Contextualization of Palm Kernel Shells as a Sustainable Biofuel

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Abstract

This document provides an overview of the context of Palm Kernel Shells (PKS), its value as a Biofuel and a discussion of the sustainability dimensions of its production and utilization. The aim is to provide a clear perspective of its background, properties and limitations and allow for a discussion on the basis of a common basic understanding.

Background

Over the past 10 to 20 years the trade in palm kernel shells or PKS has grown significantly in particular in the South East Asian region with Malaysia and Indonesia as two of the main producers of palm products. Palm kernel shells from South East Asia have become one of the main bioenergy inputs in several Asian countries, most notably Japan and South Korea, as biomass has become a reliable source of baseload capacity and an alternative to fossil fuels. The shells are easy to handle, do not require any advanced processing and are relatively cheap to procure.

However, the palm industry is often heavily criticized for being one of the main drivers of illegal deforestation and a threat to biodiversity, especially in South East Asia. Consequentially, the use of palm kernel shells as a biofuel is also under scrutiny. It is important to acknowledge the dangers of uncontrolled agriculture at an industrial scale and the importance of taking advantage of the properties of the palm fruit, such as its very high yield, without causing significant external costs. At the same time a discussion on palm kernel shells should be led under clear recognition of its implications for the growth of the overall palm industry and the potentials it offers as an energy source to quickly reduce dependence on fossil fuels, such as coal.

Figure 1: Palm Kernel Shells

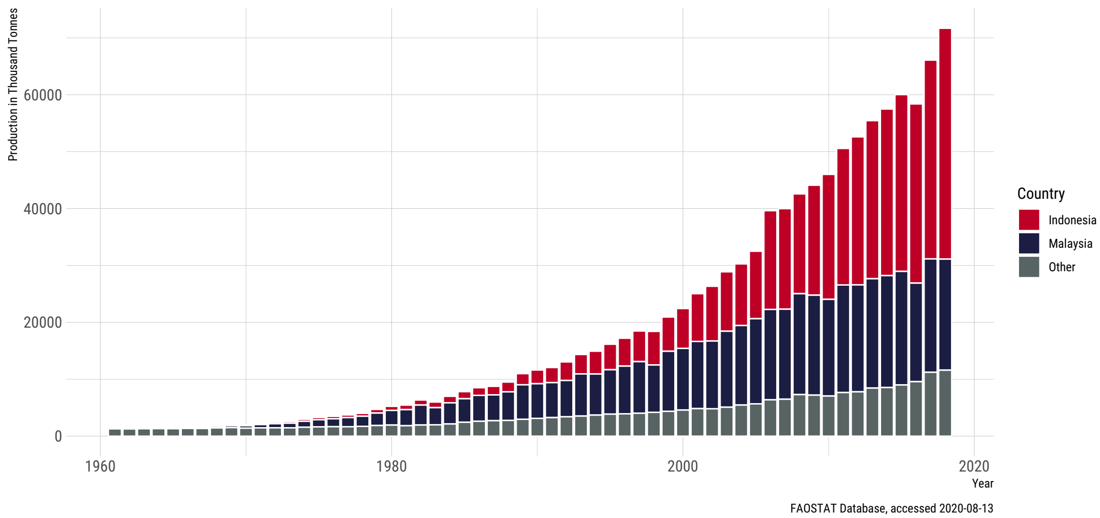

Figure 2: Global Yearly Palm Oil Production

Figure 2 shows the growth of the global palm oil production from 1960 to today and the major share of the output that comes from Indonesia and Malaysia. It is important to be aware that the output of palm kernel shells is bound to the production of palm oil and must thus have grown proportionally, not accounting for developments in choice and breeding of (hybrid) palm species, with different shell thicknesses. With an abundance of biomaterial from palm cultivation available, it is thus important to find suitable applications for all processing outputs, including palm kernel shells.

Palm Kernel Shells

Palm oil and palm kernel oil are commonly produced from three main species, Dura, Pisifera and Tenera. Tenera is a hybrid of Dura and Pisifera with the largest yield of palm oil and palm kernel oil and a thin kernel shell, making it the preferred species for new plantations, replacing Dura with its thicker shell as the main type. The following sections will give a brief overview of the “production” of palm kernel shells, its use cases and properties as a fuel and recent developments of demand in East Asia as the main markets.

Production

Starting with the harvest of fresh fruit bunches in a plantation, Figure 3 gives a simplified overview of the processing steps and some of the main and residual outputs in the palm (kernel) oil production. There are additional outputs, such as palm oil mill effluent (POME) or by-products from downstream processing, which are omitted here as the focus is on PKS, which is separated from the kernel after the nut cracking. The two main products are palm oil from the pulp of the fruit and palm kernel oil from the kernel. Assuming an ideal situation a fresh fruit bunch with a weight of around 25 kg would consist of around 60% fruits of which around 10% can be expected to be palm kernel shells.[1] This would yield around 1.6kg of PKS per fresh fruit bunch.

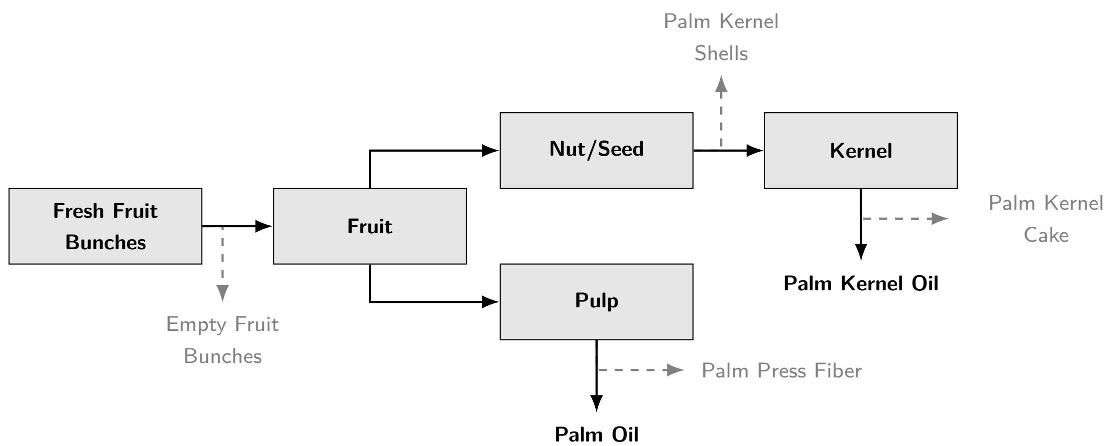

Figure 3: Palm Process and Residues

Use of Residues

Of the various by-products and residuals of the palm (kernel) oil production process, some have established beneficial use cases. For example, palm kernel meal is used as a high protein additive for animal feed and empty fruit bunches and other biomass as field covering. In their investigation into extending the palm oil value chain by introducing palm processing residues as raw materials for other products, the Malaysian Palm Oil Board lists a range of uses for various outputs.[2] For the shells however, they only list its processing into charcoal.

Besides this there are some investigations into using palm kernel shells as a coarse aggregate in concrete preparation. However, traditionally the shells have mainly been used as an on-site energy source for the mills and as filling material for building projects or streets. Theoretically they can be used as a fertilizer after decomposing underground for several months. However, due to the composition of the shells this is not only time consuming but also leads to emissions of methane. All material that could not be used for on-site energy production or for building projects, was and is frequently discarded and dumped illegally.

Palm Kernel Shells as a Biofuel

Besides some remaining palm oil, the shells mainly consist of lignin, cellulose, hemicelluloses and other carbonaceous material. It does not easily rot, is easy to handle without need for processing and has a relatively high energy and low sulphur content. Table 1 provides a comparison of some of the main properties of alternative fuels.[3] While many new power plants are designed to run fully on biomass, palm kernel shells can also be used for co-firing without requiring significant changes to the boiler. Furthermore, there is no species variation and shells are available year-round, adding further to their ease of handling and supply.

[1] FAO: Small-Scale Palm Oil Processing in Africa (2002)
[2] Malaysian Palm Oil Board: By-products of palm oil extraction and refining (2006)
[3] Sources: JRC, 2017 and BioGrace-II GHG calculation Tool - Version 3

Table 1: Relevant Data on Palm Kernel Shells

Fuel	LHV, Dry (MJ/kg)	Moisture (%)	Bulk Density, Dry (kg/m3)	Ash (%)
PKS	17.3	10	467	03 - 06
Wood Pellets	19.0	10	650	NA
Wood Chips	19.0	30	155	NA
Coal	26.5	NA	NA	NA
Natural Gas	49.2	NA	NA	NA

Note:

Values from JRC, 2017 and BioGrace-II

Development of Demand

Palm kernel shells from South East Asia have become one of the main bioenergy inputs in Japan and South Korea over the past years as biomass has become a reliable source of baseload capacity. Figures 4 and 5 highlight the growth by showing the monthly amounts imported into Japan and South Korea over the past twenty years, as well as the rolling averages over three months and two years. Figures 6 and 7 in turn depict the development of the price per ton as recorded by the respective authorities. In both countries the imported amounts have grown significantly. While the growth in South Korea was relatively stable, Japan has seen a steep increase, in particular from July 2012, when the national Feed-In-Tariff scheme was introduced. The two countries are currently the main markets for palm kernel shells and show the level of acceptance and potential of biomass in general and palm kernel shells in particular in Asia.

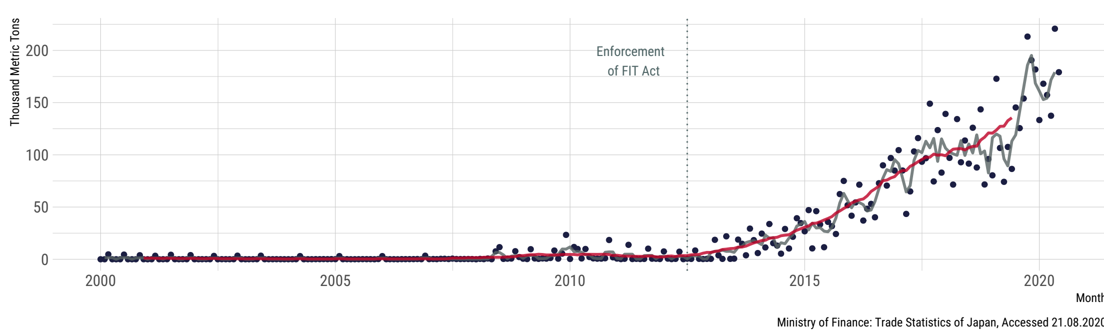

Figure 4: Monthly Import of PKS into Japan (Data from 2000 to 2019, including 3-month and 2-year rolling averages)

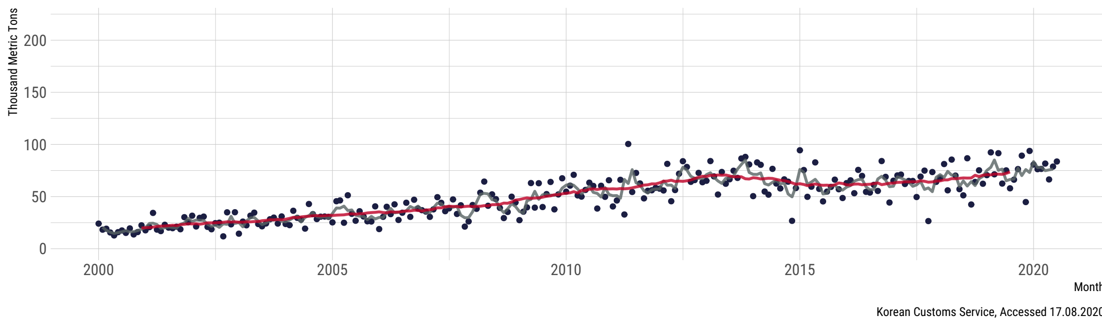

Figure 5: Monthly Import of PKS into South Korea (Data from 2000 to 2020, including 3-month and 2-year rolling averages)

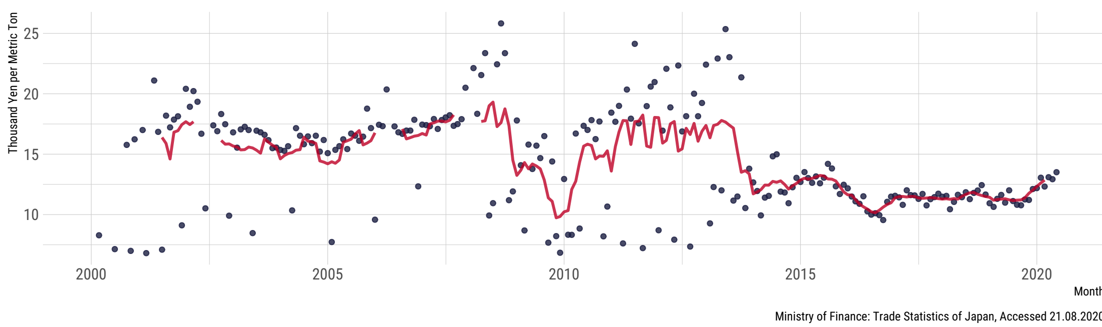

Figure 6: Value per Ton of PKS Imported into Japan (Data from 2000 to 2019)

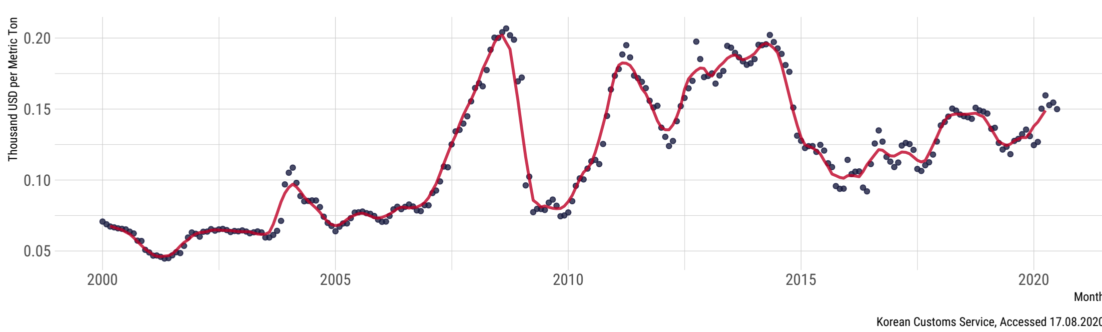

Figure 7: Value per Ton of PKS Imported into South Korea (Data from 2000 to 2019)

Sustainability

The level of acceptance of biomass and palm kernel shells depends largely on its role as a sustainable alternative to fossil fuels, especially coal. While most renewable energy sources cannot provide a baseload for an energy system, biomass, as well as hydropower, can ensure ongoing supply of electricity without dependence on wind or the sun. While solutions to overcome this challenge for PV and wind through storage solutions or decentralized and more integrated energy systems are being developed, palm kernel shells thus offer one alternative to traditional fossil fuels that is readily available. As processing residues, or waste, that do not have other relevant use cases, they can be seen as a perfect biobased input for energy generation.

Displacement

Displacement describes negative local effects of the demand for palm kernel shells as an energy input. Primarily it concerns the need for alternative materials in applications, for which palm kernel shells have traditionally been used. As described above shells are usually disposed of, legally, for example in road paving or through illegal dumping, in order to prevent self-combustion and breeding of insects, which could be harmful to nearby plantations. As was further introduced above, press fiber and kernel shells are commonly used to fire steam boilers and cover the energy needs of palm oil mills. Currently the value of palm kernel shells as a commodity does not seem to influence this use too much, as the cost of acquiring alternative fuels is higher than the revenue from sales. In case the value of shells rises significantly, this could change and might be a cause of concern. However, one could also argue that it would open mills up to using other renewable sources, such as solar panels, rather than looking for alternative inputs for their boilers and thus reduce their environmental impact. Lastly, the use of palm kernel shells as fertilizer is fairly uncommon. As the preparatory process comes with emissions of methane, a very potent greenhouse gas, its displacement could also be a positive development. A final assessment of the impact would need to be done on a case by case basis or a large sample. However, as the amount of shells available is very large, there seems to be no risk to the classification as a waste at this end.

Deforestation and Bio-Diversity

The implications of the growing demand for palm kernel shells on deforestation is very difficult to evaluate conclusively. It is not clear to what extend a low increase in total revenue for the mills will lead to new or expanded plantations and it is extremely difficult to generalize any findings. However, as this is an issue for almost all biofuels, there are certification schemes in place that can provide assurances that material is sourced from a responsibly managed plantation or mill. While the schemes generally follow national classifications, some also include metrics to calculate the economic relevance of a residue compared to all other outputs of a process. Using such metrics allows for a better understanding of a possible effect of increased demand for palm kernel shells on the overall production of fresh fruit bunches.

Certification

Certification schemes covering both, sourcing and emission reporting, have already been developed and established in Europe, especially after the introduction of the first Renewable Energy Directive[4] in 2009. While

[4] Directive 2009/28/EC

there are several different schemes, they all build on a so-called Chain-of-Custody system, which allows regulators and end-users to trace their supplies back to their source.[5] All entities in the supply chain need to have established the same classification criteria and a system for tracing incoming and outgoing shipments in order to not break the flow of information. They are further required to collect information on all relevant emissions incurred in the plantation, processing or transportation of the material, while it was in their ownership.

The general approach is applicable to any certified material but depending on its classification, the requirements can differ slightly. Classifications are usually done based on the background of a material. Waste inputs should for example be treated differently than woody or agricultural biomass, which was produced/grown with the aim of supplying an energy input. There are two essential differences in the approach to certifying and tracing waste/residue streams compared to "traditional" biomass:

1. The risk to compliance at the material source is not unsustainable practices but false declaration of the material as an end-of-life product, i.e. a waste; and
2. The material is traced back to its source or point of origin, i.e. wherever it has been generated, but certification and the documentation of material related emissions are only required from the collector onward. Based on a risk assessments a sample of points of origins might be audited as part of the collector's certification.

While national regulation can lead to an extension of the requirements, the first step for certifying palm kernel shells is hence to verify whether it is indeed a residue or waste.

Classification as a Residue

Residues are materials that a production process does not directly aim to produce. Those can be agricultural or forestry residues, which are collected directly from a field or forest, and processing residues from industrial processes. The European Commission as well as the Joint Research Centre (JRC) have classified palm kernel shells as a residue, most notably in the Renewable Energy Directive II.

As the initial aim of most biomass certification schemes is to allow companies to prove compliance to the directives, its classification is theoretically already sufficient. However, Asian countries, as the main target markets for palm kernel shells, are not part of the EU and it is worthwhile to look at additional criteria, as used by certification schemes. In general, there are two main criteria that need to be fulfilled when evaluating the use of residues as a biofuel:

- **No Competition of Use** If there is no alternative use case for the material than its use for energy generation, its use does not lead to shortages in any other fields of application, which would need to be compensated through alternative materials with environmental and economic implications.
- **No Effect on Production of Main Output** If the material has a very low (relative) economic value, its sale will not lead to increased production of the main product and therefore, in the case of palm, not be a driver of deforestation, land-use change and habitat loss.

The first point has been addressed sufficiently in the Displacement section, showing that there is indeed no relevant competition of use and thus no displacement effect. The effect of additional sales of palm kernel

[5] There are different systems but all ensure that not more certified material is sold and used than is produced.

shells on the level of production of fresh fruit bunches in turn is relatively difficult to asses, as was indicated in the Deforestation section. The mills are able to generate additional revenue per unit of input. However, the question is whether this increase is large enough to lead mills to procure more fresh fruit bunches and produce more of the main products, palm oil and palm kernel oil.

One approach to the topic is the evaluation of palm kernel shells' relative economic value compared to all other outputs of the production process it stems from. The second method is to calculate the elasticity of supply, which aims to provide insights on the effect of price changes on the production output. If both values are high, it would be an indication that there could a positive effect of an increase in the shell price on the overall production of palm oil and consequentially on overall palm plantations and deforestation. As we do not have reliable data to assess the supply side and model the impact of shell price changes on output all else being equal, we will use the import values of palm products into Japan to calculate the relative economic value.

As could be seen in Figure 4, the amount of imported material increased significantly from 2012. At this time the value of imports reported to the Japanese customs was still fluctuating quite strongly between 15,000 and 20,000 Japanese Yen per metric ton (Figure 6). The following drop in average value and reduced amplitude, to around 12,000 JPY per metric ton, is most likely due to the scale up, reduced spot market activity and long-term contracts entering into force. Albeit spot market prices have been rising over 2019, there have been various effects and the overall stable value of imports with increased demand should be another indication that until now there is no significant shortage in supplies.

In order to assess the relative economic value, of palm kernel shells, we use the approach of the Roundtable on Sustainable Biomaterials (RSB).[6] RSB requires residues to have inelastic supply and a relative economic value (or Economic Value Ratio) below 5%. They define the Economic Value Ratio as follows:[7]

$$economic\ value\ ratio = \left(\frac{M_1 - C_1}{M_1 + M_2 + M_3 + ... + M_n}\right) \times F_1 \times U_1 \qquad (1)$$

Where M_1 is the market value per ton of the evaluated material. M_2 to M_n] are the market values per ton of all other outputs of the production process. C_1 are additional processing costs at the point of origin. F_1 is the mass of the residue's output relative to the total mass of all outputs per unit of input. U_1 is the share of the material that is sold as a biofuel.

Table 2 shows the customs codes and descriptions by the Japanese Ministry of Finance, which have been used as references to obtain import data related to palm oil production outputs. Figure 8 shows the imported amounts under the different customs codes as well as the value per ton per year.[8] It clearly shows the increase in PKS imports, also in relation to all other palm outputs and its comparatively low value per ton. Further it becomes clear that "Crude Palm Oil" is rarely used for imports and has a similar market value as "Palm Oil", which is one of its subcategories.

[6] RSB, ISCC and GGL are the three most relevant certification schemes for palm kernel shells at this moment.
[7] See RSB Standard for Advanced Fuels (Waste and Residues)
[8] As the year is not completed at the time of writing, the values for 2020 are incomplete.

Table 2: Relevant Customs Codes for Palm Products in Japan

Customs Code	Customs Description	Name in Figure 7
120710000	Other oil seeds and oleaginous fruits, whether or not broken > Palm nuts and kernels	-
151110000	Palm oil and its fractions, whether or not refined, but not chemically modified > Crude Oil	Crude Palm Oil
151190010	Palm oil and its fractions, whether or not refined, but not chemically modified > Palm stearin	Palm Stearin
151190090	Palm oil and its fractions, whether or not refined, but not chemically modified > Other	Palm Oil
151321100	Coconut (copra), palm kernel or babassu oil and fractions thereof, whether or not refined, but not chemically modified > Palm kernel or babassu oil and fractions thereof > Crude oil > Palm kernel oil	-
151329100	Coconut (copra), palm kernel or babassu oil and fractions thereof, whether or not refined, but not chemically modified > Other > Palm kernel oil and its fractions	Palm Kernel Oil
230660000	Oil-cake and other solid residues, whether or not ground or in the form of pellets, resulting from the extraction of vegetable fats or oils, other than those of heading 23.04 (soyabean) or 23.05 (ground-nut) > Of palm nuts or kernels	Palm Kernel Shells

Note:
Values as of 21.08.2020.

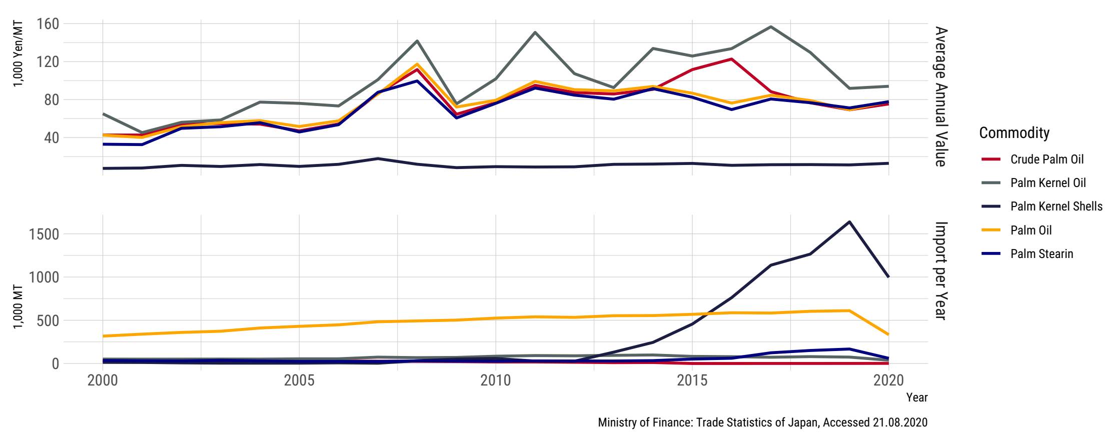

Figure 8: Annual Import Amounts and Average Values per Ton (Data from 2000 to 2020 for Palm Products)

Palm stearin does not stem from the exact same process, while whole palm kernels are excluded as they are not an output of the process. Palm kernel meal and empty fruit bunches, two other outputs that could be considered at this point, do not have a dedicated customs code or not imported to Japan. Excluding these outputs will increase the relative value of palm kernel shells and make the calculation more conservative. For the same purpose the value of U_1 is set to 1. Using the aggregated customs data for palm kernel shells, palm kernel oil and palm oil from 2019 and the weight fractions of fresh fruit bunches from the JRC (7.4%, 2.4% and 20%, JRC, 2017), the economic value ratio is calculated as follows:

$$EVR_{PKS} = \frac{11.22 - 0}{11.22 + 91.78 + 69.29} \times \frac{0.074}{0.074 + 0.024 + 0.2} \times 1 = 0.01617 \tag{2}$$

The value of 1.62% is well below the 5% required by RSB, even without all outputs considered. Palm kernel shells thus fulfill the most strict economic condition for classification as a waste. While the formula is generally used as described above, we briefly want to extend it by weighing all market values according to their mass share per input unit.

$$weighted\ economic\ value = \frac{11.22 \times 0.074}{11.22 \times 0.074 + 91.78 \times 0.024 + 69.29 \times 0.2} \times 1 = 0.04914 \tag{3}$$

This value describes the share of economic value generated per unit of input more appropriately and with 4.91% this value remains quite low. Again it should be considered that not all outputs are included in the calculations and the relative value of the shells is thus inflated. With such a low additional revenue for mills, it should be safe to assume that the sale of palm kernel shells does not lead to additional production of palm oil and increased plantation. Lastly, Figure 9 provides an overview of the development of the weighted relative economic value (not the RSB criteria) over the past twenty years. It can clearly be seen that even with the development of the palm kernel shell business, there has been no significant change of the weighted economic value of palm kernel shells. If all other (residual) outputs were included, the share of palm kernel shells would be well below 5%.

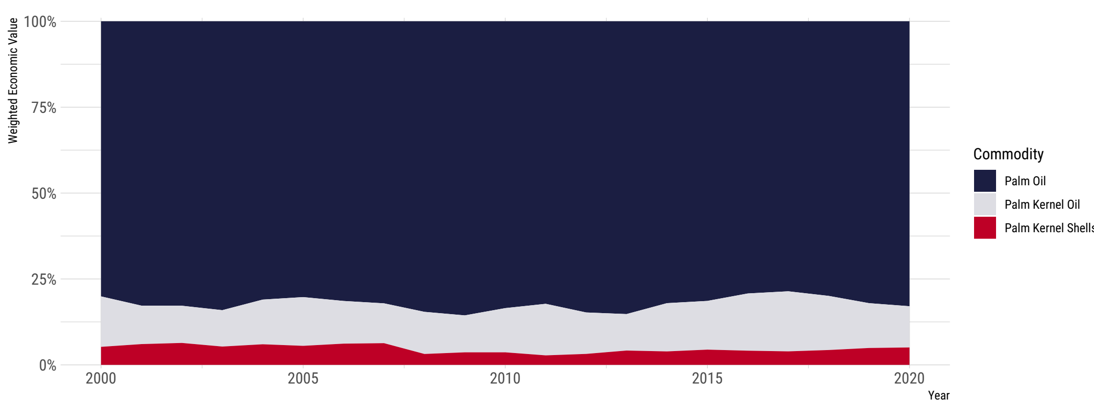

Figure 9: Development of Relative Values over Time (Data from 2000 to 2020 for Palm Outputs)

Emissions

When biomaterials do not have alternative uses and its sale as a fuel has no impact on the production of main products, their use as such does not lead to additional negative effects on the environment. All challenges and risks related to upstream processes would most likely occur whether the material is sold or not. In the case of palm kernel shells, the palm plantations would be operated in the same way to provide fresh fruit bunches for palm oil and palm kernel oil raw materials. Recognizing this, most biomass certification schemes, following the guidance of the Renewable Energy Directive, only require certification from the first collector and emission calculations from the point of origin.

> ”Wastes and residues, including tree tops and branches, straw, husks, cobs and nut shells, and residues from processing, including crude glycerine (glycerine that is not refined) and bagasse, shall be considered to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials irrespectively of whether they are processed to interim products before being transformed into the final product.” **Directive (EU) 2018/2001, Annex V, Part C, Paragraph 18**

In the case of palm kernel shells the point of origin is the palm mill, where the kernels are crushed, and the collector is the company picking up materials from those mills. The transport from the mill to the stockyard is the first transportation step for which emissions are to be calculated and attributed to the fuel. According to the RED and its recast, emissions for biomass are traditionally calculated along the supply chain according to different categories of emissions, as depicted in Equation 4.

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} \quad (4)$$

The total emissions from the use of the fuel E is disaggregated into emissions for extraction and cultivation (e_{ec}), annualized emissions accountable to land-use change (e_l), processing emissions (e_p), transport and distribution emissions (e_{td}) and emissions from the fuel in use (e_u). At the same time savings through soil carbon accumulation (e_{sca}), carbon capture and storage (e_{ccs}) and carbon capture and replacement (e_{ccr}) can be deducted.

As was explained above, palm kernel shells do not carry any emissions from upstream processes. With regard to Equation 4 land use change, cultivation and extraction and transportation to the point of origin are considered to be nil. While the directive only aims at biofuels that are imported into the European Union and individual nations can treat the matter differently, the overall approach to account all emissions to the main product and avoid double counting of upstream emissions, appears reasonable.

For palm kernel shells, which do not require significant processing, the majority of emissions then stems from land and sea transportation. Emissions from the fuel in use only concerns emissions of N_2O and CH_4 during combustion, as their global warming potential is significantly larger than that of CO_2. Emissions of the later are not counted for biomass, as they have only been sequestered recently and the plants they stem from are expected to regrow quickly. Using values of the JRC (2017), the emission values for the fuel in use are 0.003 g CH_4/MJ and 0.004 g N_2O/MJ. Including a 20% buffer, this equals 1.52 g $CO_{2\ eq}$/MJ.

Assuming 150 km land transportation on a 20 ton truck and 5,000 km sea transport by handysize bulk carrier, transport emissions would total 7.22 g $CO_{2\ eq}$/MJ.[9] The total emissions with no processing and actual values for transportation would thus be 8.72 g $CO_{2\ eq}$ per MJ of solid biofuel. This value is in line with the default value of the RED II for agricultural residues with a density larger than 200 kg/m^3 and a distance traveled between 2,500 and 10,000 km of 9.9 g $CO_{2\ eq}$/MJ.

At 30% boiler conversion efficiency, the 8.72 g $CO_{2\ eq}$/MJ would provide electricity with 29.07 g $CO_{2\ eq}$/MJ$_{electricity}$,

[9] Calculated with the BioGrace-II tool.

an emission reduction of 84% compared to the fossil fuel comparator in the European Union.[10] The reduction potential varies by country depending on the availability of local resources and the energy mix but especially compared to coal, biomass in general and palm kernel shells in particular offer great opportunities for reduced emissions.

Conclusion

Due to the ongoing growth of demand for palm oil and palm kernel oil, there is an abundance of palm kernel shells available, for which there is no use or application of relevant scale or value, except its use as a biofuel, where it offers immense emission reduction potentials, especially in economies, which still rely heavily on fossil fuels, in particular coal. As was shown, the relative value of palm kernel shells compared to the other process outputs has remained constant over the past twenty years and it seems unlikely that mills focus a lot on the palm kernel shell value in their production planning. The risk of palm kernel shell procurement leading to additional deforestation can be minimized through a sustainable sourcing strategy, engaging in supplier screening and considering suppliers' certificates.

Nevertheless, this document only presents an assessment of the current state, and it is important to continue assessing the developments in the palm industry and the possible implications of palm kernel shells based on its economic value and possible technical advances allowing for alternative uses. Unless either criteria changes, palm kernel shells should be seen as a viable input for bioenergy generation, which can significantly reduce the demand for traditional inputs for thermal power plants and provide important baseload power.

[10] The comparator is 183 g $CO_{2\,eq}/MJ_{electricity}$, based on the typical emissions and the respective share of conventional hard coal (260.8 g $CO_{2\,eq}/MJ_{electricity}$), Heavy Fuel Oil (212.2 g $CO_{2\,eq}/MJ_{electricity}$) and Natural Gas (114.7 g $CO_{2\,eq}/MJ_{electricity}$. See JRC, 2017b) in the fossil fuel part of the planned EU electricity mix in 2030.