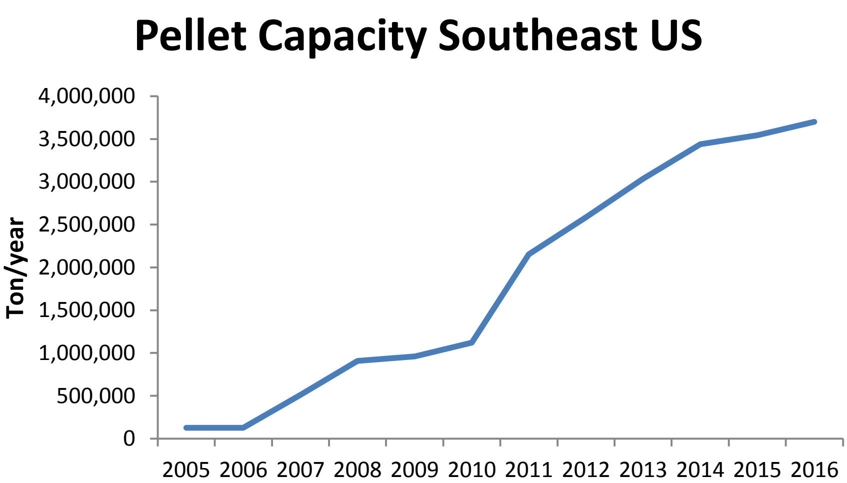


Figure 2-15 Pellet plant capacity Southeast US

The assumption is made that additional pellet plants will be installed in the geometric centre of those regions with sufficient demand. The output of existing pellet mills in the US varies between 13,000 ton/year and 750,000 ton/year, as can be seen in Figure 2-16. A large number of pellet mills have capacities between 75,000 and 150,000 tons (29%) and 440,000 and 550,000 tons (37%). In this research it is assumed that smaller sized pellet mills will be placed with a capacity of 50,000 tons. It is assumed that pellet mills will be installed according to potential, thereby being placed first in the Oblast with the highest potential and only in those Oblasts with a potential greater than 50000 tons of pellets.

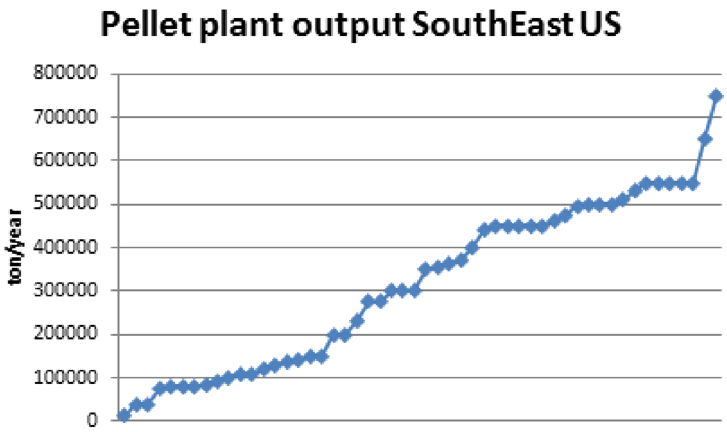


Figure 2-16 Pellet plant output Southeast US

It is outside the scope of this research to allocate the different feedstock potentials to pellet mills. Instead it is assumed that the capacity will first be filled by agricultural residues. Supply of dedicated energy crops is only used if the capacity exceeds the sustainable supply of agricultural residues.

2.6 Calculating supply chains and cost/ GHG-supply curves

Total cost and GHG emissions of delivered sustainable palm residues are investigated in order to assess whether the palm biomass is economical and sustainable. A breakdown of the whole set of costs incorporated in the biomass supply chain, considering the locations of production of agricultural and forestry feedstocks as a starting point and the export ports as an end point. Harvesting costs, transportation costs for truck, storage costs, pre-treatment costs when applicable and port costs are investigated. Subsequently, a cost-supply curve based on the costs acquired is constructed, through which the amount of biomass outweighing fossil fuel and other renewable energy sources in terms of prices is determined. Finally, solutions to reduce costs in the future are provided under different scenarios, in order to render economically viable a bigger share of the sustainable feedstock surplus.

2.5.1 Supply cost curve

The supply curve is constructed based on the total current cost of biomass supply, and cost changes in short and medium term.

$$C_D = C_H + C_{Pt} + C_{Td} + C_{Pc}$$

Where,

C_D Total supply cost of biomass (€/GJ);

C_{Fg} Harvesting cost (€/GJ);

C_{Pt} Cost of pre-treatment (€/GJ);

C_{Td} Cost of domestic transport (€/GJ);

C_{Pc} Total port cost (€/GJ);

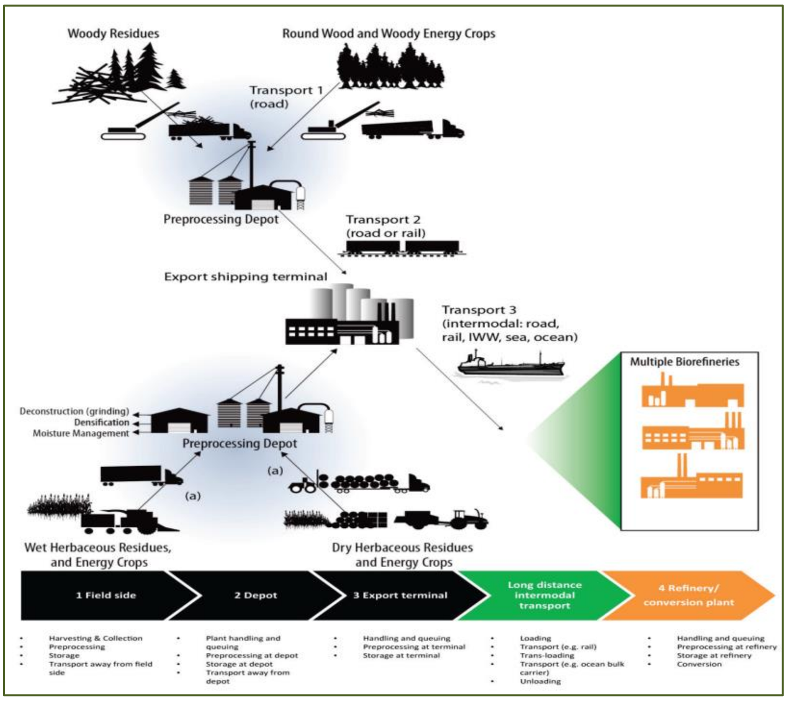


Figure 2-17 Overview of biomass supply chain [26]

All the elements of the aforementioned equation 2-7 are calculated individually based on the following data.

Data required	Units
Residues available potential	t or PJ (outcome of section 2.1.)
Fuel price	€/L
Labor costs	€/h
Electricity price	€/MWh
Exchange rates	Ksh into € (input from task 2.1.2)
Shipping capacities	m^3 and t
Feedstock densities	t/m^3
Prices of alternative sources	€/GJ
Nutrient compensation costs	€/GJ
Working hours	h
Inland transport routes and distances	km (input from task 2.1.1)
Profit embedded in each step of the supply chain	%

Table 2-9 Data required for the development of biomass supply cost-curve

The total cost in the whole supply chain of biomass from sourcing regions to Europe fluctuates depending on a number of expenses, according to Hoefnagels et al. [26]. Based on the projection for market segment and trade patterns in different scenarios, a cost supply curve is subsequently built up and a figure of supply chain components to biomass feedstock cost is also built.

$$C_T = C_D + C_{Ti} + C_{SC}$$

C_T total cost in the whole supply chain

C_{SC} cost of sustainability certification where applicable

C_D cost of biomass production and domestic transport

C_{Ti} cost of international transport

2.5.2 GHG emissions analysis

The analysis of GHG emissions released throughout the supply chain is followed by recommendations on the GHG emissions reduction in 2020 and 2030 (RED Directive).

The Biomass supply chain is designed and subsequently the GHG emissions at each stage of the chain are estimated or followed default values provided by the EC then summed up for each residue type. This is obtained through the different emission factors attributed to corresponding means (e.g. fertilizers, truck transport etc.). Subsequently, due to the fact that this study was carried out within the boundaries of Central Kalimantan, a comparison-discussion between different studies elaborating GHG emissions released throughout miscellaneous biomass supply chains including overseas shipping and final conversion processes, will be done on the basis of emission avoidance rates in relation to fossil fuel uses in Cenral Kalimantan in order to provide indications on the promising shares of the sustainable feedstock surplus potential that might be suitable for export.

3. Results: Biomass potentials in Central Kalimantan

3.1 Land-use in Central Kalimantan for palm plantation

The investigation of lands suitable for palm plantation in the whole region of Central Kalimantan is based on land availability analysis and forest function of the Ministry of Forestry Decree Number S.292/ Menhut-II/2011.

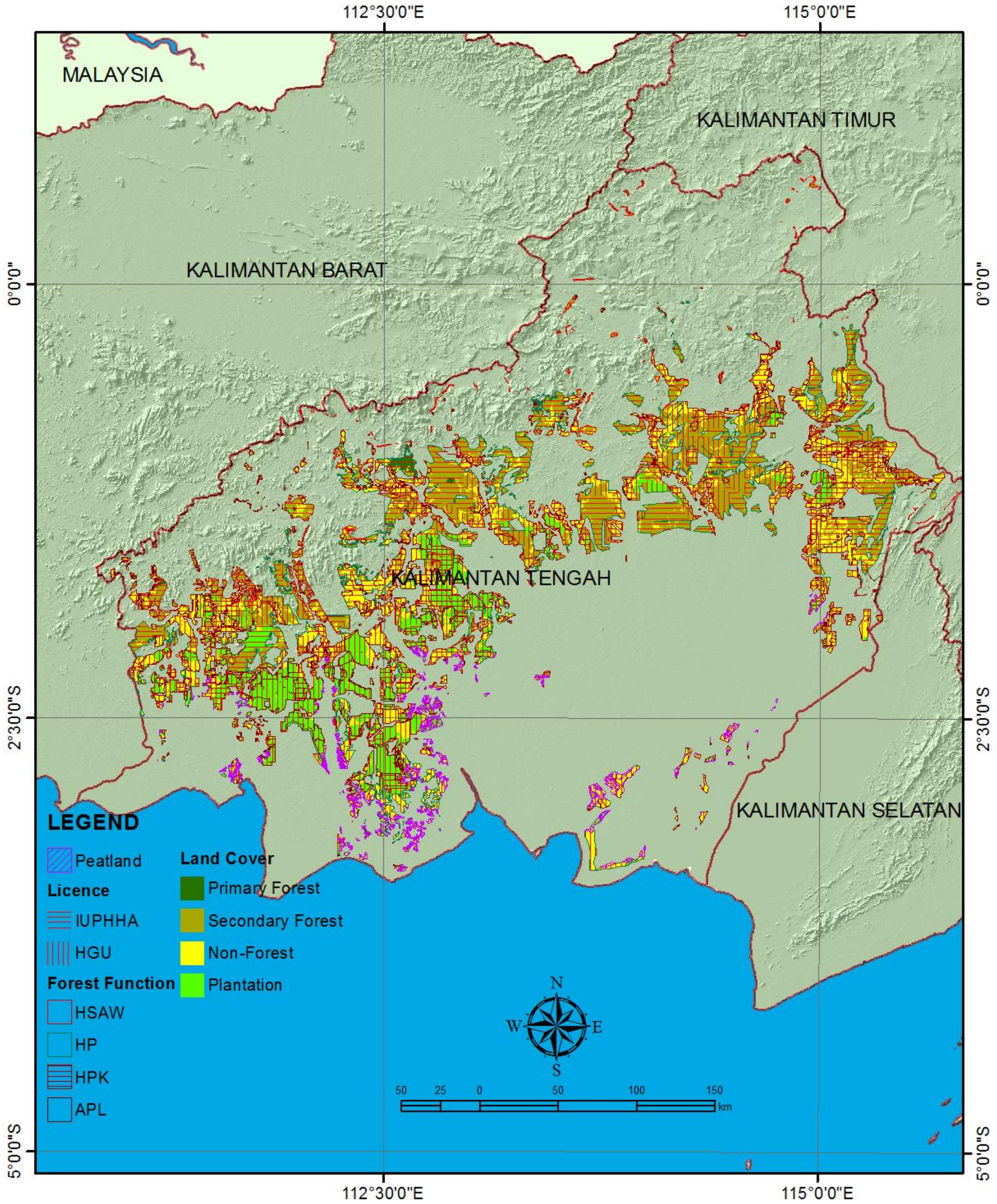


Figure 3-1 Distributions of licensed lands suitable [18]

The recommended suitable areas for palm oil plantation are areas highlighted with yellow in APL (horizontal lines), and yellow and light blue in HPK (vertical lines) and HP (oblique lines).

3.2 Determination of the current technical, sustainable, net sustainable potentials of feedstocks

The potential of palm residues which could potentially be mobilised is determined by the dry mass. Regarding the fronds and trunks, data were not available for Central Kalimantan; therefore investigations of Loh Soh Khean et al [15] for the Malaysian case study were used. The trunks are cut down every 30 years and the yield of dry trunks that could be mobilised is 74.48 t/ha. Fronds are collected through annual maintenance, this results inf about 12.00 t/ha and through replantation every 30 years, resulting in 14.47 t/ha of fronds. These numbers are roughly applied to estimate the dry tonnes of fronds and trunks in the Central Kalimantan regions.

For EFB, shell and fibre, residues to products ratios (RPR) are applied to estimate how much of these residues could be mobilised from the collection of FFB. Consequently, the moisture content and calorific values (CV) are applied to assess the total amount of these residues in dry mass. RPRs, moisture content and CV were collected via a field trip and from literature [15].

The final amount of palm residues could be calculated as presented in Appendix 3 and 4.

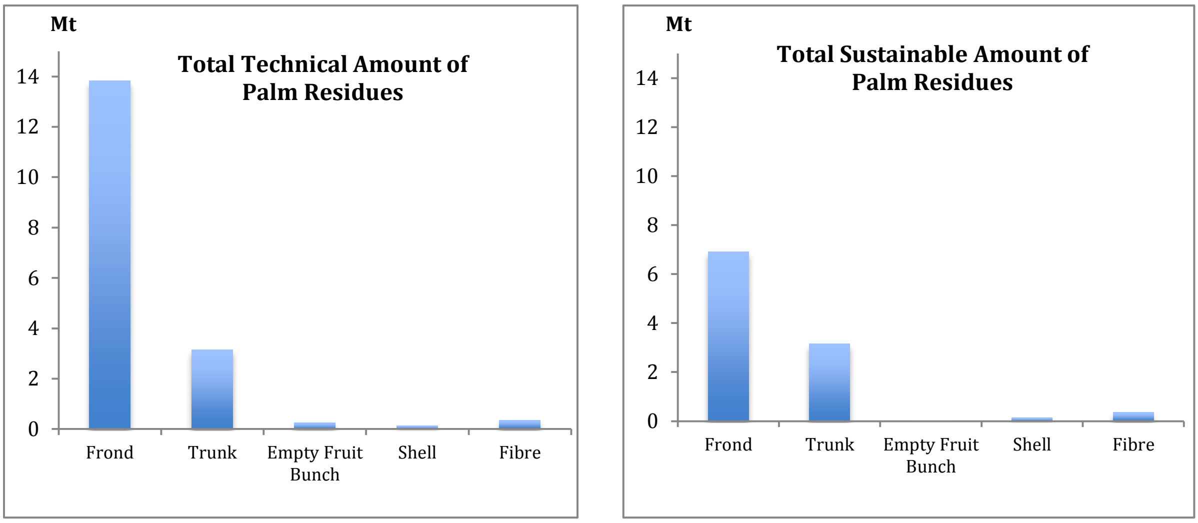


Figure 3-2 Total Technical vs. Sustainable Potentials of Palm Residues – 2011

The sustainable potentials are considered to meet the sustainability requirements: In this study, requirements are 100% fronds and 50% EFBs are to be left on field to maintain soil quality due to the fact that lands in Central Kalimantan are mainly sandy and bear low quality of fertile and there is still lack of investment for soil quality improvements.

3.3 Net sustainable volumes of feedstocks under the BAU and High export scenario, for 2020 and 2030

Technical Potential - BAU 2020

In this scenario, there are huge changes in both land expansion and yield improvements compared with the results of 2011. Land areas are more than double from 1,270,978 to 2,844,000 ha. Yields are increased for all three types of holders and therefore the total technical potentialincreases from 17.72 Mt to 30.93 Mt.

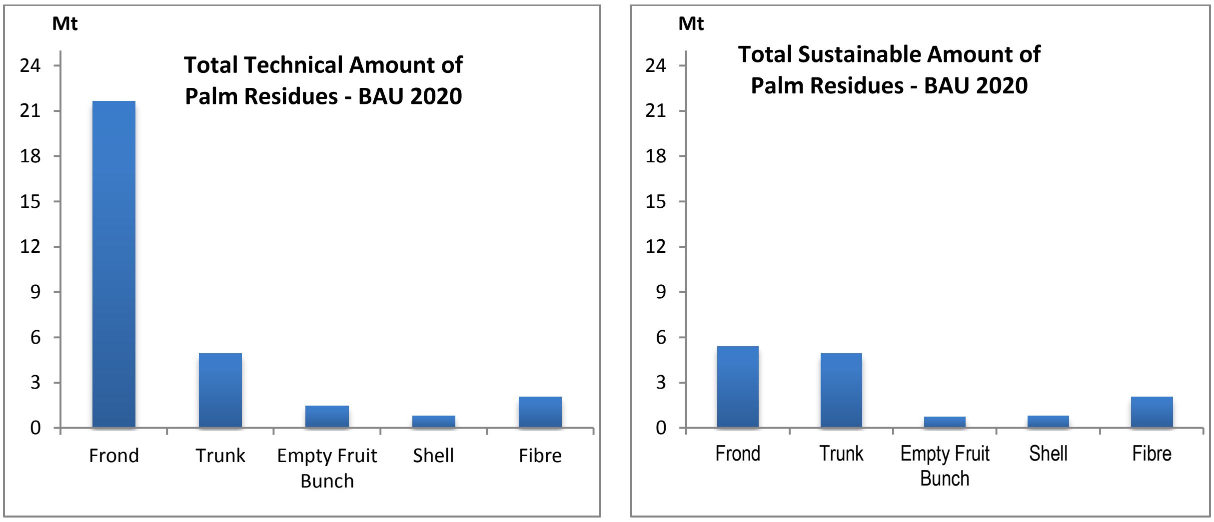


Figure 3-3 Total Technical vs. Sustainable Potentials of Palm Residues – BAU 2020

Sustainable Potential – BAU 2020

In this scenario, land areas used for palm production are kept as 2,844,000 ha. Yields are increased further for all three types of holders. The total sustainable potentials in this scenario decreases from a technical potential of 30.93 Mt in BAU to a sustainable potential of 19.36 Mt due to the assumption that 50% of fronds and EFBs will be used for maintenance of soil quality (study of use of palm residues for soil quality control bear the possibility of application of 50% of fronds and EFBs on the palm field [16]). Compared with the current sustainable potentials, there are less palm residues to be left on the field due to application of fertilisers for boosting yields and improving soil.

Exportable Potential – BAU 2020

In this scenario, the assessment of potentials is similar for the sustainable potential in BAU 2020. However, it also takes into account the utilisation of palm pellets as bioenergy consumption for local residents. There is no particular investigation of the local bioenergy demand but we assume that 25% of the sustainable potential is used locally, therefore exportable potential is equal to 75% of sustainable potential – BAU 2020.

Technical Potential - High Export 2020

In this scenario, areas for palm plantation are further mobilised due to the application of land swap mechanism. The area used for palm production increases from 2,844,000 ha to 3,159,000 ha. In comparison with the BAU 2020 scenarios, yields are also increased about 25% for independent small holders and plasma holders thanks to the better field management and appropriate application of fertilisers. Yields in private companies are not improved due to the good practices in palm cultivation and management are already applied. The total technical potential that could be mobilised amounts to 34.19 Mt.

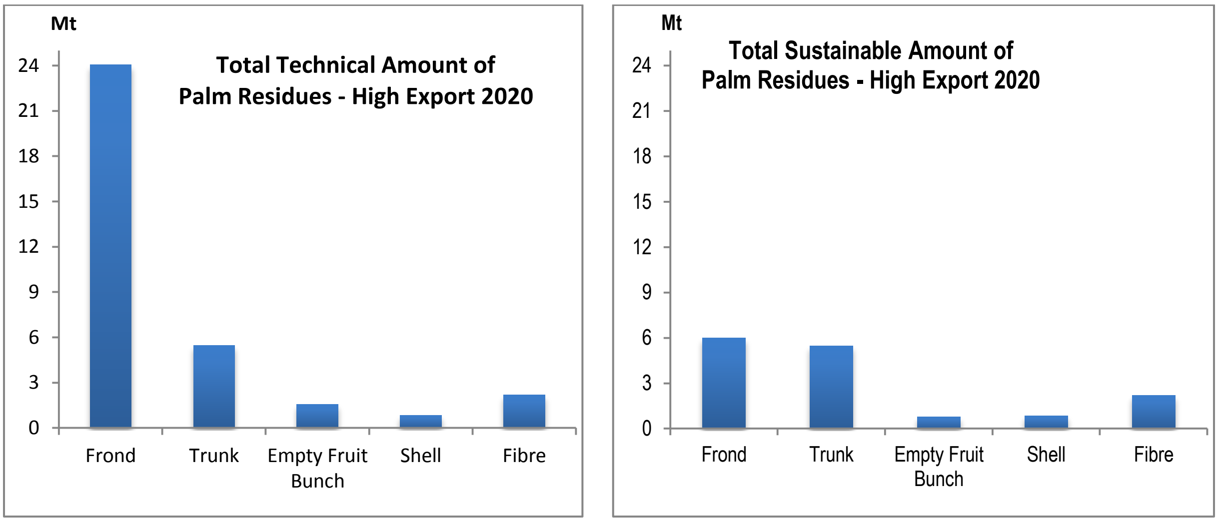


Figure 3-4 Total Technical vs. Sustainable Potentials of Palm Residues – High Export 2020

Sustainable Potential – High Export 2020

In this scenario, the area for palm plantation further increases due to the application of land swap mechanism. The total area is increased from 2,844,000 ha to 3,159,000 ha. In comparison with the BAU 2020 scenarios, yields are also increased about 25% for independent small holders and plasma holders thanks to the better field management and appropriate application of fertilisers. Yields in private companies are not improved due to the good practices that are already applied in palm cultivation and management. The total sustainable potential that could be mobilised decrease from a technical potential of 34.19 to a sustainable potential of 21.27 Mt (it is however still higher than the total sustainable potentials mobilised of 19.36 Mt of the BAU 2020)

Exportable Potential – High Export 2020

In this scenario, the assessment of potentials is similar for the sustainable potential in High Export 2020. However, it also takes into account the utilisation of palm pellets as bioenergy consumption for local residents. There is no particular investigation of the local bioenergy demand but we assume that 25% of the sustainable potential is used locally, therefore exportable potential is equal to 75% of sustainable potential – High Export 2020.

SCENARIO BAU 2030

Technical Potential - BAU 2030

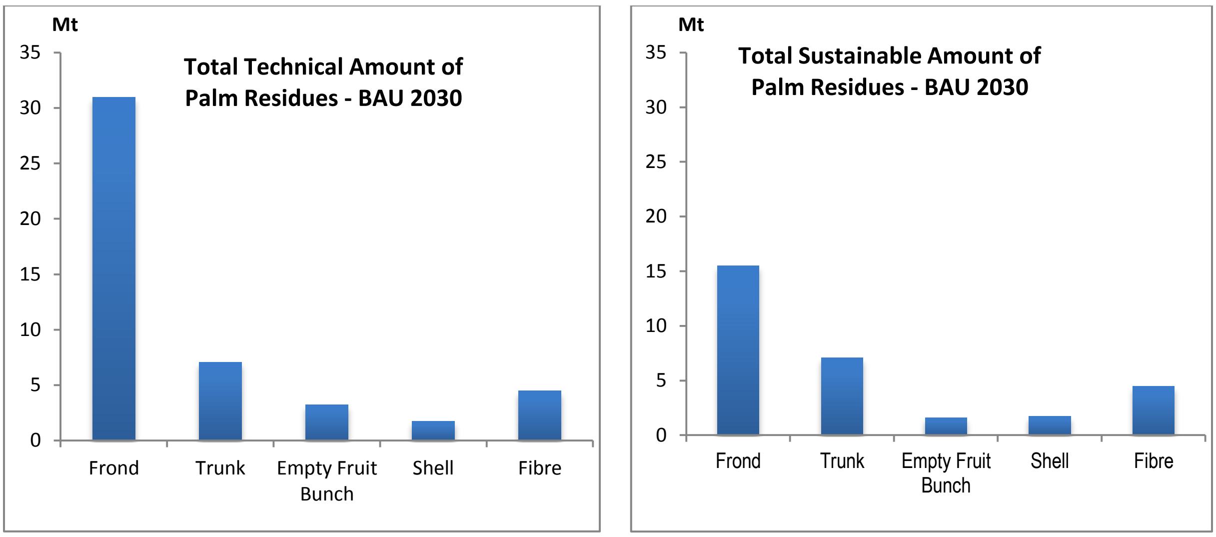


Figure 3-5 Total Technical vs. Sustainable Potentials of Palm Residues – BAU 2030

In this BAU scenario, total land area is kept at 2,844,000 ha similar to the BAU 2020 due to no governmental investment to access to land swap. In comparison with the BAU 2020 scenarios, yields continue to be increased for independent small holders and plasma holders thanks to continuous field management and appropriate application of fertilisers. Yields in private companies reach the highest level due to the application of best practices in palm cultivation and management as experienced with highest yield of palm in pricate company. The total technical potential that could be mobilised amounts to 47.41 Mt

Sustainable Potential – BAU 2030

In this BAU scenario, the total sustainable potential that could be mobilised decreases from a technical potential of 47.41 to a sustainable potential of 30.34 Mt. The decrease is due to the utilisation of 50% of fronds and EFB to cover field soil for preserve good soil quality.

Exportable Potential – BAU 2030

In this scenario, the assessment of potentials is similar for the sustainable potential in BAU 2030. However, it also takes into account the utilisation of palm pellets as bioenergy consumption for local residents. There is no particular investigation of the local bioenergy demand but we assume that 25% of the sustainable potential is used locally, therefore exportable potential is equal to 75% of sustainable potential – BAU 2030.

Technical Potential - High Export 2030

In this scenario, total land area increases up to 3,159,000 ha due to strong incentives and investment from the government to boost the palm industry growth. In comparison with the BAU 2020 scenarios, yields are increased to the maximum level due to the application of best practices in palm management including appropriate quantity of fertiliser uses, good techniques to cultivate and harvest oil palm. The total technical potential that could be mobilised amounts to 53.41 Mt

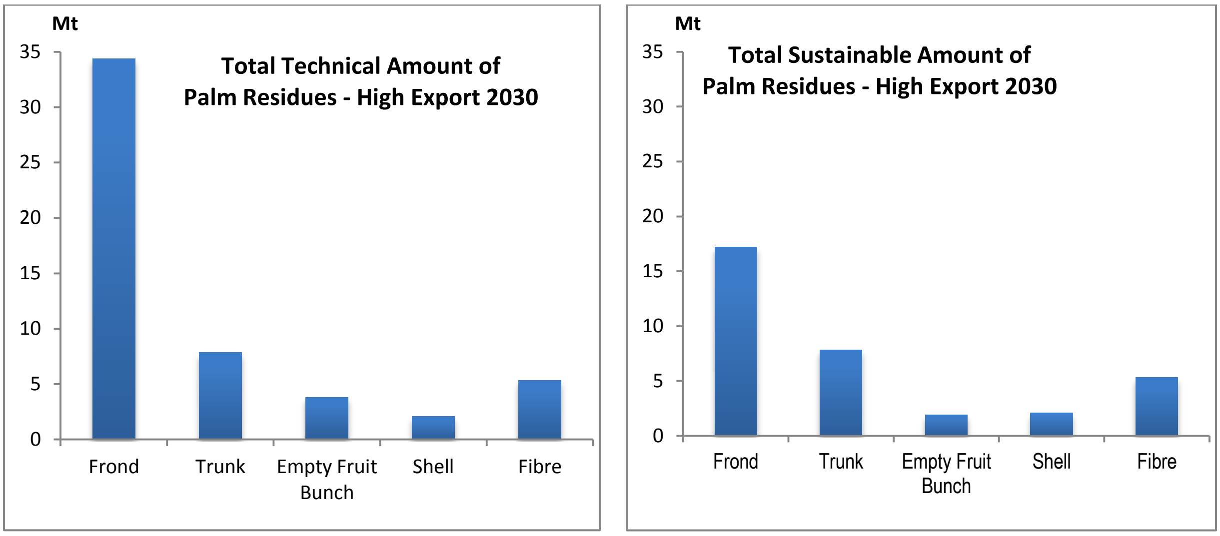


Figure 3-6 Total Technical vs. Sustainable Potentials of Palm Residues – High Export 2030

Sustainable Potential – High Export 2030

In this scenario, lands are kept to 3,159,000 ha due to strong incentives and investment from the government to boost the palm industry growth. The fronds and EFBs used as fertilisers are about

50% (in consideration with the Malaysian situation) and due to the yields boosted in all the three holders, the maximum sustainable potential that could be achieved is 34.32 Mt.

Exportable Potential – High export 2030

In this scenario, the assessment of potentials is similar for the sustainable potential in High export 2030. However, it also takes into account the utilisation of palm pellets as bioenergy consumption for local residents. There is no particular investigation of the local bioenergy demand but we assume that 25% of the sustainable potential is used locally, therefore exportable potential is equal to 75% of sustainable potential – High export 2030.

Summary of total technical and sustainable potentials over time

(Mt)	2011	2020		2030	
		BAU	High Export	BAU	High Export
Technical Potential	**17.73**	**30.93**	**34.19**	**47.41**	**53.41**
Sustainable Potential	**3.64**	**19.36**	**21.37**	**30.34**	**34.32**

Table 3-1 Summary of total potentials of palm oil in Central Kalimantan

LOCAL DEMAND IN 2020 AND 2030

Currently, there are no surpluses of palm residues to be possibly exported outside Indonesia[16]. The priority of the Indonesian energy policy is to reduce oil consumption and to use local renewable energy. For power generation, it is important to increase electricity power in order to meet national demand and to change fossil fuel consumption by utilization of biomass wastes. The development of renewable energy is one of the priority targets in Indonesia. However, the situation may change in the future and there are a number of aspects to be taken into account:

- Palm trunks, shells and fibres used as fuel to generate heat in palm oil mills will be exploited more efficiently
- Whilst fewer quantity of fronds and EFBs is used to maintain soil quality and organics carbon at the palm field due to supplementary fertilisers are provided to boost the palm yield

The total amount of palm residues is therefore additionally collected and increased over time.

Figure 3-7 and 3-8 summarise the total technical, sustainable and exportable potentials of palm residues over time for both BAU and High Export scenarios. As shown, there are no palm residues to be considered for export at the current situation (data collected in 2011) because 100% of palm residues are locally used.

In the BAU scenario, the potentials are increased in 2020 and 2030 due to expansion of palm plantation, higher palm yield and lower local use of palm residues. From a technical potential of 286 PJ in 2011, the palm residues indicate a 497 PJ in 2020 and 751 PJ in 2030. Consequently, the sustainable potential of palm residues taking into consideration sustainability criteria also grows from 65 PJ in 2011 to 318 PJ in 2020 and 491 PJ in 2030. Finally, the potential surplus potential demonstrates an amount of 249 PJ in 2020 and 375 PJ in 2030.

[16] https://www.iea.org/media/workshops/2012/bioenergyccsandbeccs/3Indonesian_Center_Crop_Research.pdf

In the High Export scenario, the potential of palm residues shows a higher quantity compared to the BAU scenario. In fact, the palm plantation areas are not changed due to the commitment of not using deforested lands, however palm yields progressively increases thanks to better soil management, implementation of best practice in plantation and better planning and cooperation of plantation farmers. The technical potentials of palm residues is 521 PJ in 2020 and 803 PJ in 2030. Consequently, sustainable potential of palm residues taking into consideration sustainability criteria are also grown to 333 PJ in 2020 and 527 PJ in 2030. The potential surplus potential demonstrates an amount of 260 PJ in 2020 and 401 PJ in 2030.

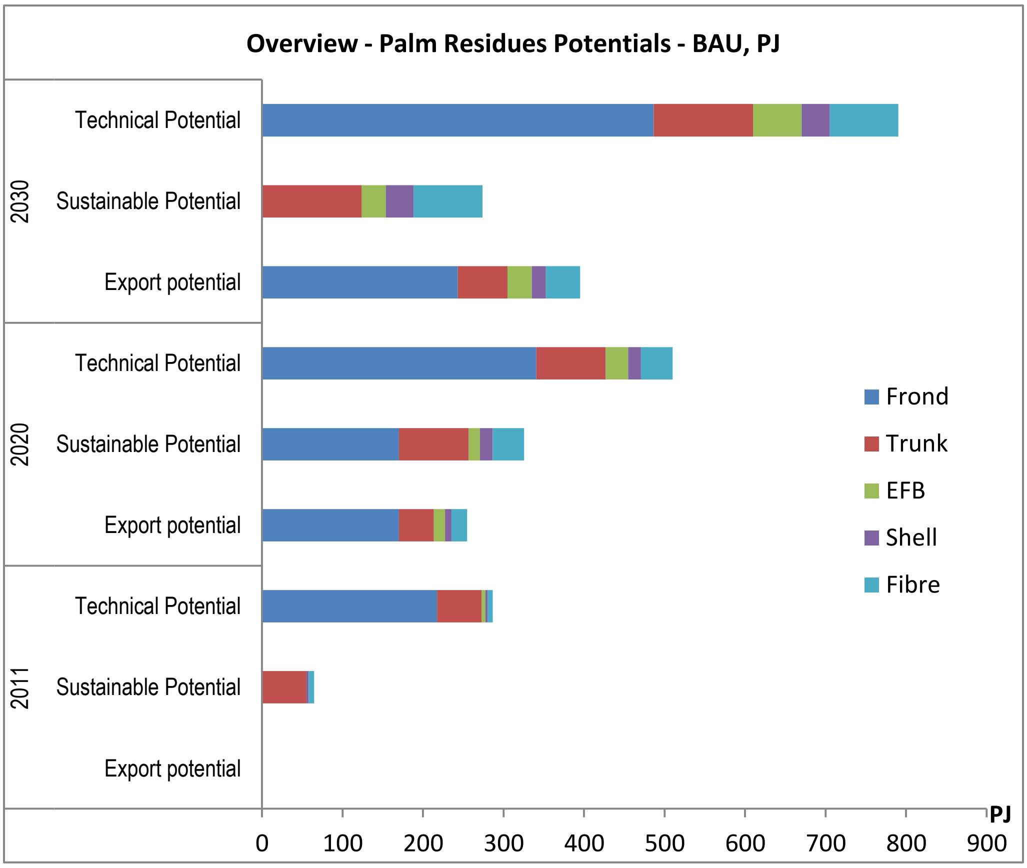


Figure 3-7 Overview of various palm residue potentials in BAU scenarios over time

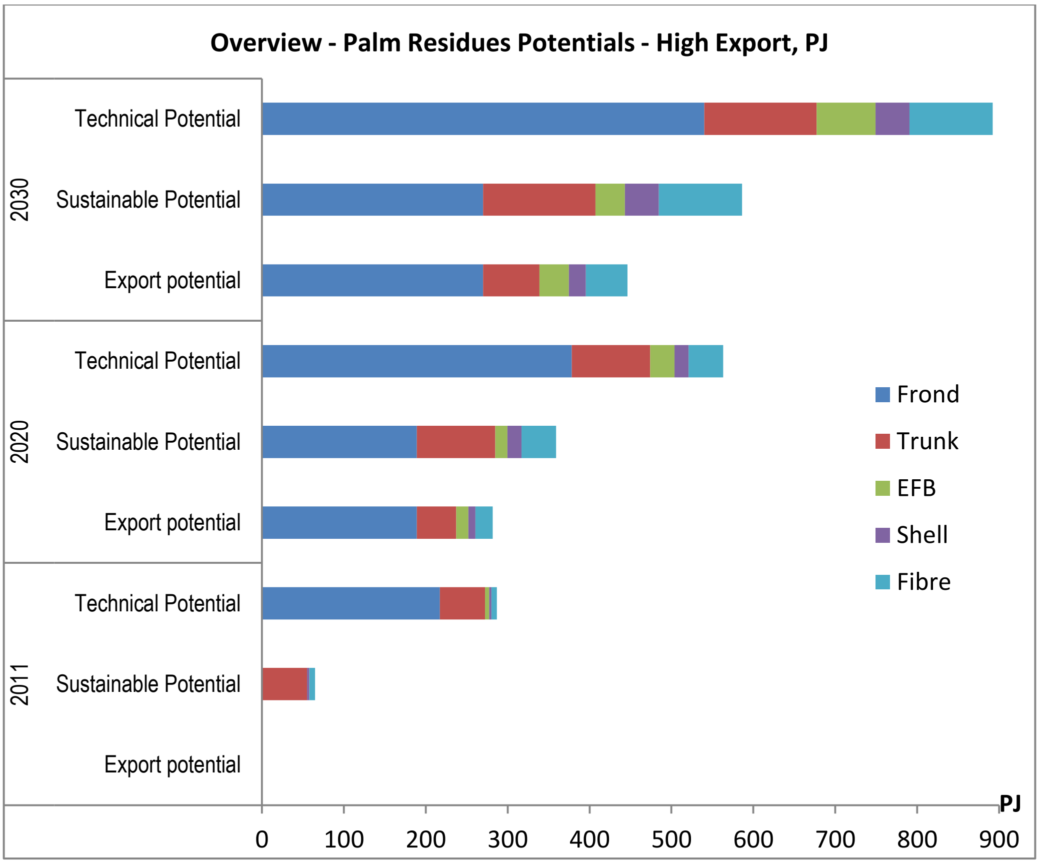


Figure 3-8 Overview of total palm residue potentials in High export scenarios over time

4. Supply Chain of Biomass Feedstocks

4.1 BAU Scenario

4.1.1 Biomass supply costs

At present, palm residues are not yet available for export because 100% of frond, trunk, EFB, shell and fibre is used domestically or left on field for soil impromvements. The inland supply-cost curves are therefore not built up for the current situation.

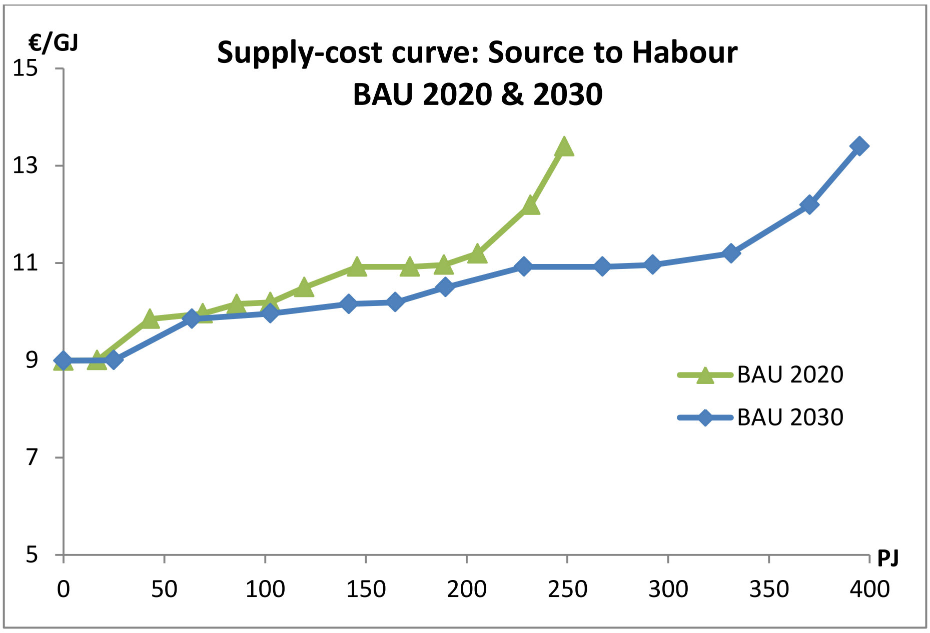


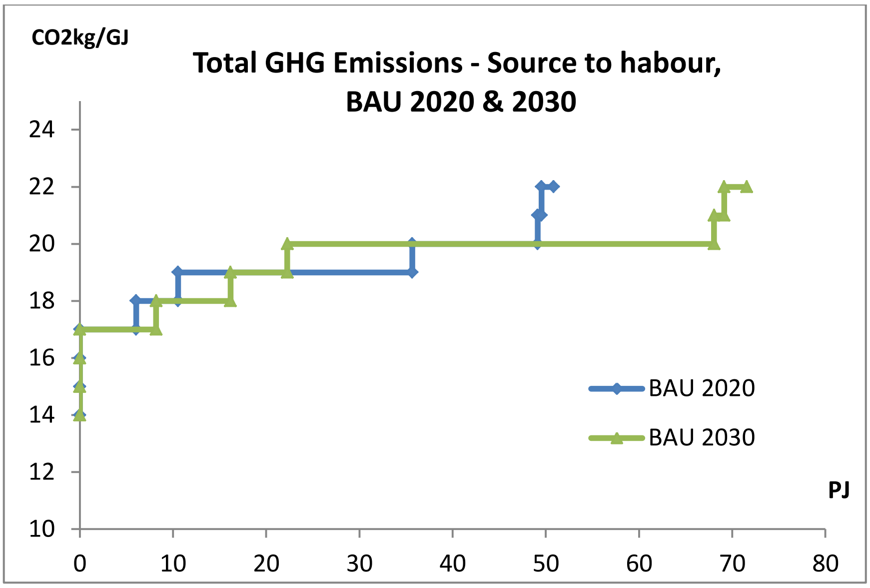
Figure 4-1 Supply-cost curve of palm residues in BAU scenarios

The total inland costs in general are competitive thanks to the combined unit of pre-treatment plant and oil mill. This combination indicates no cultivation and harvesting costs for EFBs, shells and fibres since they are considered wastes from oil mills. Fronds and trunks are also left on the palm fields; therefore no cultivation cost is regarded. However, the harvesting cost of fronds and trunks are taken into consideration to be equal as harvesting cost of FFBs. In addition, harbour cost including load/unload fees and service costs are reasonable in Indonesia compared to other sourcing countries, therefore leading to lower total costs.

The pre-treatment and profit costs of pelletisation of palm residues are considered to be invarible in the six sourcing countries in the BioTrade2020plus in order to be easily compared with prices from one country to the others.

In BAU 2020, the total inland costs of palm pellets range from 8.99 €/GJ to 13.39€/GJ. The fluctuation of cost is mainly due to different distances from collection points to oil mills where palm residues are processed then from oil mills to ports. In BAU 2030, cost ranges are similar but there are more palm residues to be mobilised and thanks to economy of scales.

4.1.2 GHG emissions



The calculation of GHG emissions of palm residues in the whole supply chain takes into account:

- Electricity production at palm mills are mostly self generated, so GHG emission intensity is lower than national average level
- GHG emissions for cultivation, harvesting and inland transports depends on local conditions
- GHG emissions in pre-treatment facilities and intercontinental transport are invariable in the six investigated countries in order to be easily compared with prices from one country to the others.

In BAU 2020 and 2030, the total inland emissions range from 16.48 to 21.06 CO_2kg/GJ. There is not much fluctuation in emissions due to the application of EU defaut values[17], however thanks to the economy of scales, there are more palm residues to be mobilised with the same emisssions values.

4.2 High export scenario

4.2.1 Biomass supply costs

[17] https://ec.europa.eu/energy/sites/ener/files/2014_jrc_biomass_report.pdf

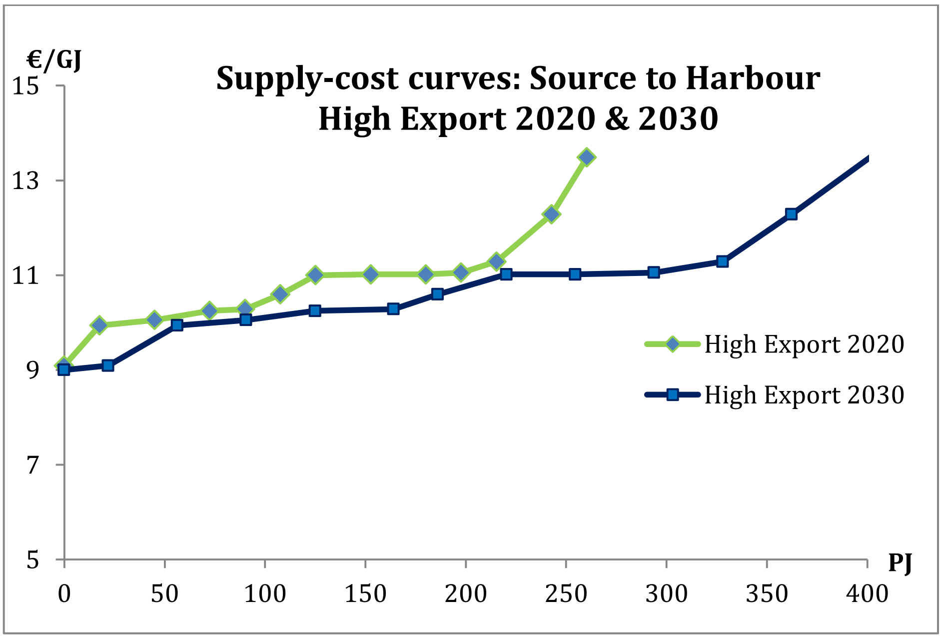
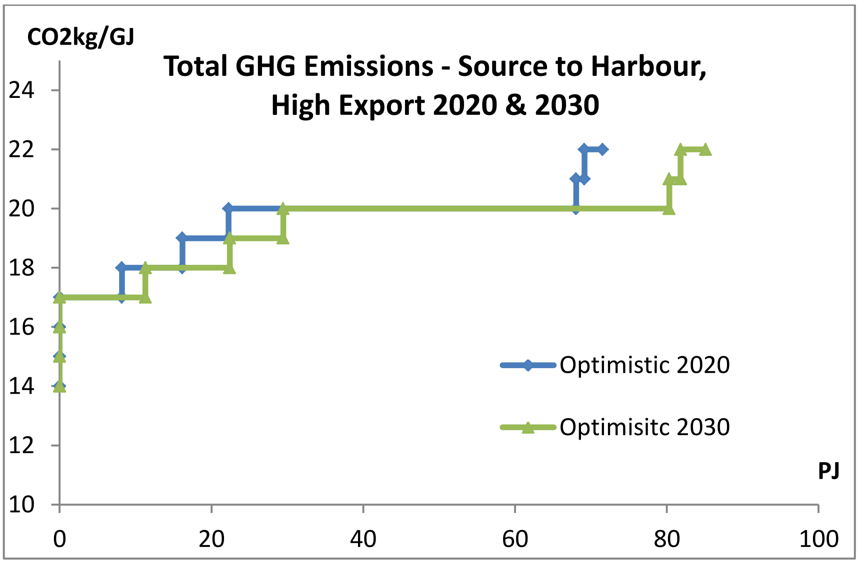


Figure 4-2 Supply-cost curve of palm residues in High export scenarios

The total costs in the High export scenarios are continuously reduced thanks to the additional palm residues to be mobilised.

In High Export 2020, the costs of palm residues range 9.94 €/GJ to 13.49€/GJ, lower compared to the BAU scenario. In High Export 2030, the costs of palm residues are lowest ranging from 9.09 €/GJ to 13.39 €/GJ. These costs are competitive at the port to be potentially exported.

4.2.2 GHG emissions



The calculation of GHG emissions of palm residues in the whole supply chain also takes into account:

- Electricity production at palm mills are mostly self generated, so GHG emission intensity is lower than national average level
- GHG emissions for cultivation, harvesting and inland transports are based onlocal conditions

- GHG emissions in pre-treatment facilities and intercontinental transport are invariable in the six investigated countries in order to be easily compared with prices from one country to the others.

In the High Export 2020 and 2030 scenarios, the total inland emissions similarly range from 16.79 to 21.06 CO_2kg/GJ. There is not much fluctuation in emissions due to the application of EU defaut values[18] for all timelines and scenarios. Also thanks to the economy of scales, there are more palm residues to be mobilised with the similar emisssions values.

[18] https://ec.europa.eu/energy/sites/ener/files/2014_jrc_biomass_report.pdf

5. Discussion

Total costs

Total domestic costs of palm pellets in both scenarios BAU and High Export in 2020 and 2030 are presented in Figure 5-1. It is indicated that costs are more competitive in the two High Export scenarios and especially in 2030 where palm yields reach the maximum productivity.

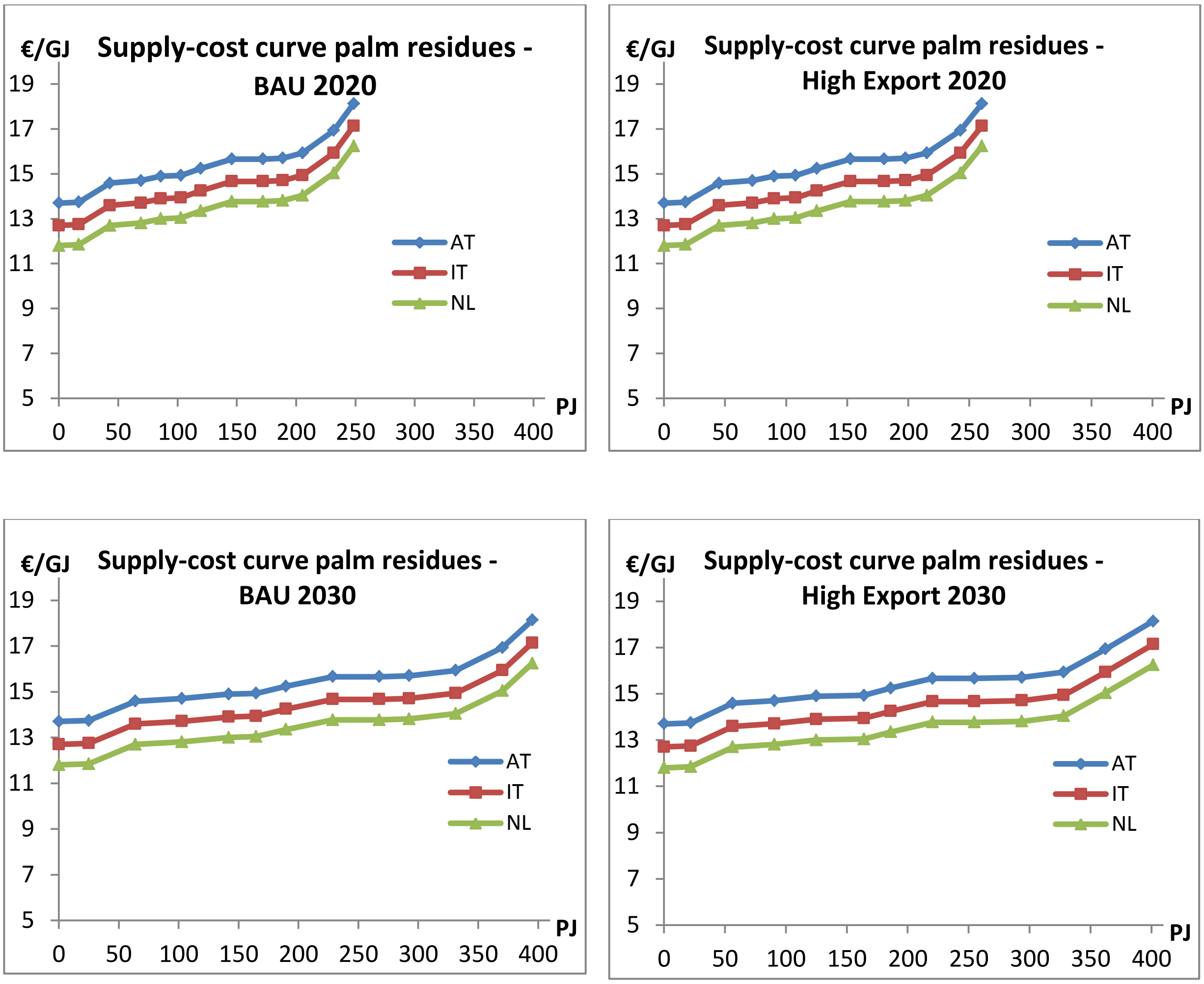


Figure 5-1 Summary of supply-cost curves of palm residues to the EU over time

The cost curves display the price of potential surplus of palm residues from well to wheel chains. These cost curves already consider the transport distances to exploit palm residues which can be reached without emitting high GHG emissions. Total costs of palm pellets reaching Italy are the lowest as Italy is the closet destination in Europe from Indonesia export habour. The costs at the Dutch harbour is slightly higher whilst the costs to Austria is highest due to farther distance from imported ports.

The Argus Biomass Market report [29] for wood pellets price shows prices in 2015 and prediction up to 2018, the highest bidding price, a cif ARA spot price, of 175.95 €/ton translates to 11.01 €/GJ, indicating that only a small part of palm pellets could be imported to Italy and the Netherlands in 2020 and 2030 but it is unlikely there are biomass to be mobilised from Indonesia to Austria due to high costs. A cif ARA spot price, of the lowest price of 158.40 €/ton translates to 9.91 €/GJ, indicating that there would have no palm pellets to be imported to the EU.

cif ARA €/t	Bid	Ask
Quarter 1, 2015	158.40	162.90
Quarter 2, 2015	161.78	164.03
Quarter 3, 2015	160.65	164.70
Quarter 4, 2015	165.60	168.30
2016	168.98	172.58
2017	172.80	176.40
2018	175.95	179.55

Table 5-1 Wood pellets forward prices (Argus Biomass Market [29])

Another issue which has not been thoroughly investigated due to lack of time and human resources is local demand of using palm pellets as renewable energy for other domestic purposes. It is in fact very difficult to predict local consumption of palm residues for future timelines. However, it is likely that these quantities of palm pellets will be mainly attributed for export due to high pellet prices whilst local households could mobilise other local alternative energy carriers from agricultural products such as rice, maize and cassava.

GHG emissions

Figure 5-2 presents the total GHG emissions of palm pellets for all scenarios and timelines. As explained in the section 4.2.2, although the range of GHG emissions is fixed due to application of EU default values for the four scenarios, there are more palm pellets to be mobilised at the same GHG in the future timelines as well as in High Export scenarios.

GHG emissions of palm pellets reaching Italy indicate lowest values whilst to the Netherlands showing highest number. This can be explained by the location of Italy as the nearest destination from the Indonesian habours whilt the Netherlands is the most remote country.

In addition to the calculation of GHG emissions, the estimation of GHG savings of using palm pellets as bioenergy carriers compared to FT-diesel use has been investigated. It is interesting to note that using palm pellets could save a significant amount of GHG emissions, in average it saves 82% in consideration with FT-diesel for transport fuel and 88% when being compared to electricity generation from FT-diesel. More details are provided in Table 5-1. These numbers also indicate that GHG emissions reduction requirements in a number of EU countries would be met (a requirement of 60% GHG emissions reduction in the UK, 70% GHG emissions reduction in Denmark and the Netherlands).

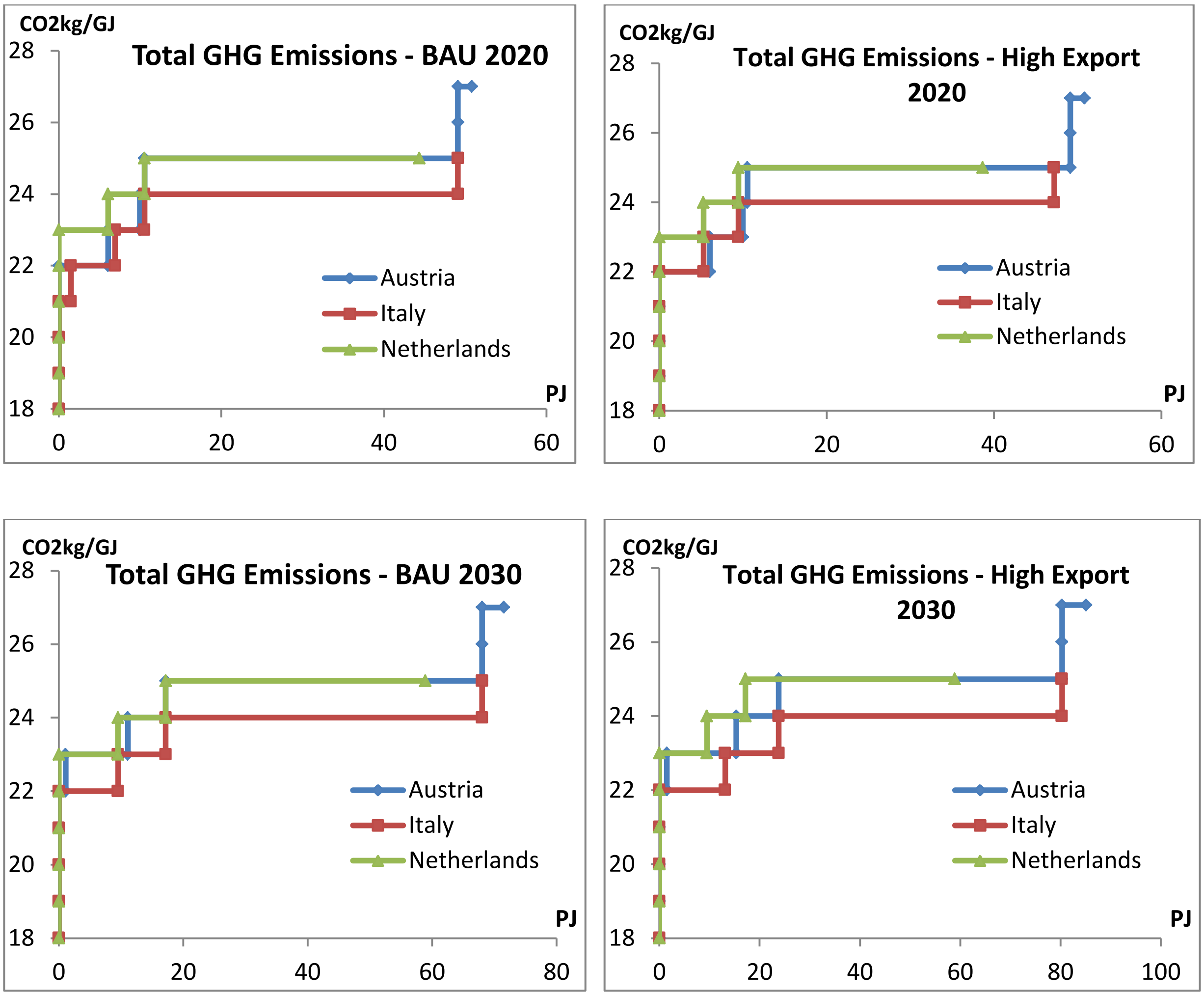


Figure 5-2 Summary of GHG emissions curves of palm residues to the EU over time

Feedstock type	GHG emissions of feedstock supply (g CO2-eq/MJ)			GHG emission savings – FT-diesel: FT-diesel (NGCC)			GHG emission savings – FT-diesel: Electricity generation		
	Austria	Italy	Netherlands	Austria	Italy	Netherlands	Austria	Italy	Netherlands
Frond	26.36	25.56	26.86	80%	80%	79%	87%	87%	86%
Trunk	25.86	23.48	24.78	80%	82%	81%	87%	88%	87%
EFB	22.84	22.09	23.39	83%	83%	82%	88%	89%	88%
Shell	21.78	21.05	22.36	83%	84%	83%	89%	89%	89%
Fibre	22.67	21.93	23.59	83%	83%	82%	89%	89%	88%

Table 5-1 Summary of GHG savings of palm pellets compared to FT-diesel

Competition of resources

It is predicted that biomass demand for energy in South Korea, Japan and China will rise[19] vigorously but with some uncertainties depending on policies of these governments towards renewable resources. Korea consumes 2% of renewables of its total energy in 2011 but has established the renewable ambition of 6% share of total energy in 2020 and up to 10% in 2030 in which biomass import counts for 50% of total capacity[20]. As the world 10th largest energy consumer, it currently looks for biomass resources overseas but targets mainly the surrounding countries due to the short trade routes such as Northwest America, Russia, Malaysia, Indonesia and Vietnam. Similarly, Japan imports 76 Mtoe of biomass in 2012 and expects to triple its powers from renewable resources[21]. The lignite coal used in both South Korea and Japan has similar heat content as wood pellets; this therefore facilitates the import of biomass, which is estimated to be a substaintial share in the short and long term future. China at present employs mostly domestic resources for bioenergy and biofuel production but also anticipates importing gigantic amounts of biomass to meet its renewable energy target. The analysis of the International Renewable Energy Agency shows that the country could realistically achieve scaling up modern renewables to 26%[22]. This indicates that palm pellets potentially to be exported from Indonesia may prioritise these three big markets due to short transport route and no strict sustainability requirements for solid biomass used as renewable energy carrier for heat and power, making it easier to comply with import requirements

European sustainability criteria for solid biomass

In this case study, there are three sustainability criteria applied for estimating sustainable palm pellet potentials from Indonesia. If these sustainability considerations are not implemented, the total biomass (palm pellets) potentials might be muh higher compared to the estimated results.

In the EU, Belgium already implements GHG emission criterion whilst Denmark, the Netherlands and the UK are going to implement sustainability criteria for solid biomass. These require palm pellets, as solid biomass used for bioenergy production, if imported to the EU to be legally and sustainably sourced and follow sustainability rules of the (European) importing countries. Currently in Central Kalimantan, there are only a small number of companies which are RSPO certified [18] and the cost of registration and maintenance of being sustainably certified may lead to the increase of total palm pellet price. Given this perspective altogether with competition for bioenergy resources from South Korea, Japan and China, palm pellets might not be easily imported to the European countries.

Uncertainties

In this report, EFBs, shells and fibres are taken for granted as currently they are partly used and mostly abandoned at the oil mills as wastes. The feedstock cost might be added once the pre-treatment technology will be mature and palm residues could be commercialised and used as renewable energy resources. At present, harvesting costs of trunks and fronds are applied as for FFBs (which in fact is high compared to other regions) but these harvesting costs might be considered to be zero because trunks and fronds have to be removed nevertherless in a regular management of palm plantation.

Another uncertainty is the data collection on palm plantation. Since information was mostly collected by desk study, palm plantation and yields were supposed to be equally distributed in the whole island. This might not be the case in reality, especially regarding harvesting and transport costs, therefore total costs may be changed accordingly.

Data and information regarding the percentage of collected palm residues, fertiliser quantity applied to boost higher productivity were used from sources focused on the Malaysian palm plantation

[19] http://biomassmagazine.com/articles/8837/asian-markets-for-wood-pellets
[20] http://www.asiabiomass.jp/english/topics/1211_03.html
[21] http://www.cmtevents.com/aboutevent.aspx?ev=140916
[22] http://irena.org/remap/IRENA_REmap_China_report_2014.pdf

perspective which might not be completely relevant for Central Kalimantan, in particular the soil quality in the two regions are different.

The proximity of production areas to the oil mills was roughly estimated as a matter of fact that there are no current references on transport routes available in Central Kalimantan. This may affect the total cost accordingly.

A GHG emission calculation has been applied following the EU default values which might not be accurate for Indonesian region. Costs might also be higher in case RSPO certification would be implemented. The companies and farmers however could apply for carbon trading to get benefit to compensate for the aforementioned costs in case the carbon price is high (and they may lose profit if the carbon price is (estimated) lower than 5 €/ton CO_2).

6. Conclusion & Recommendations

Indonesia is the country with the highest palm plantation area and production in the world. Currently, a large quantity of palm residues is abandoned or inefficiently used, this forms a promising potential to be used as bioenergy carrier for heat and power generation. The study has investigated the total amount of palm residues which could be mobilised for bioenergy production and indicated a high quantity of palm pellets to be potentially exported to other countries. The results however show some uncertainties mainly due to limited time and resources, therefore an in-depth investigation of local geographical conditions, domestic demand of palm residues usage is recommended for better results of palm pellet assessment.

The study also found out that processing palm residues into pellet forms for bioenergy production would help to reduce greenhouse gas (GHG) emissions through avoidance of methane production from fronds, trunks, EFB that would have otherwise, been left to decay under conditions on field or in a solid waste disposal site. Air pollution currently is a serious issue in Indonesia, therefore use of palm residues for energy could improve local environments accordingly.

Through FAOSTAT statistics, agricultural crops such as rice, cassava and maize (see appendixes 12-14) indicate high biomass potentials to be used for bioenergy production. An investigation of local use and assessment of these feedstocks is therefore also recommended.

In summary, this study advocates a sustainable vision of investigating, using and trading sustainable bioenergy resources and a development of a sustainable palm oil industry in Indonesia which should be cleanand resource efficient. A number of Malaysian oil mills have already applied and succeeded to receive financial CDM aids to implement projects of pelletised palm residues, therefore similar projects are recommended to be built up also in Indonesia, in particular Central Kalimantan where palm plantation is being expanded and exploited.

7. References

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Appendices

Appendix 1 Palm plantation and oil productivity in Kalimantan (2000 - 2012)

			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
West Kalimantan	Total Area	Ha	363,269	389,006	406,372	416,807	358,175	381,791	492,112	451,400	499,548	602,124	750,948	683,276	885,075
	Production	Ton	433,582	493,029	528,352	758,367	560,028	761,963	1,050,450	1,005,100	845,409	862,515	1,102,860	1,434,171	1,601,200
	Productivity	Kg / Ha	1,707	2,005	1,975	2,667	2,064	2,645	2,919	2,924	2,428	2,365	2,928	2,770	2,897
Central Kalimantan	Total Area	Ha	196,801	217,666	221,034	241,615	401,663	434,481	571,874	616,331	870,201	1,091,620	911,441	1,003,100	1,024,973
	Production	Ton	165,590	193,068	245,924	288,078	489,139	908,301	1,383,317	1,387,696	1,449,294	1,677,976	2,251,077	2,146,160	2,771,268
	Productivity	Kg / Ha	2,490	2,837	2,866	2,774	2,093	3,559	4,075	3,992	3,718	3,451	3,449	3,430	4,273
South Kalimantan	Total Area	Ha	120,694	129,673	138,634	141,638	172,650	134,621	243,451	257,862	290,852	312,719	353,724	420,158	423,208
	Production	Ton	90,889	115,568	176,308	193,213	242,356	125,868	307,370	337,400	386,738	424,309	698,702	1,044,492	1,164,672
	Productivity	Kg / Ha	2,884	2,934	2,895	2,904	2,124	2,025	2,126	2,158	2,330	2,442	3,069	3,459	3,768
Eats Kalimantan	Total Area	Ha	128,256	144,567	191,146	201,871	171,581	201,236	237,765	339,294	409,566	530,552	446,094	676,395	716,662
	Production	Ton	99,377	102,049	114,239	140,967	191,415	278,257	328,141	377,577	432,802	553,834	800,362	805,587	1,092,483
	Productivity	Kg / Ha	2,347	2,651	2,820	2,708	1,931	2,472	2,678	3,383	2,772	2,945	3,344	2,740	3,752

Appendix 2 Total technical potential of palm residues in 2011

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
RPR (%)			**21.07**	**4.29**	**15.42**		
Dry quantity t/ha	**10.88**	**2.48**					
Moisture content (fresh)	**0.75**	**0.706**	**0.67**	**0.12**	**0.37**		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**	**Kt**	**PJ**
Independent small holders	1,573,455	359,041	50,410	27,370	70,431	2,081	33.9
Plasma holders	2,765,648	631,083	78,744	42,754	110,018	3,628	58.9
Private estates (ordinary + RSPO)	9,489,138	2,165,291	123,070	66,821	171,948	12,016	193.9
Total Techical MT	13.83	3.16	0.25	0.14	0.35	**17.73**	**286.73**

Appendix 3 Total sustainable potential of palm residues in 2011

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
SRF	**0**	**1**	**0**	**1**	**1**		
CV (MJ/kg) dry	16	17	19	20	19	Kt	PJ
Tonnes dry matter							
Independent small holders	1,573,455	359,041	50,410	27,370	70,431	8.16	8.16
Plasma holders	2,765,648	631,083	78,744	42,754	110,018	13.98	13.98
Private estates (ordinary + RSPO)	9,489,138	2,165,291	123,070	66,821	171,948	42.45	42.45
Total Mt	0.00	3.16	0.00	0.14	0.35	**3.64**	**64.59**

Appendix 4 Total technical potential of palm residues in BAU 2020

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
RPR (%)			**21.07**	**4.29**	**15.42**		
Dry Quantity t/ha	**10.88**	**2.48**					
Moisture content (fresh)			**0.67**	**0.12**	**0.37**		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**	**Kt**	**PJ**
Tonnes dry matter							
Independent small holders	4,331,981	988,499	151,474	82,243	211,633	5,766	93.91
Plasma holders	5,198,377	1,186,198	283,948	154,170	396,721	7,219	118.46
Private estates (ordinary + RSPO)	12,129,546	2,767,796	1,035,399	562,172	1,446,619	17,942	297.44
Total Techical Mt	21.66	4.94	1.47	0.80	2.05	**30.93**	**509.82**

Appendix 5 Total sustainable potential of palm residues in BAU 2020

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
SRF	0.5	1	0.5	1	1		
CV (MJ/kg) dry	15.72	17.47	18.88	20.09	19.06	**Kt**	**PJ**
Tonnes dry matter							
Independent small holders	2,165,990	988,499	75,737	82,243	211,633	3,524.1	58.43
Plasma holders	2,599,188	1,186,198	141,974	154,170	396,721	4,478.3	74.92
Private estates (ordinary + RSPO)	6,064,773	2,767,796	517,699	562,172	1,446,619	11,359.1	192.33
Total Mt	10.83	4.94	0.74	0.80	2.05	**19.36**	**325.69**

Appendix 6 Total technical potential of palm residues in High export scenario 2020

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
RPR (%)			**21.07**	**4.29**	**15.42**		
Dry Quantity t/ha	**10.88**	**2.48**					
Moisture content (fresh)			**0.67**	**0.12**	**0.37**		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**	**Kt**	**PJ**
Tonnes dry matter							
Independent small holders	4,811,789	1,097,984	189,401	102,836	264,624	6,467	105.51
Plasma holders	5,774,147	1,317,581	352,146	191,199	492,005	8,127	133.66
Private estates (ordinary + RSPO)	13,473,009	3,074,356	1,035,399	562,172	1,446,619	19,592	323.92
Total Techical Mt	24.06	5.49	1.58	0.86	2.20	**34.19**	**563.08**

Appendix 7 Total sustainable potential of palm residues in High export scenario 2020

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
SRF	0.5	1	0.5	1	1		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**	**Kt**	**PJ**
Tonnes dry matter							
Independent small holders	2,405,894	1,097,984	94,701	102,836	264,624	3,966.0	65.90
Plasma holders	2,887,073	1,317,581	176,073	191,199	492,005	5,063.9	84.95
Private estates (ordinary + RSPO)	6,736,504	3,074,356	517,699	562,172	1,446,619	12,337.4	208.25
Total Mt	12.03	5.49	0.79	0.86	2.20	**21.37**	**359.09**

Appendix 8 Total technical potential of palm residues in BAU scenario 2030

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
RPR (%)			**21.07**	**4.29**	**15.42**		
Dry Quantity t/ha	**10.88**	**2.48**					
Moisture content (fresh)			**0.67**	**0.12**	**0.37**		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**		
Tonnes dry matter						**Kt**	**PJ**
Independent small holders	6,188,544	1,412,141	331,383	179,925	462,995	8,575	140.65
Plasma holders	7,426,253	1,694,569	617,585	335,319	862,866	10,937	181.19
Private estates (ordinary + RSPO)	17,327,923	3,953,994	2,251,854	1,222,649	3,146,203	27,903	468.52
Total Techical Mt	30.94	7.06	3.20	1.74	4.47	**47.41**	**790.35**

Appendix 9 Total sustainable potential of palm residues in BAU scenario 2030

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
SRF	0.5	1	0.5	1	1		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**	**KT**	**PJ**
Tonnes dry matter							
Independent small holders	3,094,272	1,412,141	165,692	179,925	462,995	5,315.0	88.88
Plasma holders	3,713,126	1,694,569	308,792	335,319	862,866	6,914.7	116.99
Private estates (ordinary + RSPO)	8,663,962	3,953,994	1,125,927	1,222,649	3,146,203	18,112.7	311.06
Total Mt	15.47	7.06	1.60	1.74	4.47	**30.34**	**516.93**

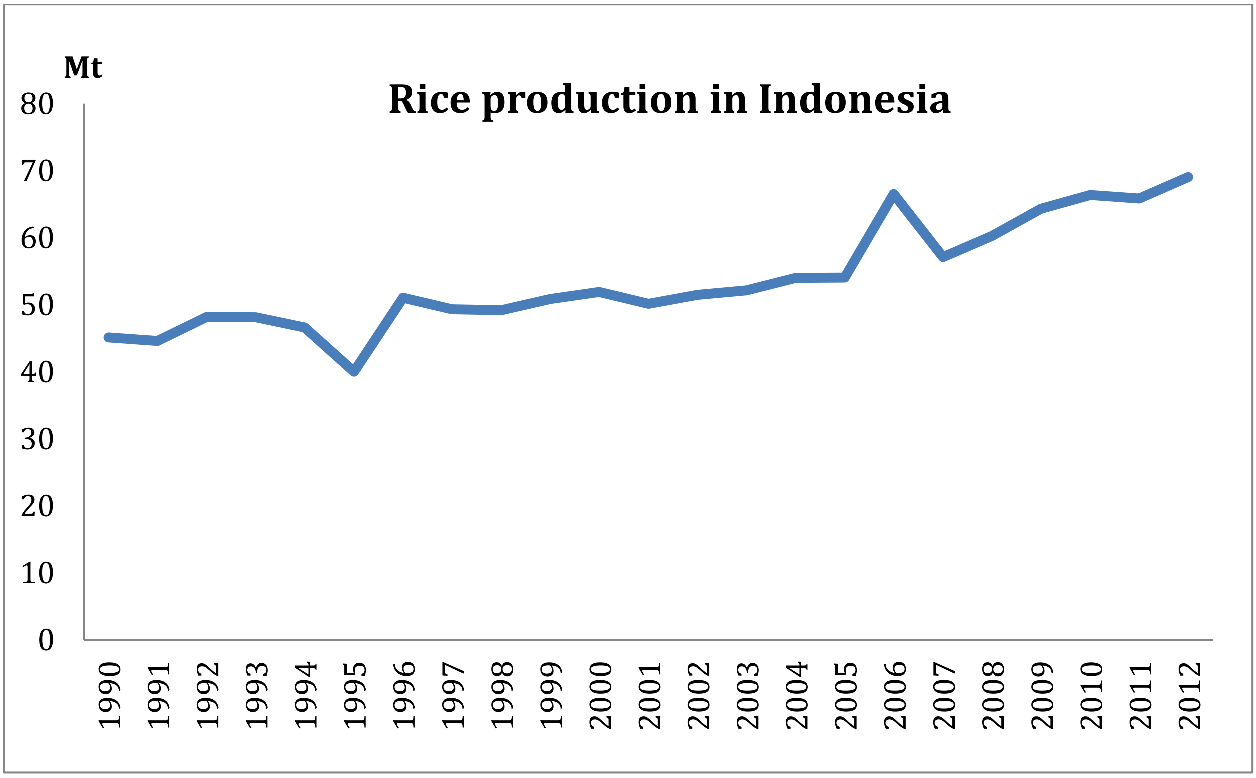
Appendix 10 Total technical potential of palm residues in High export scenario 2030

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
RPR (%)			**21.07**	**4.29**	**15.42**		
Dry Quantity t/ha	**10.88**	**2.48**					
Moisture content (fresh)			**0.67**	**0.12**	**0.37**		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**		
Tonnes dry matter						**Kt**	**PJ**
Independent small holders	6,873,984	1,568,549	457,572	248,439	639,301	9,788	161.28
Plasma holders	8,248,781	1,882,259	850,198	461,617	1,187,863	12,631	210.52
Private estates (ordinary + RSPO)	19,247,155	4,391,937	2,501,268	1,358,069	3,494,675	30,993	520.41
Total Techical Mt	34.37	7.84	3.81	2.07	5.32	**53.41**	**892.21**

Appendix 11 Total sustainable potential of palm residues in High export scenario 2030

	Frond	Trunk	Empty Fruit Bunch	Shell	Fibre		
SRF	0.5	1	0.5	1	1		
CV (MJ/kg) dry	**15.72**	**17.47**	**18.88**	**20.09**	**19.06**	**KT**	**PJ**
Tonnes dry matter							
Independent small holders	3,436,992	1,568,549	228,786	248,439	639,301	6,122.1	102.93
Plasma holders	4,124,390	1,882,259	425,099	461,617	1,187,863	8,081.2	137.66
Private estates (ordinary + RSPO)	9,623,578	4,391,937	1,250,634	1,358,069	3,494,675	20,118.9	345.51
Total Mt	17.18	7.84	1.90	2.07	5.32	**34.32**	**586.10**

Appendix 12 Rice production in Indonesia



Appendix 13 Cassava production in Indonesia

Appendix 14 Maize production in Indonesia