



Rainforest Foundation
Norway



PFAD and biofuels



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PFAD AND BIOFUELS

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Executive Summary

Palm fatty acid distillate (PFAD) is a fraction of palm oil that is produced due to the formation of free fatty acids as oil palm fresh fruit bunches are harvested and brought to palm oil mills. Free fatty acids are considered undesirable in food and cosmetics applications for palm oil and are therefore separated out into a distinct PFAD product stream. The properties of PFAD are in many respects similar to those of palm oil, and PFAD can be used as feedstock for a range of applications. These include soap manufacture and other oleochemical applications, livestock feed as 'rumen protected fats' fed mostly to dairy cattle, and as a biofuel feedstock. PFAD can be used for conventional biodiesel production, but its properties are better suited for the production of 'hydrotreated vegetable oil' renewable diesel and renewable jet. It is unknown how many renewable diesel/jet producers use PFAD as a feedstock, but the Finnish company Neste, one of the world's largest producers of these fuels, has identified PFAD as one of its feedstocks.

PFAD is less valuable than palm oil because it is not used for human consumption, but still has significant value. Per tonne, the price of PFAD is normally about 80% of that of palm oil, meaning that per unit mass, PFAD is a more valuable commodity than soybeans, wheat, sugar, or crude oil. If PFAD is displaced out of its existing markets for use in biofuel feedstock, it will lead to increased demand for potential substitute materials. In many applications, the lowest cost potential substitute material for PFAD will be palm oil, and therefore, diverting PFAD into

biofuel use will predictably cause increased palm oil demand.

On average, PFAD production by the oil palm industry is equal to about 4% of crude palm oil production. Indonesia and Malaysia are by far the world's largest producers of palm oil, and are, therefore also the world's largest producers of PFAD. It can be estimated on this basis that Indonesia produces about 1,800 thousand tonnes of PFAD annually, and Malaysia produces about 700. Trade statistics suggest that the majority of PFAD from Indonesia and Malaysia is exported and that the most important destination for these exports is the EU and UK, followed by China and India. It is unclear what fraction of this exported PFAD is currently used in each application, but the main destination countries in the EU are believed to be the Netherlands, Italy, and Spain, all of which are home to renewable diesel/jet plants.

Diverting PFAD to biofuel feedstock use is a concern because it will lead to increased palm oil demand, and palm oil expansion is linked with extensive tropical deforestation and peat loss. The link between palm oil and deforestation has been recognised in Europe's Renewable Energy Directive by classifying palm oil as a 'high indirect land use change risk' feedstock. This classification means that EU Member States must phase out, by 2030 at the latest, any government support provided to encourage the supply of palm oil-based biofuels. Both palm oil and palm oil derivatives are excluded from support under the newly introduced 'REFuelEU' policy, a mandate for the use of biofuels and e-fuels in European aviation.

The status of PFAD in the Renewable Energy Directive is less clear, though, and its eligibility to receive support now varies between Member States. In particular, it is important whether PFAD is treated as a co-product of palm oil production or as a residue of palm oil production. The argument for treating it as a co-product is that it has a substantial value and a well-defined market. The argument for treating it as a residue is that it is not something that is purposefully produced, its production being an incidental result of damage to palm fresh fruit bunches during handling.


Some Member States have already chosen to exclude PFAD-based fuels from support in their national implementation of the Renewable Energy Directive alongside palm-oil-based fuels, or else have clarified that it must be treated as a co-product rather than as a residue and is therefore not eligible for favourable treatment offered to encourage the use of waste and residues for fuel production. PFAD-based fuels may also be eligible to receive support under the new FuelEU Maritime Regulation to reduce the greenhouse gas intensity of shipping. Food-and-feed-based fuels are not permitted to be counted towards these maritime targets, but if PFAD is treated as a residue, then PFAD-based fuels could potentially be used.

Like consuming palm oil itself, consuming PFAD for biofuel feedstock drives overall palm oil demand and therefore, creates pressure for deforestation. Driving tropical deforestation is counter-productive to European commitments on



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climate change under the Paris Agreement, on biodiversity under the Kunming-Montreal Framework, and on forest conservation under the Glasgow Declaration. Driving deforestation is also an obviously undesirable outcome of a renewable energy policy that is explicitly intended to contribute to climate objectives. If the production and indirect land use change emissions from replacing PFAD in existing applications are taken into account, analysis suggests that PFAD-based fuels are worse for the climate than fossil diesel or jet fuel.

Countries in both Europe and the rest of the world can avoid these perverse outcomes by excluding PFAD-based biofuels from policy support, as many of them have already done for palm oil-based fuels. 

RECOMMENDATIONS

- Palm oil, soy oil and PFAD are unsuitable as biofuel feedstocks due to their link to deforestation and biodiversity loss. Consumption should be phased out as soon as possible.
- EU Member States to further reduce deforestation pressure by excluding PFAD-based fuels from policy support in their national implementation of the Renewable Energy Directive, as many of them have already done for palm-oil-based fuels
- EU Member States to classify PFAD as a co-product rather than a residue, so that it does not receive the more favourable regulatory treatment given to biofuels from waste and residues
- Similarly, other jurisdictions that limit the use of palm oil biofuels in their own biofuel policies, such as the United States and Canada, could clarify that PFAD is to be treated as a co-product of palm oil
- Biofuel producers should phase out PFAD as a feedstock (e.g. for HVO) as PFAD consumption by the biofuel industry indirectly drives increased palm oil production due to the need for substitution in other applications which are dependent on PFAD

Introduction

The oil palm is a tree species that originates in West Africa but was spread to Southeast Asia as a plantation crop in the mid-nineteenth century and has since been adopted in parts of South America. The oil palm produces bunches of bright red fruits that are very rich in oil ('fresh fruit bunches'), as well as containing a kernel which itself has a high oil content (Figure 1). It has the highest yield of vegetable oil per unit area of any major oil crop and has become the most produced vegetable oil in the world.

Oil palm's affinity for tropical warmth and rain makes oil palms an ideal crop to grow in locations where the natural vegetation is rainforest. This has created a competition between oil palm cultivation on the one hand and natural rainforest ecosystems on the other.

FIGURE 1 OIL PALM FRUIT

Illustration from FAO (1990)

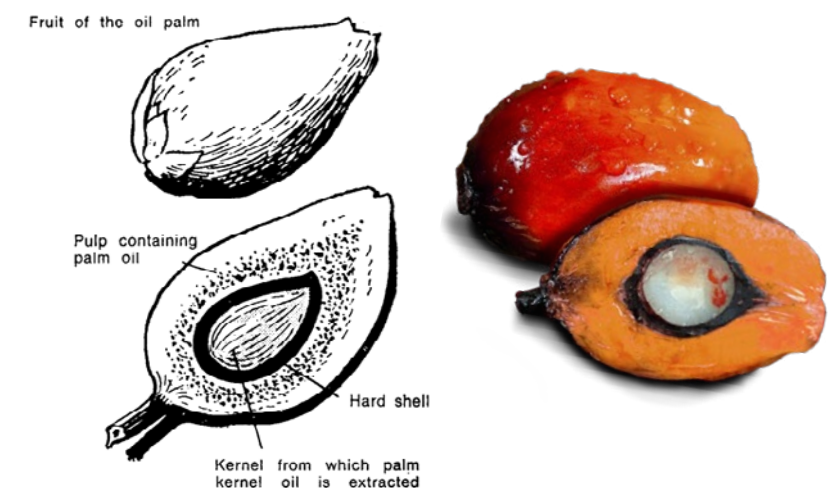
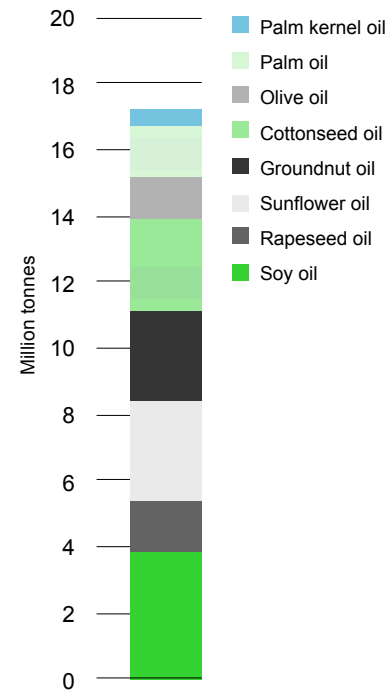


Photo: Shutterstock

FIGURE 2
WORLD VEGETABLE OIL
PRODUCTION, 1965

Source: FAOstat



Sixty years ago, palm oil was just one vegetable oil competing for space in a diverse world market. In 1965, less oil was produced from oil palms than from soybeans, sunflower seeds, groundnuts, or cottonseed (Figure 2). In the intervening period, this picture has changed dramatically, and now, more vegetable oil is produced from

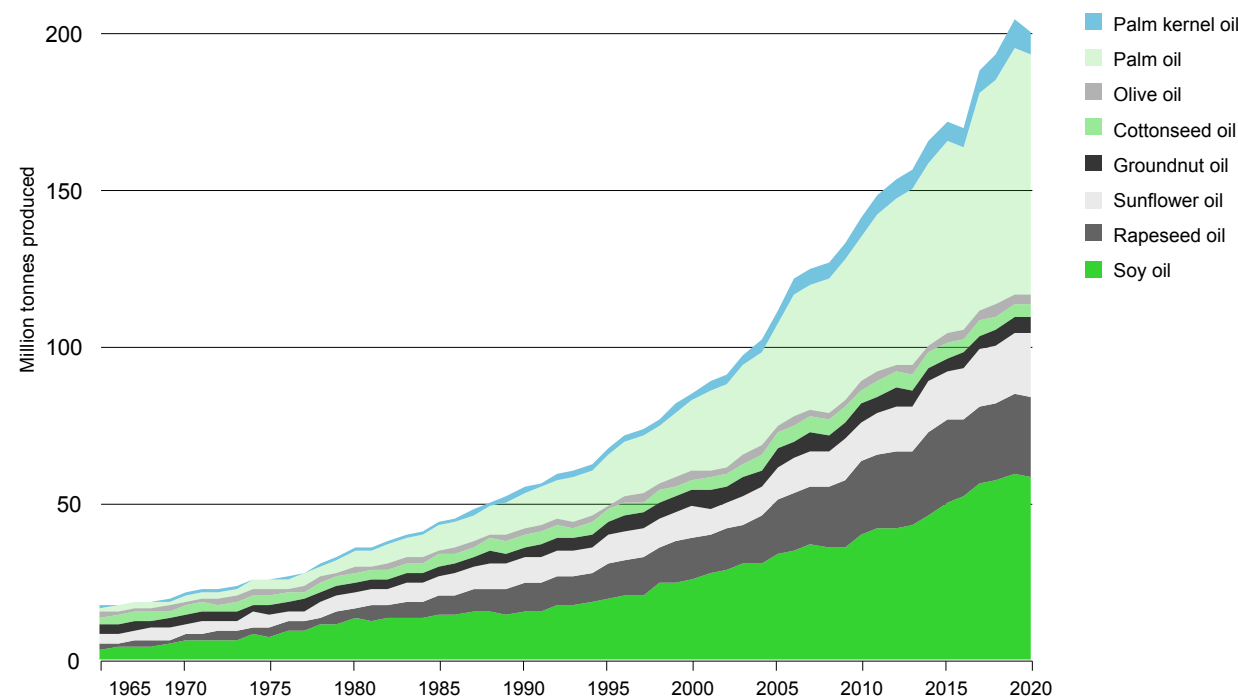
the oil palm than from any other crop in the world (Figure 3). In 2020, palm oil and palm kernel oil together constituted 40% of the total global vegetable oil production reported by FAOstat, with Indonesia and Malaysia being by far the world's largest producers.



Photo: Adobe Stock

FIGURE 3 PRODUCTION OF MAJOR VEGETABLE OILS, 1965 TO 2020

Source: FAOstat



PFAD

Palm oil is usually mechanically extracted by pressing the palm fruit, and palm kernel oil by separating and pressing the palm kernels. This differs from the typical commercial extraction process for soybean or rapeseed, which uses a hexane solvent to separate the oil from the associated meals. Palm fatty acid distillate (PFAD) is an output stream from palm oil refining that concentrates the free fatty acids present in the crude palm oil produced at the palm oil mill.

When palm oil is produced by fresh fruit bunches growing on oil palm trees, it is primarily in the chemical form of 'triglycerides'. Triglycerides are vegetable oil molecules, sometimes referred to as 'esters', in which three fatty acid chains are bound together by attachment to a glycerol backbone. The free fatty acid (FFA) content in the oil in fresh fruit bunches is low while they are growing on the tree, but FFAs start to form following fruit harvest as the fatty acid chains 'break loose' from the glycerol molecules, a process that is greatly accelerated by any rough handling of the fruit bunches between the plantation and the mill (see box).

FFAs in palm oil are undesirable because they reduce the oxidative stability, bleachability¹, and nutritional value of the product (Nor Shafizah et al., 2022). There is, therefore, an industry-standard limit of 5% set on the permissible FFA content in crude palm oil, and lower limits on refined palm oil products². In order to meet the FFA specifications on refined products, FFAs must be removed at the palm oil refinery – this is done as part of the deodorisation process by distilling the FFAs into a fraction referred to as palm fatty acid distillate, PFAD. PFAD consists

primarily of palmitic and oleic fatty acids (Chang et al., 2016)³. The palm oil industry does not actively target the production of PFAD, as it has a slightly lower value than the palm oil it is separated from. It is, therefore in the interest of the palm oil industry to minimise PFAD production to the extent possible.

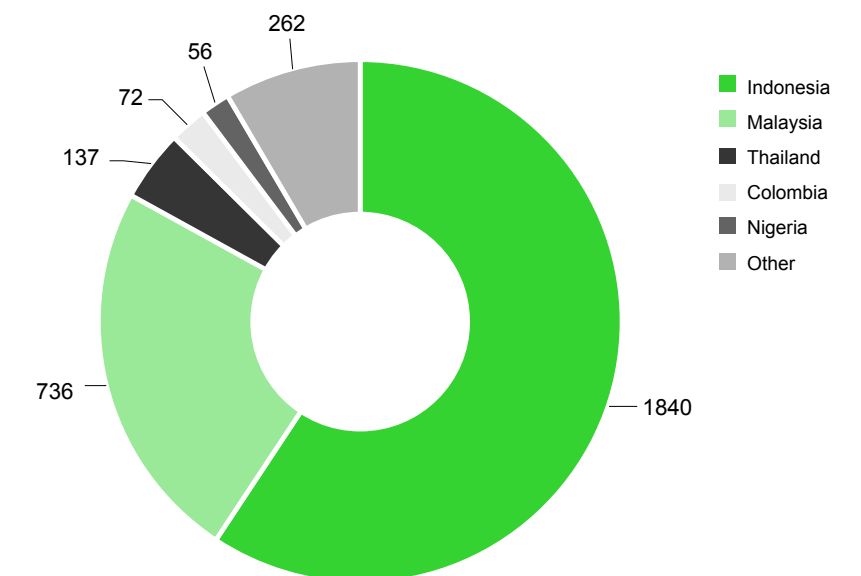
Statistics for PFAD production are not readily available, but it is estimated that PFAD represents about 4% of crude palm oil production (Gapor Md Top, 2010). This is broadly consistent with values for monthly PFAD output in Malaysia reported by Mantari et al. (2020) and attributed to the Malaysian Palm Oil Council (MPOC)⁴, which shows about 700 thousand tonnes a year of PFAD production in the period 2012-2018 against total reported Malaysian

palm oil production of about 19 million tonnes a year during that period⁵, and with an Indonesian PFAD yield of 3.7% for 2018 reported by Golden Agri Resources (2020).

Globally, the US Department of Agriculture reports that just under 80 million tonnes of palm oil were produced in the agricultural year 2022/23.⁶ If global PFAD production was about 4% of that amount, it implies about 3.1 million tonnes. Figure 4 shows the estimated PFAD output for 2022/23 for the largest palm oil-producing nations based on 4% PFAD yield – more than half of the global supply is produced by Indonesia, nearly a quarter by Malaysia, and smaller amounts by other countries in Southeast Asia, South America, and Africa.

FIGURE 4 ESTIMATE OF PFAD PRODUCTION FOR MAJOR PALM OIL PRODUCING COUNTRIES, 2022/23, THOUSAND TONNES

Source: Own calculation based on USDA PSD data



1) The extent to which the colour of the oil can be removed during the bleaching process.
2) E.g. Malaysia sets a limit of 0.1% on refined, bleached deodorised (RBD) palm olein and 0.25% of RBD palm stearin (Corley & Tinker, 2015)
3) A similar fatty acid distillate is produced alongside palm kernel oil, this is referred to as palm kernel fatty acid distillate, PKFAD, but this is produced in much lower volumes.
4) The underlying statistics do not now seem to be available from the MPOC website.
5) <https://mpoc.org.my/monthly-palm-oil-trade-statistics/>
6) <https://apps.fas.usda.gov/psdonline/>

Markets for PFAD

PFAD has a variety of uses, which echo the non-food applications for refined, bleached, deodorised (RBD) palm oil. The palm oil producer Wilmar states that,

Common applications for fatty acids include rubber processing, candles, and cosmetic products or use as feedstock to produce derivatives such as MCTs, soap, and metallic soap. Intermediate chemicals such as fatty alcohols, fatty amines, and fatty esters can also be manufactured from fatty acids.⁷

Similarly, Golden Agri Resources states that, “PFAD is used as a renewable raw material in biofuels production as well as to produce candles, soaps, other oleochemical products, and animal feed” (Golden Agri Resources, 2020, see box).

In the absence of higher-value markets, PFAD can also be used as a boiler fuel substituting fuel oil (Cheah et al., 2010; Nuansa Kimia Sejati, 2011).

PFAD as biofuel feedstock

With the growth of the global biofuel industry since 2000, PFAD is now also used as a biofuel feedstock. It is not possible to comprehensively identify the biofuel producers using PFAD as feedstock, but it is known that it has been an important feedstock for hydrotreated vegetable oil (HVO) renewable diesel¹² produced by Neste¹³. Free fatty acids are not favoured for the production of fatty acid methyl ester biodiesel. However, it is possible, as the standard biodiesel reaction is optimised for the transesterification of triglyceride molecules, PFAD is considered a good feedstock for hydrotreating for the production of



Photo: Adobe Stock

RUMEN-PROTECTED FATS

One animal feed application of PFAD is as a ‘rumen-protected fat’ or ‘bypass fat’, a feed additive primarily used in cattle diets. Rumen-protected fats can be produced by calcium addition to fatty acids such as PFAD, or also by hydrogenation or fractionation of vegetable oils (Solorzano & Kertz, 2005; Voigt et al., 2006). The relatively high melting point of these fats allows them to pass through the rumen in a solid state and be digested in the small intestine, complementing starchy energy feeds (Solorzano & Kertz, 2005; Voigt et al., 2006).^{8,9} The use of bypass fats can enhance ruminant animal growth and milk yield, and passing fat through the rumen avoids the toxicity of unsaturated fats to rumen microbes and the consequent impact on fiber digestion (Naik, 2013; Theurer et al., 2009). PFAD-based cattle feed is marketed as ‘Megalac’ by Volac Wilmar¹⁰ in the UK and by Arm and Hammer¹¹ in the U.S. The Indonesia Oil Palm Plantation Management Agency has recently supported research to increase rumen-protected fat production and use in Indonesia itself (BPD PKS, 2020).

“PFAD has a variety of uses, which echo the non-food applications for RBD palm oil”

7) <https://www.wilmar-international.com/oleochemicals/products/home-care/distilled-palm-oil-fatty-acid>

8) <http://www.tridentfeeds.co.uk/news-events/news/understanding-rumen-protected-fats/>

9) <http://www.progressivedairy.com/topics/feed-nutrition/the-case-for-rumen-protected-fats>

10) <https://www.megalac.com/>

11) <https://ahfoodchain.com/en/segments/dairy/products/megalac>

12) Renewable diesel is the main output from Neste’s process but is generally produced with other lighter hydrocarbons such as propane and/or naphtha as co-products, and the process can produce renewable jet fuel too.

13) Cf. <https://www.neste.com/products/all-products/raw-materials/pfad-residue-palm-oil-refining>

renewable diesel and renewable jet fuels. Kiatkittipong et al. (2013) suggested that renewable diesel yields in a hydrotreating process with PFAD as feedstock could be better than achieved with crude palm oil.

The vegetable oil hydrotreating process produces hydrocarbon molecules with a range of chain lengths (i.e. the number of carbon atoms in the molecule). The molecules with fewer carbon atoms (up to about 11) may be appropriate for chemical industry feedstock or for use blended with petrol, while molecules with larger numbers of carbon atoms may be used in renewable diesel or further processed to produce fuel meeting renewable jet specifications. As we will discuss further below, the eligibility rules under EU policy will restrict the use of PFAD in jet fuel. Some hydrotreating plants will produce only road fuels, in which case this difference in treatment will not be important for them. For plants that produce both renewable diesel and renewable jet, it will be impor-

tant that they are able to identify batches of renewable jet fuel as non-PFAD. This could be achieved by running the facility in two modes – a diesel-only mode when running PFAD, and a diesel-and-jet mode when running other feedstocks. EU biofuel policy uses mass balance accounting rules so that if (for example) two equal-sized batches of PFAD and of used cooking oil are combined and intermingled before fuel production, half of the fuel from that intermingled batch can be treated as wholly PFAD-based, and half as wholly UCO based. This means that if a facility processes mixed batches of multiple feedstocks, there may be occasions when a batch that is labeled as a non-PFAD-based renewable jet could still contain PFAD-derived molecules.

There is a dearth of information available regarding the quantities of PFAD used in different applications, and an assessment for the European Commission of whether PFAD should be considered for addition to

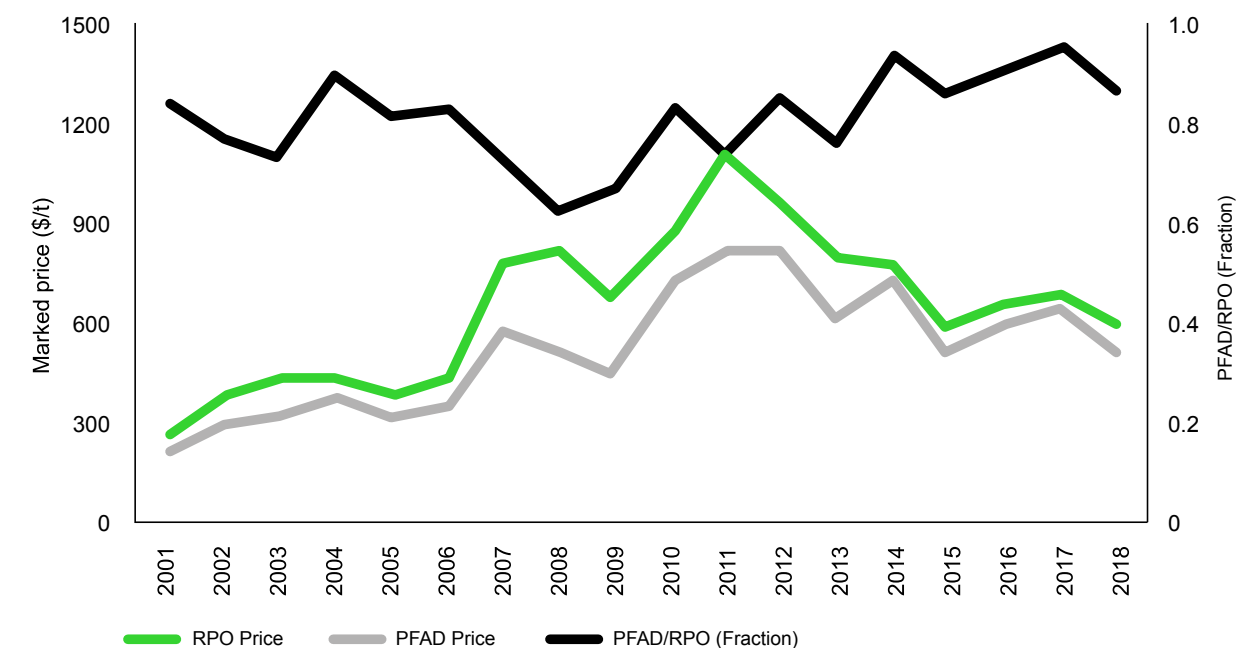
Annex IX of the Renewable Energy Directive found that “Data on the relevant shares of PFAD use per application could not be readily identified” (Haye et al., 2021). Nevertheless, as will be demonstrated in the next section, PFAD is a valuable resource that it is entirely utilised by the applications identified.

Prices for PFAD

While PFAD is considered a lower quality product for the food or oleochemical markets than RBD palm oil, the price per tonne is still comparable. Figure 5 shows a comparison of Malaysian export prices for RBD palm oil versus PFAD over the period 2001 to 2018 (Xu et al., 2020). Through this period, PFAD was generally 80% or more of the price of RBD palm oil, the exception coming during the food price crises of 2007/08 and 2010/12, during which PFAD prices were not inflated as strongly as palm oil prices. The latest available data from MPOB for Malaysian export prices in 2022 and 2023¹⁴ has PFAD at 81% of the price of RBD palm oil.

FIGURE 5 MALAYSIAN EXPORT MARKET PRICES OF REFINED PALM OIL VERSUS PFAD (2001–2018)

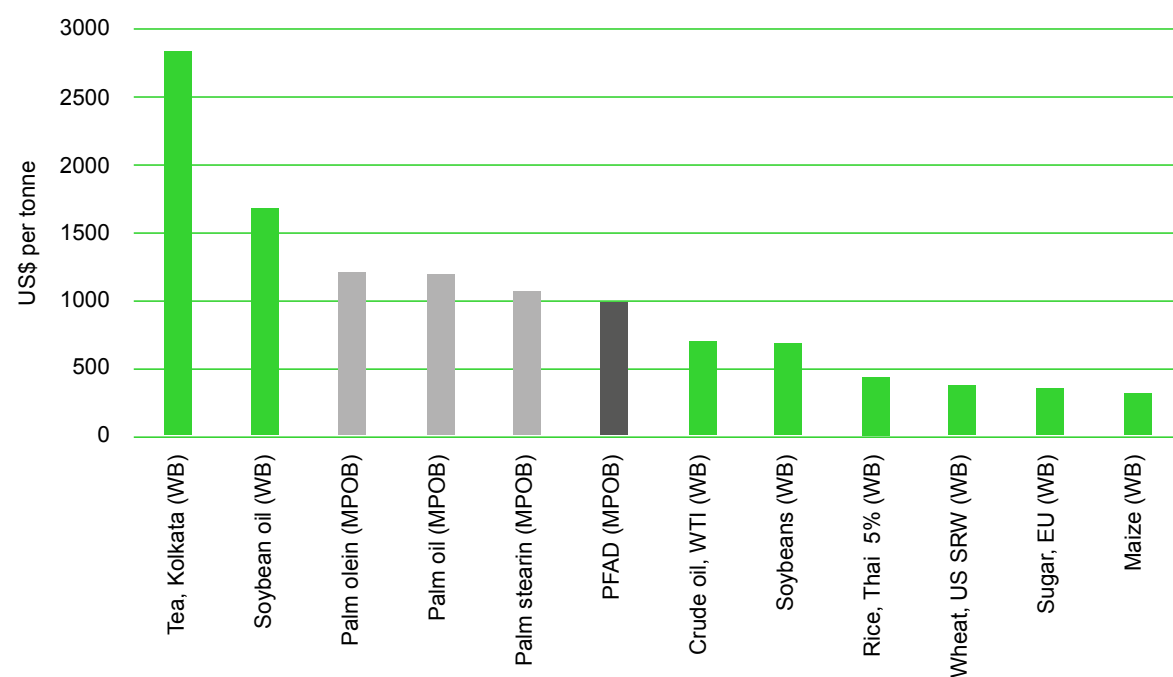
Source: Xu et al. (2020), quoting MPOB data



14) <https://bepi.mpob.gov.my/index.php/price/daily?view=article&id=1033>

FIGURE 6 2022 AVERAGE PRICES FOR SELECTED COMMODITIES

Source: (World Bank, 2023), <https://bepi.mpob.gov.my/index.php/price/daily?view=article&id=1033>



“PFAD trades for a lower price than other palm oil fractions, soy oil, or tea, but has a higher value than crude oil, soybeans, rice, wheat, sugar, or maize.”

Trading at a modest discount on palm oil still leaves PFAD as a relatively high-value agricultural commodity. Figure 6 shows 2022 Malaysia export prices for different palm oil fractions as reported by MPOB, alongside the average prices reported by the World Bank for various other commodities. PFAD trades for a lower price than other palm oil fractions, soy oil, or tea but

has a higher value than crude oil, soybeans, rice, wheat, sugar, or maize. Characterising PFAD as a waste or low-value residue would certainly not be accurate.

Alternatives to PFAD in non-biofuel markets

While PFAD has a demonstrably high market value, it is not the main driver of palm oil production – it is the demand for RPO that determines the amount of PFAD entering the economy and not the other way around. In the jargon, PFAD is said to possess an inelasticity to demand. Consequently, if PFAD consumption by the biofuel industry increases, then PFAD use in other applications has to diminish. The supply gap will need to be substituted by some alternative materials (ICF International, 2015).

There is no evidence that there are excess resources of acid oils from the refining of other vegetable oils without existing uses that could be mobilised to replace PFAD. For one thing, other vegetable oil production systems do not produce fatty acid distillates or other acid oils in volumes comparable to PFAD generation.

Free fatty acid content in crude soy oil, for instance, should rarely rise above 1% unless the oil is stored for protracted periods in high temperatures and/or with high moisture content (de Alencar et al., 1998), and should typically be around 0.33%, compared to 4% for crude palm oil (Hammond et al., 2005). In any case, the supply of other by-product oils and fats is inelastic, and these materials will also have their own existing uses.

In the oleochemicals and soap industries, the obvious substitutes for PFADs would be alternative vegetable or animal oils. Along with tallow, Biermann et al. (2011) identified palm oil, palm kernel oil,

“Characterising PFAD as a waste or low-value residue would certainly not be accurate.”

and coconut oil as the most important vegetable oils for industrial applications globally. In the soap industry, tallow and coconut oil, in particular, have had a significant role as raw materials, but in recent decades global production of tallow and coconut oil has been relatively static while the production of palm oil and associated oils has risen dramatically; as a result, palm oil (for applications traditionally based on tallow) and palm kernel oil (for applications traditionally based on coconut oil) have taken a growing role in the soap and oleochemicals markets (Thiagarajan, 2004). As one might expect, RBD palm oil has a similar fatty acid composition to PFAD. Palm oil is also almost always cheaper than the other primary vegetable oils such as soy, rapeseed, and sunflower oils, and any market with access to supplies of PFAD should also have access to supplies of palm oil, given that they come from the same sources. It is, therefore, likely that if the availability of PFAD for soaps and oleochemicals is reduced, it will simply be replaced by either RBD palm oil or by the most appropriate palm oil fractions for the application (palm olein, palm stearin or palm kernel oil). PFADs can also be used for extraction of tocotrienols (a family of bio-chemical compounds which comprise vitamin E) for which palm oil is again an alternative (Lau Lik Nang & Yuen May, 2015; Thiagarajan, 2004).

In the animal feed sector, one option would be to replace PFAD-based rumen-protected feeds with similar rumen-protected feed products. As an alternative to PFAD, rumen-protected calcium soaps could be produced by hydrolysis of soy or palm oils to produce free fatty acids and reaction with calcium (Eastridge, 2002; Solorzano & Kertz, 2005). The details of ruminant physiology mean that palm has a favourable fatty acid profile compared to other lipid bases, as palm has a much higher ‘saturated palmitic’ content than other vegetable oils (43% for palm, as against 10% for soy and 4% for canola (Zambiasi

“Consequently, if PFAD consumption by the biofuel industry increases, then PFAD use in other applications has to diminish.”

et al., 1974)). The advantage here is that saturated fats are less toxic to the rumen than unsaturated fats (Naik, 2013), and longer-chain saturated fatty acids such as palmitic acid are less digestible than shorter chains and will make it through to the intestine (Solorzano & Kertz, 2005). This would suggest that palm oil would be preferred over other vegetable oils for replacing PFAD in animal feed, but the decision will also be influenced by which oils are most readily available in the region in question. In the U.S., where the consumption of soy oil is much higher than the consumption of palm oil, soy oil may be a preferred alternative (ICF International, 2015), whereas in Southeast Asia, palm oil would be the obvious choice. In the EU and UK, palm oil is already ubiquitous in applications for which the lowest-priced vegetable oil is favoured, and thus in the event of a reduced supply of PFAD hydrolysed palm oil may be considered the most likely alternative basis for calcium soap manufacture for animal feed applications in Europe.

The other option in animal feed applications would be to reduce the use of rumen-protected fats altogether in favour of alternative lower-price energy feeds. For example, as rumen-protected fat prices increased in 2017 an article

on ‘Farm Business’ argued that farmers could save money by switching from rumen protected fats to using higher energy sugar-based feeds or using dietary supplements to enhance digestion.¹⁵ Farmers could also simply switch to diets based on lower-cost energy feeds such as feed wheat or feed corn, but would lose the benefits provided by rumen-protected fats for animal growth and output.

The final application for PFAD is as boiler fuel. As noted in the previous section, PFAD prices are significantly above crude oil prices, and therefore, energy recovery from PFAD is only likely to be appealing to palm oil refineries that struggle to access PFAD export markets. As an alternative in those applications, it can be assumed that palm refinery operators would shift to the lowest cost comparable fuel available, likely to be heavy fuel oil. Fuel oil should be able to be burned in any facility currently burning PFAD. There may also be potential in the longer term for any facility moving away from PFAD combustion to shift to fundamentally different materials, such as underutilised biomass residues from oil palms or natural gas.

There is a lack of statistics available regarding the shares of current uses of PFAD, or of data to identify which markets may stop using PFAD if it is diverted to biofuel use, and therefore it is not possible to confidently predict exactly how and where demand for replacement materials might be affected. Malins (2017a) provided an indicative estimate of what could be the main substitutes required as PFAD is displaced to fuel use could be palm oil for animal feed (0.32 tonnes per tonne of PFAD), soy oil for animal feed (0.08 tonnes per tonne of PFAD), palm oil for oleochemicals (0.32 tonnes per tonne of PFAD), soy oil for oleochemicals (0.04 tonnes per tonne of PFAD), rapeseed oil for oleochemicals (0.04 tonnes per tonne of PFAD), and fuel oil for energy (0.08 tonnes per tonne of PFAD).

15) <https://web.archive.org/web/20220423094857/http://www.farmbusiness.co.uk/livestock/dairy/reduce-reliance-on-rumen-protected-fats-to-cut-price-rise-impact.html>

PFAD trade

Using trade statistics published by the UN and by national statistical bodies, it is possible to get a sense of the international trade in PFAD. In the harmonised system (HS) for commodity statistics, PFAD exports fall under code 382319, “Industrial monocarboxylic fatty acids; acid oils from refining; (other than stearic acid, oleic acid or tall oil fatty acids)”. UN Comtrade (2022) reports global trade data only to this level of precision (six-digit HS codes), but some national statistics have better resolution. Indonesia reports PFAD exports under the 8-digit code 38231920 and PKFAD exports under 38231930 (BPS, 2022). EU import statistics identify ‘fatty acid distillate’ under code 38231930¹⁶ and ‘distilled fatty acids’ under code 38231910. The code for distilled fatty acids may be used to refer to fatty acids purposefully produced from vegetable oils via hydrolysis.

UN Comtrade data for 2021 show that Malaysia and Indonesia are not only the main producers of PFAD but also the main exporters. Between them, they exported 4.7 million tonnes of acid oils under code 382319 in 2021 – this compares to only 83 thousand tonnes for Thailand and 310 tonnes for Colombia. Comtrade data is available only up to the sixth digit of the HS codes, and therefore, fatty acid distillate cannot be distinguished from other acid oils in the Comtrade data. In addition to PFAD this number will include PKFAD and some other acid oils. The Indonesian export statistics for 2021 show PFAD as about half of the total volume of exported fatty acids from refining under code 392319 (1.5 million tonnes). This is only slightly less than the PFAD production in 2021 of 1.7 million tonnes (estimated from USDA PSD palm oil production statistics based on 4% PFAD yield). This shows that the vast majority of PFAD produced in Indonesia is exported. According to the Indonesian data, the amount

“Main substitutes required as PFAD is displaced to biofuel use, could be palm oil and soy oil for animal feed and oleochemicals, and fuel oil for energy.”

of PKFAD exported is relatively minor – only 96 thousand tonnes in 2021. The additional 1.5 million tonnes of acid oil exports from Indonesia identified under HS code 382319 are described in Indonesian statistics as ‘acid oils from refining’ and ‘other acid oils from refining’. It is not clear to us precisely what is included in these volumes, but it is not incon-

ceivable that these related HS codes could also include some quantity of PFAD (e.g. in mixed batches with palm acid oil¹⁷).

For Malaysia, Comtrade reported 1.6 million tonnes of acid oil exports in 2021, against an estimated PFAD production of 700 thousand tonnes. This could be consistent with almost all Malaysian PFAD production being exported (in which case PFAD would make up approximately half of acid oil exports, as in Indonesia).

The most important destination for these acid oil exports is the EU, as shown in Figure 7. Notice that Singapore is also a significant export destination, receiving 170 thousand tonnes in 2021. Singapore is the location of one of Neste’s renewable diesel facilities.

Within the EU, the primary destination is the Netherlands, followed by Italy and Spain (Figure 8). These are all countries with renewable diesel production capacity (e.g. Neste in Rotterdam, Eni in Italy, and Repsol in Spain).

FIGURE 7 DESTINATION OF EXPORTS OF ACID OILS UNDER HS CODE 382319 FROM INDONESIA AND MALAYSIA, 2021

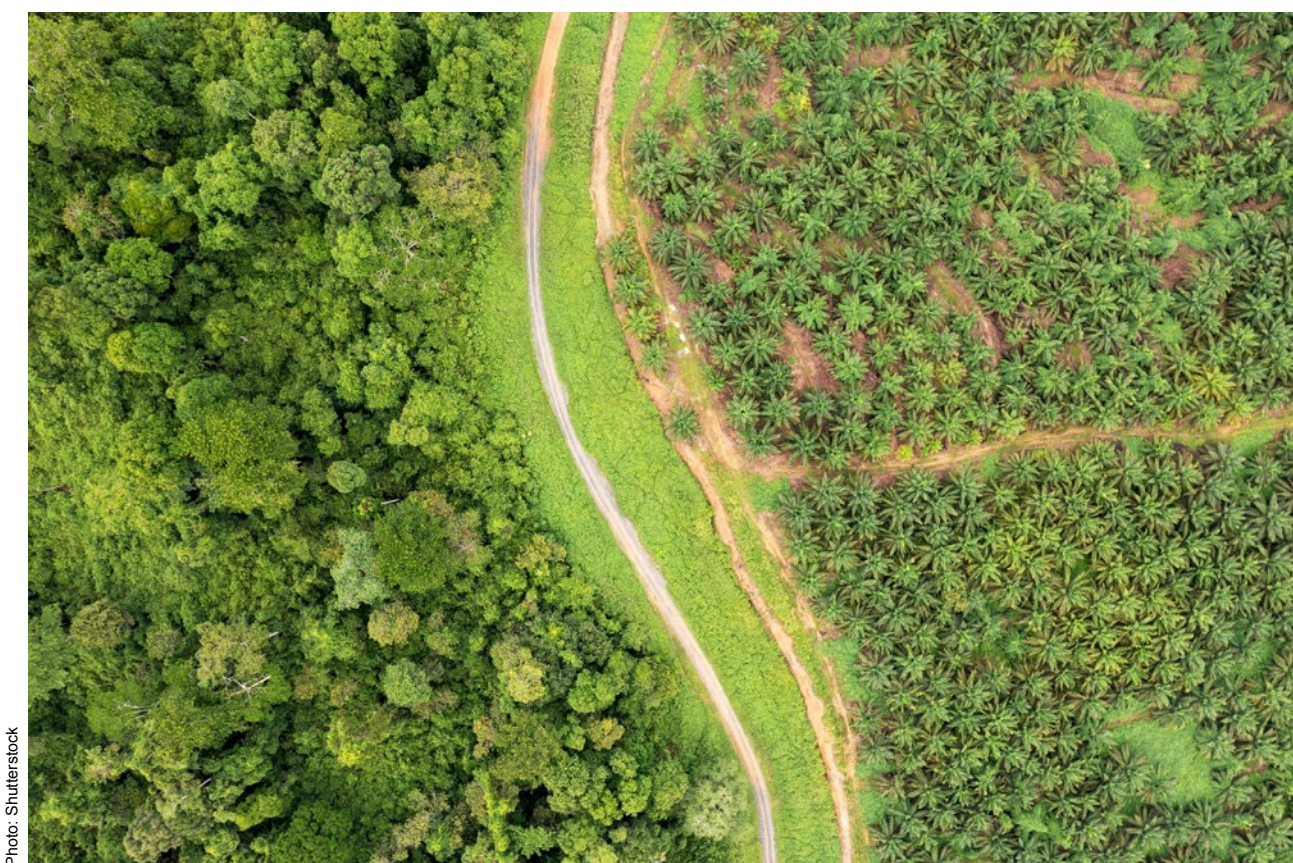
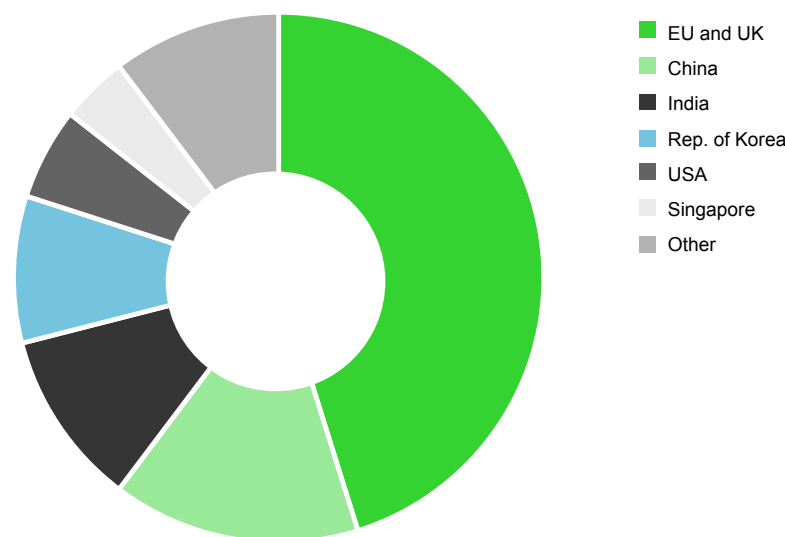
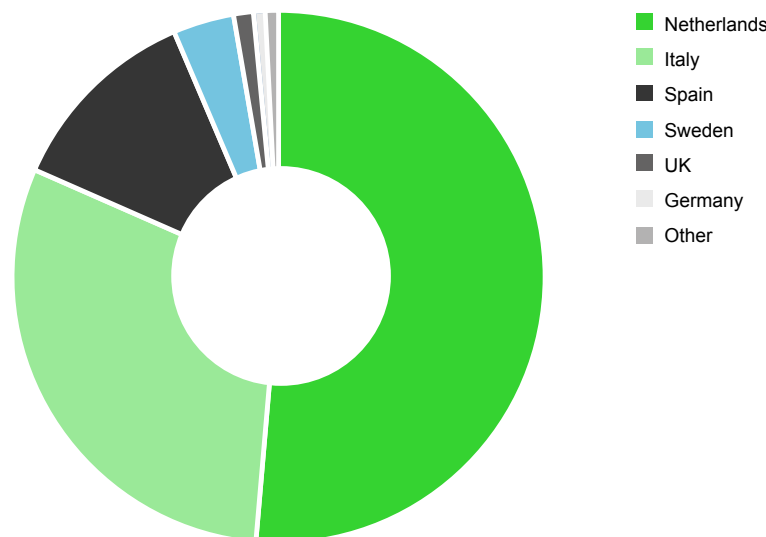



Photo: Shutterstock

FIGURE 8 EU MEMBER STATES IMPORTING ACID OILS UNDER HS CODE 382319 FROM INDONESIA AND MALAYSIA



EU import data¹⁸ provide additional detail on these acid oil flows. In 2021, 1.2 million tonnes of imports from Malaysia and Indonesia were identified as fatty acid distillates¹⁹, of which 1 million tonnes came from Indonesia. A further 400 thousand tonnes of imports were identified as distilled fatty acids and other acid oils. Imports from other countries were relatively minor – after 178 thousand tonnes of fatty acid distillates from Malaysia, the next largest source was 9 thousand tonnes from Honduras. This data would not include any imports of biofuel produced from PFAD, for example, if the PFAD exported to Singapore were to be used to produce renewable diesel at Neste’s facility and the produced fuel were then exported to the EU. 

¹⁶) It is not clear to us why there is an apparent difference in use of the codes between the Indonesian and EU reporting, with Indonesia using the code 38231920 while the EU does not. We believe that PFAD is included with PKFAD under 38231930 in the EU data.

¹⁷) Palm acid oil is a similar material but is produced in alkaline refining while PFAD is produced in physical refining. As most palm oil is refined using physical methods, production of PAO is lower than that of PFAD.

¹⁸) <https://trade.ec.europa.eu/access-to-markets/en/statistics>. These exclude the UK.

¹⁹) This could include some amount of PKFAD and perhaps coconut oil fatty acid distillate but is likely to be dominated by PFAD.

Deforestation risk from palm and PFAD

The palm oil industry in Indonesia and Malaysia has been endemically linked to deforestation for many years. Palm oil has been identified as a 'deforestation risk commodity' by various analysts, and analysis of the connection between demand for palm oil from the biofuel industry and 'indirect land use changes' (ILUC) in high carbon stock areas suggests that driving consumption of palm oil biofuels may lead to net increases rather than decreases in emissions when compared to continuing to use fossil fuels (Hugo Valin et al., 2015; Malins, 2018, 2019a). The European Union's Renewable Energy Directive (RED II) prohibits the supply of biofuels produced from feedstock that was grown on recently deforested areas or recently drained peat swamps, but these prohibitions cannot prevent indirect land use changes. Malins (2020) estimated, based on historical deforestation data, that every tonne per year of additional palm oil demand might be expected to lead to about 0.15 hectares of deforestation and 0.08 hectares of peat loss.

Tropical deforestation is recognised as a major source of greenhouse gas emissions and a driver of biodiversity loss. Using policy to increase demand for palm oil while it is still a deforestation-linked commodity will undermine the achievement of climate and biodiversity targets. Analysis of deforestation

"Using policy to increase demand for palm oil while it is still a deforestation-linked commodity will undermine achievement of climate and biodiversity targets."

and oil palm areas in Indonesia suggests that moderating palm oil demand growth, and therefore palm oil prices, is correlated with lower rates of deforestation (Gaveau et al., 2022). The Paris Agreement reiterates the importance of policy approaches to reduce emissions due to deforestation. Delivering the climate change mitigation targets of the Paris Agreement²⁰, the forest conservation goals of the Glasgow Declaration²¹, and the biodiversity

protection goals of the Kunming-Montreal Framework²² will all be made easier by reducing the pressure for more palm oil expansion.

The RED II created the category of 'high ILUC-risk' feedstock, and palm oil is currently the only feedstock that has been identified as high ILUC-risk (European Union, 2019). This means that support and subsidies for palm oil biofuels must be phased out in EU Member States²³ no later than 2030. This is based on a review that concluded that in the period from 2008-2015, about 45% of oil palm expansion occurred at the expense of forest land and 23% at the expense of peatland (European Commission, 2019). EU Member States, including Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, and Portugal, have already adopted or proposed limits on support for palm oil biofuels under their biofuel support policies (Radzi & Hassan, 2022), and palm oil use for biofuels is extremely limited in the UK and Norway even without a direct phase out of support²⁴.

There is by now a broad recognition in the EU that the role of palm oil as a deforestation driver is problematic – but what does this mean for PFAD? Palm oil expansion is a driver of deforestation, but is PFAD demand for biofuels a driver of palm oil expansion? There are essentially

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three ways to consider the question of PFAD-linked deforestation:

- 1. The 'no impact' argument.** Some industry voices such as Neste have argued that PFAD should be understood as a 'residue'. Neste claims that the use of PFAD by the biofuel industry, "does not increase pressure to expand oil palm farming" and, therefore, should not be allocated any of the deforestation emissions associated with palm-led deforestation. This argument ignores, however, the reality that if PFAD is a valuable material and that if it was not being used to make biofuel, it would be used for something else. Under this version, zero deforestation emissions would be allocated to PFAD.
- 2. The 'shared responsibility' argument.** An alternative view is that PFAD is a valuable output of the palm oil production system, and therefore that the emissions associated with palm-led deforestation should be allocated

between RBD palm oil, PFAD, and other palm oil outputs (e.g., palm kernel oil) on some proportional system. It is often argued that the fairest way to make such an allocation is by the value of the outputs – a larger share of emissions is then allocated to the more valuable products. Xu et al. (2020) provide an example of this sort of emissions allocation using ILUC estimates for palm oil and conclude that when allocating a share of emissions from palm oil production and associated deforestation then the lifecycle emissions of PFAD-based renewable diesel would be between 75 and 280 gCO₂e/MJ – a range from slightly better than fossil diesel to three times as bad as it.

- 3. The 'consequential' argument.** The third way of considering the impact of PFAD demand is to try to assess what the consequences are for other markets when PFAD is displaced into the biofuel market. This involves trying to identify which non-biofuel markets

are most likely to reduce their consumption of PFAD as they shift to biofuel use and the materials that are likely to replace PFAD in those applications. The emissions from producing more of those materials (including any associated ILUC emissions) are then attributed to the use of PFAD as biofuel. Malins (2017) presents a version of such a consequential analysis. It is estimated in that study that displacement of 1 tonne of PFAD leads to about 0.64 tonnes of additional demand for palm oil, plus smaller amounts of additional demand for soy oil, rapeseed oil, and fuel oil. The analysis estimates that the indirect emissions for substitute materials for PFAD used in renewable diesel could fall in a range from 92 to 221 gCO₂e/MJ²⁶ – implying lifecycle emissions that are somewhere from slightly worse than fossil diesel to about two and a half times worse as bad as it.

20) https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf

21) <https://web.archive.nationalarchives.gov.uk/ukgwa/20230418175226/https://ukcop26.org/glasgow-leaders-declaration-on-forests-and-land-use/>

22) <https://www.cbd.int/article/cop15-cbd-press-release-final-19dec2022>

23) And in EFTA Member States if the RED II is incorporated into the EEA agreement.

24) Cf. (for Norway) <https://www.regnskog.no/en/news/rule-changes-put-halt-to-norways-use-of-palm-oil-biodiesel>; (for the UK) <https://www.gov.uk/government/statistics/renewable-fuel-statistics-2022-fifth-provisional-release>

25) <https://www.neste.com/products/all-products/raw-materials/pfad-residue-palm-oil-refining>

26) This excludes the emissions from producing and distributing the fuel, which Xu et al. (2020) estimates as an additional 14 gCO₂e/MJ

Lifecycle emissions from PFAD biofuels

Figure 9 provides an illustration of the GHG intensity that could be calculated for PFAD-based renewable diesel depending on the emissions terms that are considered in the calculation. The emissions increase from left to right as the scope of the calculation changes as follows:

- 1. The first emissions intensity score on the left would be delivered by treating PFAD as a residue so that no emissions from palm oil cultivation or processing are considered and ignoring indirect emissions from producing replacement materials and from land use change.
- 2. The second score would be delivered by treating PFAD as a co-product of the palm oil production process instead of as a residue and, therefore, allocating cultivation and processing emissions to it, but by continuing to exclude any ILUC emissions.
- 3. The third score would be delivered by treating PFAD as a residue, as in case 1, and still ignoring ILUC, but adding the emissions required to produce substitute materials for current consumers of PFAD.
- 4. The fourth score would be delivered by treating PFAD as a co-product (like the second case), and also including a low-end estimate of ILUC emissions from Malins (2017a).
- 5. The fifth score would be delivered by treating PFAD as a residue and including emissions to produce replacement materials (like the third case) and also a low-end estimate for ILUC associated with those replacement materials from Malins (2017a).
- 6. The sixth score would be delivered by treating PFAD as a co-product (like the second case) and including a high-end estimate of ILUC emissions from Malins (2017a).

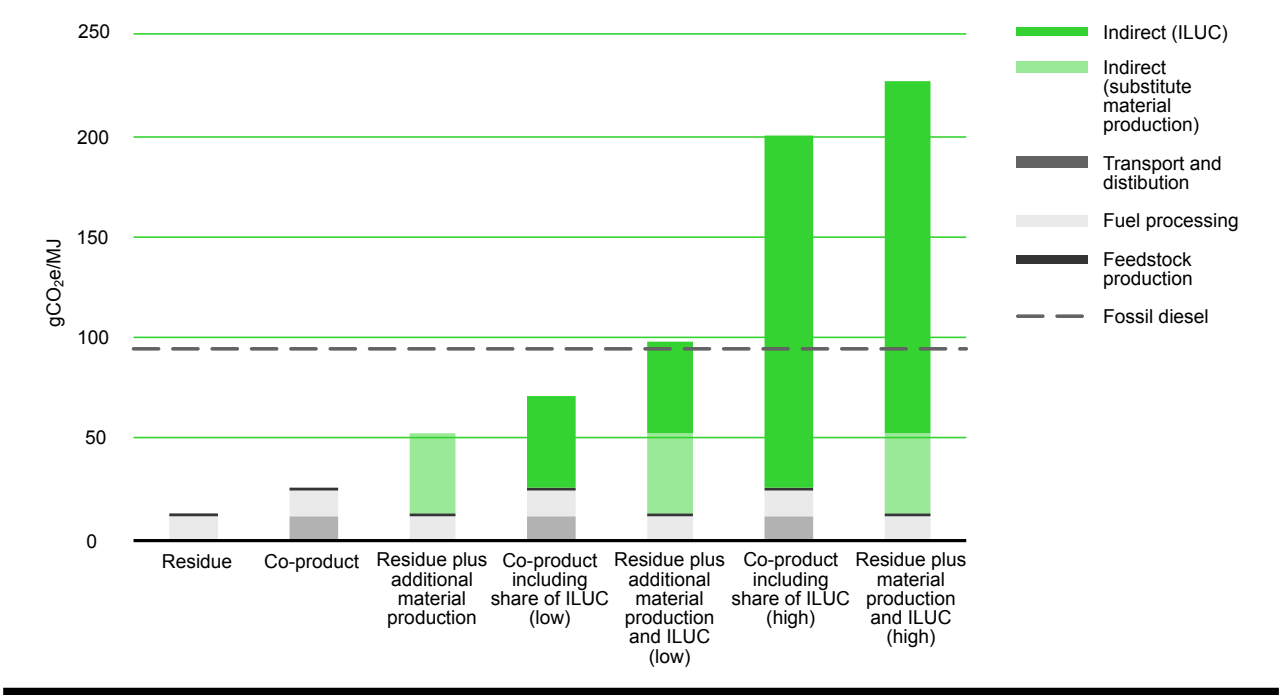
- 7. The seventh score would be delivered by treating PFAD as a residue and including emissions to produce replacement materials (like the third case) and also a high-end estimate for ILUC associated with those replacement materials from Malins (2017a).

The least favourable set of methodological choices would give total lifecycle emissions as high as 230 gCO₂e/MJ.

The data from Malins (2017a) can also be used to calculate an estimated rate of deforestation per tonne of annual PFAD biofuel consumption. If consumption of 1 tonne of PFAD leads to 0.64 tonnes of additional palm oil demand, and a tonne of palm oil demand is associated with 0.15 hectares of deforestation and 0.08 hectares of peat loss, then every tonne of PFAD demand would be associated with approximately 0.1 hectares of deforestation and 0.05 hectares of peat loss.

FIGURE 9 ESTIMATES OF EMISSIONS ASSOCIATED WITH PFAD BIOFUEL CONSUMPTION WITH DIFFERENT TERMS INCLUDED IN THE LCA

Source: Feedstock production, fuel processing and transport and distribution from Xu et al. (2020), indirect emissions from Malins (2017a). Assumes methane capture from effluent ponds.



EU policy and PFAD demand

Biofuel support policy in the EU is dictated by the Renewable Energy Directive (RED II). This is in the process of being updated through the Fit for 55 process. This revised 'RED III' had been agreed²⁷ upon but not yet formally adopted by the European Union at the time of writing. The RED III introduces high targets for using renewable energy in transport but does not introduce any major changes specific to PFADs. The RED III does introduce an additional requirement for the European Commission in relation to the assessment of which feedstocks are high ILUC risk, which is that the Commission must consider whether the threshold used to determine high ILUC-risk status should be lowered. Lowering this threshold would make it more likely for additional feedstocks to be identified as high-ILUC risk (and less likely for palm oil to be removed from the high-ILUC-risk category even if new analysis identifies reductions in its role as a deforestation driver).

The Renewable Energy Directive is complemented by the newly introduced 'REFuelEU' policy, which mandates the use of alternative fuels in aviation, and 'FuelEU Maritime', which mandates GHG intensity reductions in the energy used in shipping. As noted above, the use of palm oil biofuels to meet EU renewable energy targets is currently set to be phased out by 2030, but this does not necessarily also apply to fuels from PFAD.

One important question is whether PFAD is to be treated as a co-product of the palm oil industry or as a residue. PFAD is not mentioned explicitly in RED II or RED III, which define a residue as "a substance that is not the end product(s) that a production process directly seeks to produce; it is not a primary aim of the production process, and the process has not been deliberately modified to produce it". As shown above, treatment as a residue would lead to a more favourable treatment of the GHG intensity of PFAD-based fuels, as the RED rules state that no emissions from feedstock production should be allocated to residues. To

"The use of palm oil biofuels to meet EU renewable energy targets is currently set to be phased out by 2030, but this does not necessarily also apply to fuels from PFAD."

the best of our knowledge, the European Commission has not given any explicit indication of whether it considers PFAD to be a residue or not, though Haye et al. (2021) suggest that it fits the RED definition of a residue. Irrespective of whether it is considered a residue or not, it has not been included in the list of materials that are eligible for additional policy support contained in Annex IX of the RED II. This means that it is in a less favourable position than materials such as used cooking oil and animal fats – in particular, it is not eligible for 'double counting' incentives extended to the feedstocks listed in Annex IX. Several Member States (the Netherlands, Germany, Sweden) plus Norway have excluded PFAD from treatment as a residue under their national RED implementations, and it is identified as a 'product' under the UK Renewable Transport Fuel Obligation (T&E, 2020). In Sweden, the status of PFAD was changed from residue to co-product in 2020, giving it a less favourable treatment in the Swedish system and leading to a 90% reduction in the supply of PFAD-based renewable diesel between 2019 and 2020 (Energimyndigheten, 2023).

The RED is not explicit about whether the designation of a feedstock as high ILUC risk can also apply to some or all of the co-products and residues associated with producing that primary feedstock. Thus, it is not entirely clear how PFAD demand for

EU biofuels will be affected by the high ILUC-risk designation of palm oil. In practice, the treatment of PFAD will be determined by Member State implementations of the RED II/III. For example, it is understood that France, Denmark, and Italy will phase out support for PFAD-based biofuels alongside palm-oil-based fuels and that Spain will limit the contribution from PFAD-based fuels (Koster et al., 2022; Lieberz & Rudolf, 2023). Other Member States may continue to credit PFAD-based fuels towards their RED II targets.

The REFuelEU Aviation mandate explicitly excludes fuel produced from PFAD and other materials derived from the palm and soy crops (except those listed in Annex IX of the RED) towards its targets for alternative aviation fuel use. This puts PFAD alongside all food/crop-based biofuels, biofuels produced from intermediate crops, and biofuels from soapstocks. The FuelEU Maritime regulation²⁸, however, only excludes food-and-feed-based fuels from making a contribution, and if PFAD is identified as a residue, it would fall outside the RED II/III definition of food and feed materials. It therefore seems likely that in Member States where PFAD-based fuels can be counted as a residue under RED targets, they will also be allowed to be counted towards maritime targets.²⁹

Going beyond the biofuel economy, the EU Deforestation Regulation is introducing due diligence requirements for all importers of palm oil to the EU. While it was unclear in the original proposal whether lower-value products from the palm oil supply chain would be covered, the final regulation explicitly covers various palm products, including all acid oils classified under HS code 382319. This will require any companies (including biofuel producers) except SMEs importing PFAD to undertake chain of custody checks, to record the location of the plantations from

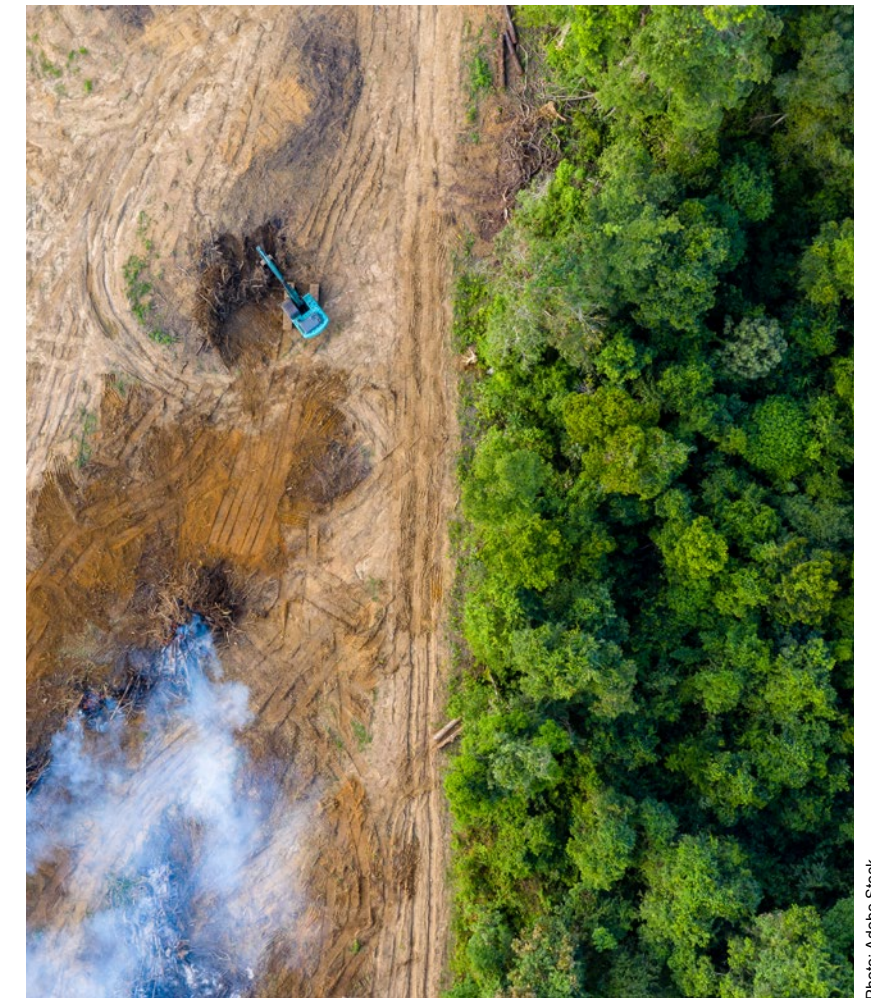



Photo: Adobe Stock

which the PFAD was sourced, and to demonstrate that the plantations from which the PFAD was derived were deforestation-free. The Regulation does not address the issue of indirect land use change emissions but seeks to reduce deforestation across the board by constraining market opportunities for products from deforested areas. The Regulation does not currently require the same due diligence to be undertaken by companies importing processed biofuels into the EU, but there is a clause (Article 34 (3)) requiring the European Commission to assess by 2025 whether biofuels should be added to the scope of the Regulation.

Overall, the opportunities and incentives for the use of PFAD-based fuels in the EU have been significantly constrained over the past decade through a combination of EU-level action (keeping PFAD out of Annex IX of the RED, excluding it from REFuelEU) and through complementary Member State action (Member States that treat PFAD as a co-product rather than as a residue, and that are phasing out support for PFAD based fuels alongside other palm-oil-based fuels). On the other hand, there is still a degree of ambiguity about the status of PFAD and remaining market opportunities for PFAD-based fuels in some Member States. 

27) <https://data.consilium.europa.eu/doc/document/PE-36-2023-INIT/en/pdf>

28) <https://data.consilium.europa.eu/doc/document/PE-26-2023-INIT/en/pdf>

29) <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1115&qid=1687867231461>

Alternatives for sustainable transport decarbonisation

Ever since the first RED was adopted in 2009, there has been ongoing pressure to evolve EU alternative fuels policy to improve incentives for more sustainable fuel production pathways with a greater long-term potential while reducing or eliminating support for the least sustainable options. Through this process, the incentives for palm-oil-based biofuels have been significantly constrained, helping to alleviate deforestation pressure from the palm oil market, while the incentives for novel advanced biofuel production pathways and (more recently) for 'electrofuels'³⁰ have been gradually strengthened through the creation of sub-targets.

The most scalable biofuel pathways are based on the conversion to fuel of cellulosic and lignocellulosic material, ideally residues with no existing productive use (Harrison et al., 2014). This can include collecting small branches and twigs from forestry operations, collecting crop residues from fields, and separating biomass from municipal waste streams. There are still sustainability issues associated with even these technologies – these relate primarily to guaranteeing sustainable forestry practices, limiting residue removals from agriculture and forestry to sustainable rates, and managing competition between biomass crops and other land uses. If the wood harvest is increased without simultaneously delivering accelerated rates of tree growth, there is a risk of causing a 'carbon debt', whereby it could take

decades to actually deliver net reductions in atmospheric CO₂ with bioenergy (Baral & Malins, 2014). The RED II/III attempts to reduce this risk by placing requirements for the adoption of sustainable forestry practices in areas from which wood for bioenergy is sourced. While these issues are important, delivering a sustainable supply of biomass is a more tractable problem than the issues around the use of food commodities and high-value lipids like PFAD for fuel.

Electrofuels bypass many of the main issues with biofuels because renewable electricity production is fundamentally more land efficient than biofuel cropping (in terms of energy generated per hectare) with a much lower water footprint and without the need for application of fertilisers or pesticides (Malins, 2017b). There are still risks, though, primarily that fossil power generation will be indirectly increased (or that its rate of retirement will be slowed) to meet additional electricity demand from an electrofuel industry (Malins, 2019b), which could potentially lead to increased rather than reduced GHG emissions. There is also a broader question about whether and when it is worthwhile to use renewable electricity to produce fuels (with significant efficiency losses through the conversion system and when the fuels are used in vehicles) when it could be used directly, e.g. in battery electric vehicles. Many analysts, therefore see electrofuels as relevant primarily for applications like

aviation and possibly shipping, where direct electrification is impractical.

Simultaneously with the redirection of fuel policy, the market for electric vehicles has been rapidly developing, and the EU is on a pathway to eliminating sales of fossil-fuelled passenger cars from 2035, while Norway will eliminate them already in 2025. Electric drive vehicles are significantly more energy efficient than combustion engine vehicles, with air quality co-benefits as electric motors have no exhaust emissions in use³¹.

While some stakeholders may have been frustrated by the length of the process that has been required to re-orient EU clean transport policy in this way, the overall direction of travel has been very positive. The electric vehicle revolution is clearly underway, but the commercialisation of production of advanced biofuels and of electrofuels remains stubbornly unrealised. The finalisation of the RED III should provide context for Member States to finalise their policy frameworks for 2030, but 2030 is getting close. Advanced biofuel and electrofuel production will be capital-intensive industries that are entirely dependent on policy support to be financially viable. Delivering a rapid upscaling of these industries will require intelligent policy setting, giving clarity to producers about the value that will be provided for their fuels, and guaranteeing that they will never be made to compete in the market against cheaper less sustainable options.




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Setting policy to reduce biofuel-driven deforestation

Through the high ILUC-risk policy, the EU is phasing out its counter-productive support for palm oil expansion as a climate solution. The next step is to also reduce support for feedstocks like PFAD, the consumption of which indirectly drives increased palm oil production. A mandate that supports PFAD biofuels ends up being a (not very well disguised) backdoor mandate for increased palm oil consumption. There are already examples of Member States restricting support from RED II/III to PFAD-based fuels, both by classifying PFAD as a co-product so that it does not receive the more favourable regulatory treatment given to biofuels from residues and by restricting PFAD-based biofuels alongside other palm-oil-based fuels treated as high ILUC-risk. If other EU Member States follow these examples, it could go a long way to eliminating EU biofuels as a market opportunity for PFADs.

REFuelEU gives us the first example of limiting the use of PFAD fuels at

the EU level. Other Member States could further reduce deforestation pressure by restricting or eliminating support for PFAD fuels in their own biofuel policies. This should include seeking to ensure that the FuelEU Maritime regulation does not become a market of last resort for less sustainable fuels that are excluded from the aviation mandate and from national RED implementations. This could be achieved by clarifying that PFAD should be treated as a palm oil co-product and, therefore, as a food-and-feed-based fuel.

Similarly, other jurisdictions that limit the use of palm oil biofuels in their own biofuel policies, such as the United States and Canada, could clarify that PFAD is to be treated as a co-product of palm oil to which a share of the responsibility for palm-drive deforestation should be allocated. 

RECOMMENDATIONS

- Palm oil, soy oil and PFAD are unsuitable as biofuel feedstocks due to their link to deforestation and biodiversity loss. Consumption should be phased out as soon as possible.
- EU Member States to further reduce deforestation pressure by excluding PFAD-based fuels from policy support in their national implementation of the Renewable Energy Directive, as many of them have already done for palm-oil-based fuels
- EU Member States to classify PFAD as a co-product rather than a residue, so that it does not receive the more favourable regulatory treatment given to biofuels from waste and residues
- Similarly, other jurisdictions that limit the use of palm oil biofuels in their own biofuel policies, such as the United States and Canada, could clarify that PFAD is to be treated as a co-product of palm oil
- Biofuel producers should phase out PFAD as a feedstock (e.g. for HVO) as PFAD consumption by the biofuel industry indirectly drives increased palm oil production due to the need for substitution in other applications which are dependent on PFAD

30) Fuels synthesised using hydrogen from electrolysis using renewable electricity, sometimes referred to in EU policy as RFNBOs, which stands for renewable fuels of non-biological origin.

31) Although tyre and brake wear still lead to particulate matter emissions and the greater weight of electric vehicles may aggravate this, it is understood that overall air pollution will be significantly reduced (Woo et al., 2022)

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