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The advanced and waste biofuels paradox

Availability and sustainability of advanced and waste biofuels

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Executive summary

Increasingly promoted as sustainable alternatives to damaging crop-based biofuels, so-called “advanced and waste” biofuels are foreseen as a key pillar of European fuel mandates. In this report, T&E evaluates their environmental impacts, limited availability and fraud risks.

Europe’s increased ambition for advanced and waste biofuels

As part of the “Fit for 55” package, several policies mandate the use of advanced and waste biofuels. The main policy tool is the Renewable Energy Directive (RED, or REDIII), but the Fuel EU and ReFuel EU regulations also provide support to these biofuels, for shipping and aviation specifically. Under the Annex IX of the RED, advanced and waste biofuels are distinguished between materials requiring novel biofuels technologies (Part A), such as forestry residues, and mature pathways, such as used cooking oil and animal fats (Part B). With REDIII's enhanced ambition, a new combined objective of 5.5% for both renewable hydrogen derivatives and Part A biofuels must be met by 2030, which will likely trigger a push for presumably cheaper Part A biofuels. On the other hand, Part B feedstocks are limited to 1.7% of the total transport energy.

Altogether with increased targets, **the inclusion of the aviation and maritime sectors in the scope is expected to triple the demand for Part A feedstocks** by 2030 compared to 2022 and de facto **raises the current cap on Part B materials** by 20%. The number of incentivised feedstocks in Annex IX also increased, with the recent addition of five feedstocks in Part A and four in Part B, such as intermediate crops or crops grown on degraded land.

Oily feedstocks’ current dominant contribution

In recent years, the use of advanced and waste feedstocks has been growing significantly, slowly replacing food and feed-based biofuels and reaching **40% of all biofuels consumed in 2022.** The same year, thanks to double-counting mechanisms, Annex IX biofuels made up almost 60% of the overall biofuels' contribution to the transport target. Biofuels overall covered close to 7% of transport energy demand in the EU.

Feedstocks such as used cooking oil and animal fats accounted for almost two thirds of advanced and waste volumes, followed by industrial waste and Palm Oil Mill Effluent feedstocks which increased by significant volumes. While Italy, Spain, and Germany accounted for more than half of Annex IX biofuels consumed in 2022, Sweden was proportionally the largest user, covering 13% of its transport energy with advanced and waste biofuels.

Questionable environmental benefits

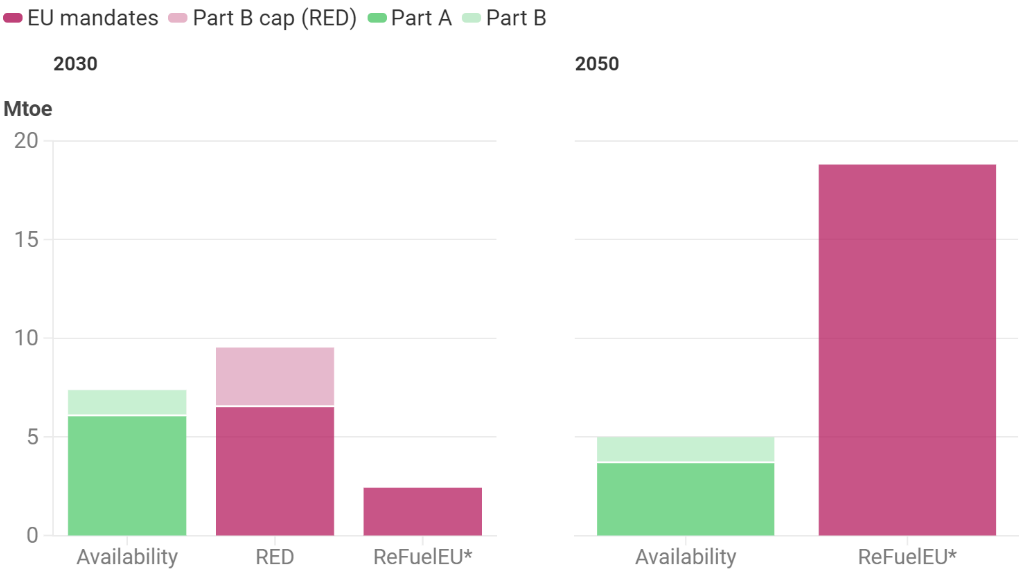
Despite being increasingly advertised as a green solution, using advanced and waste materials to produce biofuels comes with significant challenges. Burning biomass still releases greenhouse gas emissions and it can take years, or decades in the case of wood, for the emitted carbon to be captured again. Incentivising the use of primary forestry residues, such as bark or tree tops, essential to regeneration and biodiversity, will likely result in increased pressure on European forests, where harvesting rates are already very high. Although using land for biofuels has proven to be highly inefficient and has caused land-use change, intermediate and other energy crops are considered "advanced" and will likely increase pesticides, fertilisers and water usage.

Moreover, most feedstocks in Annex IX are already employed in other sectors, such as sawdust for material applications or crude glycerine in the chemical industry. Diverting these feedstocks may lead to indirect emissions if their existing applications start to use less sustainable materials, potentially cancelling any savings compared to fossil fuels.

Sustainable feedstocks, a very scarce resource

While used cooking oil or animal fats categories 1 and 2 can be sustainable feedstocks, domestically available volumes are very limited and already largely processed as biofuels. Other feedstocks such as the biodegradable fraction of municipal and industrial waste or sewage sludge might also be deemed sustainable, but associated processing technologies are still very uncertain today and these volumes should decrease in the future thanks to increases in recycling and reusing. Altogether, truly sustainable biofuels are thus expected to be scarce and will not be enough to meet ambitious EU mandates for decarbonising the transport sector in the long run. Renewable hydrogen fuels will be essential to decarbonise the aviation and shipping sectors and zero-emissions vehicles, especially electric, are the best available options to decarbonise the road sector.

European mandates higher than sustainable biofuels availability



Source: Transport & Environment, based on data from the ICCT, Greenea, EFPRA and 2synfuel • Sustainable feedstocks include the biodegradable fraction of municipal waste and sewage sludge (Part A) and domestically collected used cooking oil and animal fats categories 1 and 2 (Part B). *ReFuelEU mandates include both Part A and Part B feedstocks.

Inevitable risks of fraud

As a result of high incentives and increased reliance on imports, advanced and waste biofuels, such as UCO, palm derivatives, intermediate crops and crops grown on degraded land, are more and more susceptible to fraud. While the long-awaited EU Union Database is supposed to improve transparency along the biofuels supply chain, the certification processes' inherent weaknesses make it unlikely to stop fraud on its own. Instead, the EU and its member states must take other steps to combat fraud effectively and ensure truly sustainable feedstocks are used for the production of biofuels.

Recommendations

1	Remove problematic feedstocks from the Annex IX list or at least limit their contribution to the RED targets.
2	Identify domestic availability before setting targets, with a special attention to the cascading principle and the waste hierarchy.
3	Set the target for advanced biofuels at maximum 3.5%, with double counting. Keep a cap on Annex IX part B at 1.7% or lower.
4	Require more information from economic operators and enforce rules for more transparency per fuel supplier.
5	Tackle fraud with the creation of a dedicated fraud investigation unit and by completely reviewing the certification system.
6	Focus on cleaner alternatives for the decarbonization of the transport sector: prioritise direct electrification and target hydrogen and e-fuels for shipping and aviation.

T&E position on advanced and waste biofuels

Palm derivatives
Directly related to deforestation, Palm Fatty Acid Distillates (PFAD) should not be used for biofuels, while other residues such as Palm Oil Mill Effluent (POME) should be used in producing countries.

Forestry residues
Primary forestry residues are essential for forest regeneration, biodiversity and carbon sinks and should be left in forests. Secondary residues from wood transformation should be prioritised for long-lasting application such as biomaterials.

Intermediate crops
With risks of triggering additional demand for land, increasing the use of fertilisers, pesticides and irrigation, intermediate crops should be prioritised for non-energy uses.

Energy crops
Difficult to monitor and potentially subject to fraud, crops grown on severely degraded land and other energy crops should not be used for biofuels, as rewilding could bring more climate and biodiversity benefits.

Agricultural residues
Since agricultural residues are already used for soil amendments and biogas production and are anticipated for various biomaterial applications like building insulation, they should not be prioritised for biofuels production.

Used cooking oil
Waste oil collected from households or restaurants can be used to produce sustainable biofuels if collected domestically. Imported feedstocks or biofuels are likely subject to fraud and should be prioritised for the producing countries' own needs.

Animal fats
By-products of industrial meat production, animal fats in categories 1 and 2 can be considered as a sustainable source for biofuels production if collected domestically. Because of existing uses as animal feed or in the oleochemical industry and high risks of indirect emissions, animal fats in category 3 should not be used for biofuels.

Biodegradable fraction of municipal and industrial waste
While mixed fossil waste should not be used for biofuels, separately collected biowaste could provide emission savings when converted to biofuels. However, their availability is expected to decrease with increased reuse and recycling efforts and conversion processes are still uncertain.

Sewage sludge
Produced from wastewater treatment facilities, sewage sludge can be used to produce sustainable liquid biofuels, but conversion processes remain currently uncertain.

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Introduction

As substitutes to conventional crop-based biofuels, which have been proven to damage the climate and the environment [1], “advanced and waste” biofuels are more and more promoted as sustainable alternatives. While recent trends show that waste-based biofuels produced from used cooking oil and animal fats reached one third of the European Union’s consumption of biodiesel in 2022 [2], very little data is available regarding advanced biofuels feedstocks’ development.

Advanced and waste feedstocks are listed in the Annex IX of the Renewable Energy Directive[1] and receive a special treatment to be incentivised towards the transport target. In theory, the Part A of the Annex IX refers to feedstocks that require novel technologies, such as municipal solid waste or forestry residues, while the Part B includes feedstocks that can be processed through mature technologies. In addition, other biofuels, such as animal fats Category 3 or Palm Fatty Acid Distillates (PFAD), are not explicitly part of the Annex IX nor of the category of food and feed crops, but are increasingly advertised as sustainable feedstocks.

The revised RED targets adopted in spring 2023 include for the first time a combined subtarget of 5.5% for both advanced biofuels and renewable hydrogen derivatives by 2030. Part B feedstocks remain in theory limited to 1.7% of the total transport energy, but national governments can derogate to this limit. Despite many concerns regarding the sustainability of these feedstocks, the Annex IX list keeps being expanded and risks reproducing similar flaws as with the promotion of unsustainable crop-based biofuels [3].

In this report, Transport & Environment analyses most recent trends on advanced and waste biofuels and attempts to evaluate the sustainability and availability of the feedstocks that are promoted in the RED. Analysing current and projected uses as well as highlighting increasing risks of fraudulent practices, this assessment aims to provide a critical overview of the Annex IX and suggests options for Member States to ensure strong safeguards are included in the national implementation of the RED.

[1] The full list of feedstocks can be seen in the Annex 1 of this report.

1. Advanced and waste biofuels in the EU: trends and context

1.1. Annex IX biofuels consumption

As part of the Renewable Energy Directive, Member States are required to report their consumption of different renewable energy sources, including biofuels. The Short Assessment of Renewables Energy Sources (SHARES) tool [4] is designed to aggregate energy data and calculate the contribution of renewables to the RED targets. This database then discloses the consumption of biofuels, including advanced and waste feedstocks from the Annex IX, and its analysis provides an overview of the current trends across the EU.

A shift from crops to advanced and waste feedstocks?
While biofuels volumes reported by Member States have been historically almost exclusively produced out of crops, Figure 1 shows a clear uptake of advanced and waste biofuels in recent years. The share of Annex IX biofuels indeed grew from representing 7% of all compliant biofuels in 2011 to almost 40% in 2022, equivalent to a thirteenfold volume increase. Between 2021 and 2022 alone, advanced and waste biofuels consumption increased by 20%. At the same time, the volumes of food and feed based biofuels have been declining since 2019, reaching in 2022 their lowest level since 2013.

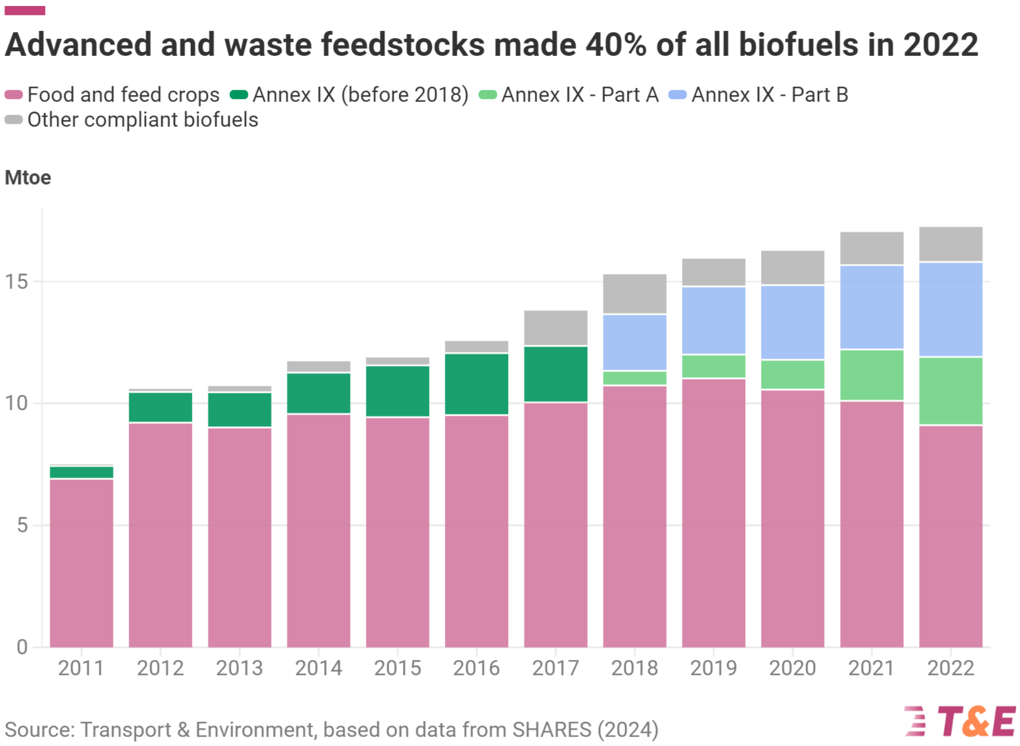

Figure 1: Biofuels consumption reported to the EU (2011-2022)

While total compliant biofuels consumption represented 6.6% of transport energy in the EU in 2022, their contribution to the RED transport target actually reached around 8.8%[2] thanks to the double-counting mechanism incentivising advanced and waste biofuels. Annex IX biofuels therefore represented almost 60% of the overall biofuels' contribution to the RES-T target.

[2] This figure may not reflect the exact biofuels contribution to the RES-T target because of the cap on Annex IX Part B feedstocks. SHARES reports an overall target of 9.6% when taking into account renewable electricity used in transport, on top of biofuels.

Oily feedstocks' overwhelming contribution to Annex IX biofuels

Looking more closely at the Annex IX data from SHARES, around 60% of reported biofuels volumes were classified as Part B feedstocks in 2022, with used cooking oil accounting for almost half of all advanced and waste biofuels. Figure 2 shows that industrial waste listed in Part A were the second most reported feedstocks, with around 20% of Annex IX volumes, followed by animal fats categories 1 and 2 and Palm Oil Mill Effluent (POME). Industrial waste, a broad category that may include waste from food processing, brown grease and even potentially Palm Fatty Acid Distillates (PFAD), also benefited from the largest absolute increase between 2021 and 2022, with a 60% jump in volumes being reported.

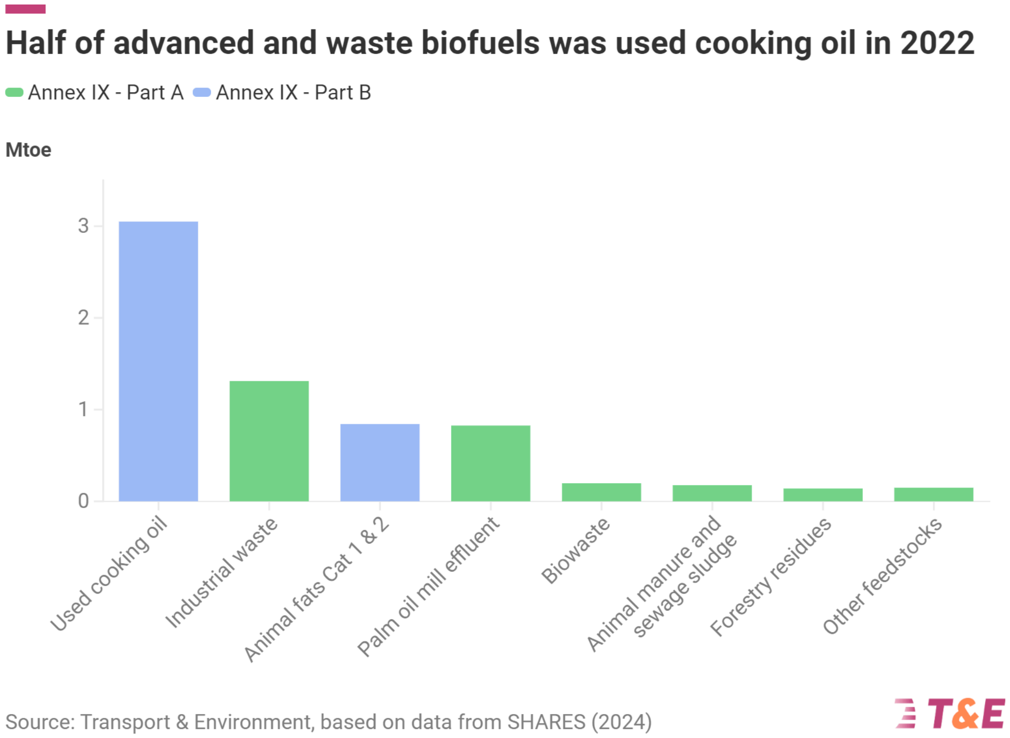

Figure 2: Advanced and waste biofuels consumed in the EU in 2022

Member States' bet on specific feedstocks

In 2022, six countries totalled around 80% of the advanced and waste biofuels reported in the EU, with Italy, Spain and Germany consuming more than half of volumes alone (Figure 3). Sweden was the largest consumer in relative terms with almost 13% of its overall transport energy being covered by Annex IX biofuels in 2022.

Unlike other Member States, Spain's advanced and waste volumes consisted mainly of Part A feedstocks, which represented around two thirds of the country's Annex IX biofuels. Industrial waste biofuels indeed grew by 160% in Spain between 2021 and 2022 and made the largest share with more than 40% of the country's reported volumes.

In addition, POME biofuels volumes grew three-fold between 2021 and 2022 in Germany, making it the country most responsible for the increase in POME consumption in the EU. In 2022, these palm derivatives thus accounted for almost a fifth of all Annex IX biofuels in Germany.

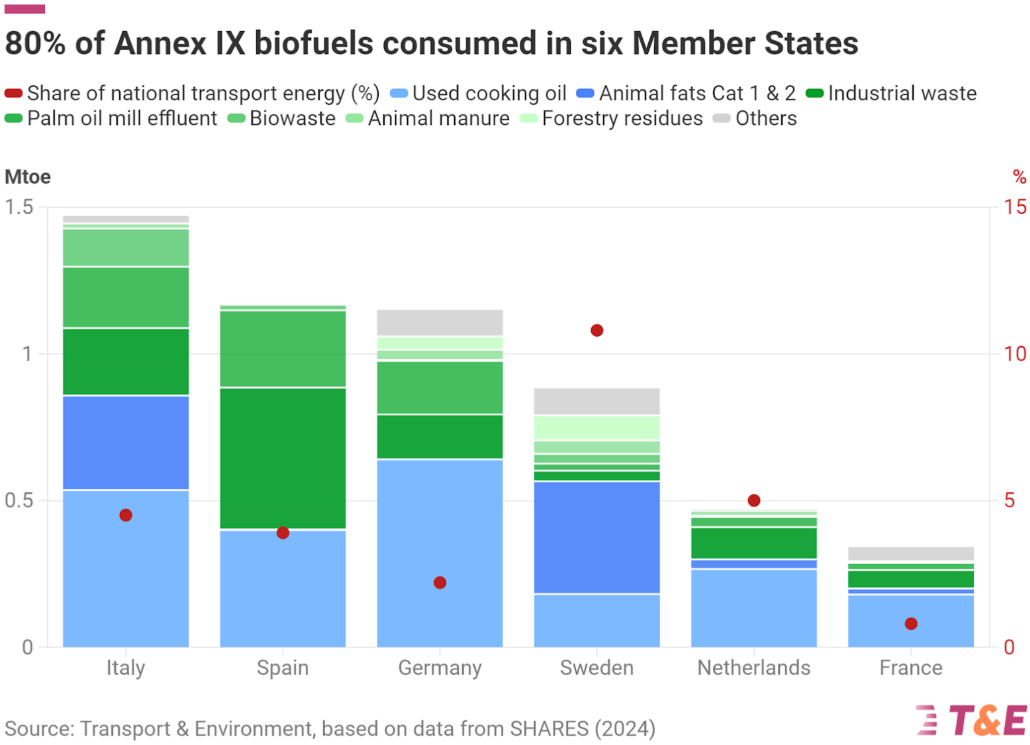

Figure 3: Annex IX biofuels consumption in main EU countries in 2022

1.2. RED revision and enlarged list of advanced feedstocks

In 2023, the revised Renewable Energy Directive introduced a combined subtarget for green hydrogen derivatives and advanced biofuels of 5.5% by 2030, including a minimum 1% supply of Renewable Fuels of Non-Biological Origin (RFNBOs).

Increased targets and enlarged scopes will lead to higher advanced and waste biofuels volumes
Taking into account the double-counting mechanism that promotes the use of advanced feedstocks as well as the incentive to use such biofuels in the shipping and aviation sectors[3], the share of advanced biofuels should actually reach between 1.9% and 2.25% of the EU's transport final energy consumption by 2030[4]. Moreover, the expansion of the transport target to the international aviation and shipping sectors will further increase the overall scope and the volumes required to meet a given target will thus be larger [5].

The combined scope expansion and increased target will result in a tripled consumption of advanced feedstocks by 2030 compared to current consumption levels (Figure 4). Similarly, the unchanged 1.7% limit on Part B biofuels will in practice lead to a 20% increase of the cap volumes because of the addition of maritime and aviation fuels to the target denominator. However, Part B consumption seems to be already above both the cap in any case, due to flexibility granted to Member States [6].

[3] A multiplier of 1.2 applies to Annex IX Part A volumes specifically used in the shipping and aviation sectors.
[4] Depending on if all or none of these advanced biofuels go to the aviation and shipping sectors, as shown in Figure 4.

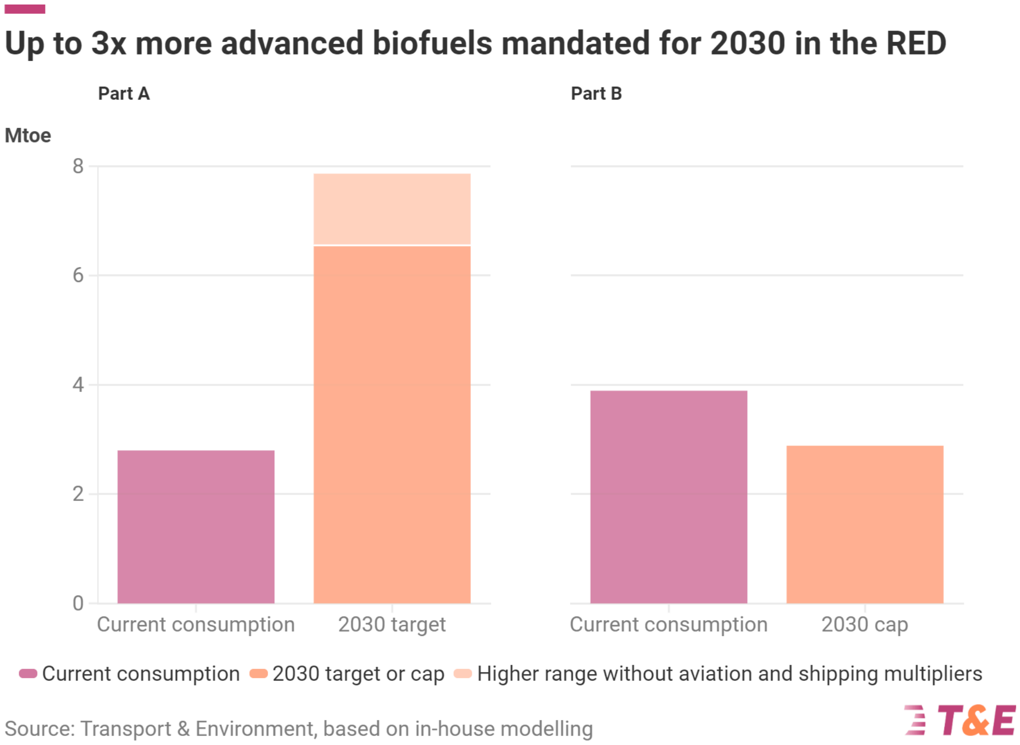

Figure 4: 2022 Annex IX consumption vs 2030 RED target and cap

Expansion of Annex IX feedstocks
On top of the original 17 and 2 feedstocks respectively included in Part A and Part B of the Annex IX of the RED, 5 additional feedstocks have been recently classified in Part A and 4 in Part B [7][5]. Most of the new feedstocks relate to some form of crops, such as intermediate crops, damaged crops or crops grown on degraded land which raises many concerns over their sustainability and risks of fraud. These aspects will be covered in Section 2.

Moreover, for the first time this list is differentiating between biofuels produced for the aviation sector (Part A) and for other transport sectors (Part B), following an intense lobbying by both fuels suppliers and the aviation industry [8]. For instance, intermediate crops and crops grown on severely degraded land will be accounted for in Part A if used in the aviation sector or in Part B if used in road or shipping transport.

2. Potential and impacts of advanced and waste feedstocks

The Annex IX of the Renewable Energy Directive differentiates between feedstocks that can only be processed with advanced technologies, such as gasification or pyrolysis, and feedstocks that can be processed only with mature technologies, such as hydroprocessing. Regardless of the biofuel pathway, so-called advanced and waste feedstocks can have different environmental impacts, depending on their origin, extraction process and current uses. This section aims to assess the potential and impacts of key feedstocks.

[5] See Annex 1 for the full list of feedstocks now part of the RED Annex IX.

2.1. Part A: POME and palm derivatives

Description and current uses

As part of the Annex IX Part A (g) sub-category, **Palm Oil Mill Effluent** (POME) and **Empty palm Fruit Bunches** (EFB) are residues of the extraction of palm oil, mainly in South-East Asian countries. More specifically, POME is a wastewater generated from palm oil milling activities that can be harmful for the environment. Such waste is nowadays often treated in anaerobic open ponds to limit the hazardous pollution before being discarded, but the decomposition of POME releases methane, which has a significant climate impact. Empty fruit bunches and other palm residues are currently partly used as a soil amendment, to provide organic carbon and nutrients to the soil while reducing erosion, and in some cases combusted to produce heat and power for palm mills [9].

POME contains palm oil sludge which can be converted into biodiesel (FAME), renewable diesel (HVO) or biokerosene (HEFA) as any other oily feedstock. Empty fruit bunches and other solid residues could also be converted into advanced biofuels, for instance as lignocellulosic ethanol or as synthetic hydrocarbons.

In 2022, EU Member States reported a consumption of around 800 thousand tonnes of oil equivalent (ktoe) of biofuels processed out of POME and EFB [4]. Given that EFB conversion to biofuels will require advanced technologies that are not fully mature yet, it is very likely that most of the volumes are referring to POME. In addition, trade records show that the same year the EU imported around 0.2 Mt of POME from Indonesia and Malaysia [9], implying that most of the consumed volumes may have been imported as already refined biofuels.

Availability and projected competing uses

With palm production generating around 2% of palm oil sludge, it is estimated that the global availability of palm oil sludge could be around 1 Mt per year[6] [11].

However, palm oil producing countries are more and more looking into POME for biogas production. Methane released during the anaerobic treatment of POME wastewaters can indeed be captured, purified and used for energy. Such pathways are promoted to reduce methane emissions while decarbonising local power generation. In 2019, Malaysia had almost one third of its palm mills equipped with biogas capture facilities and is planning more [12]. As for other palm residues, POME is increasingly foreseen as an interesting fertiliser in replacement of fossil fertilisers to improve soil quality.

Emissions and other environmental impacts

POME and other palm derivatives' emissions are not explicitly detailed in the RED. The ICCT estimates that direct emissions of POME HVO should be around 27 gCO_{2eq}/MJ, equivalent to a 71% emissions reduction compared to fossil fuels [13].

Potential indirect emissions of POME are not known as of today. The increasing competition with uses should nonetheless be monitored as it could lead to displacement effects, if fossil fuels were to be used instead. Furthermore, POME and EFB are currently considered as residues of the palm oil industry and therefore the EU rules do not require as much traceability to prove that the initial palm oil was not linked to direct deforestation. Because of its link with other palm oil products and limited traceability, POME is

[6] It is also estimated that empty palm fruit bunches production is in the order of 48 Mt per year, assuming an EFB yield of 1.6 t/ha per year [9] and a global harvested area of 30 Mha in 2022 [10], but biofuels technologies to process such materials are not yet developed at large scale.

classified as subject to high risk of fraud in the European Commission's feedstock assessment study [14].

Hide and seek with PFADs in the RED?

Incorrectly considered by biofuels producers as waste or residues from the production of palm oil, **Palm Fatty Acid Distillates** (PFAD) are in fact lower quality palm oil by-products that can be processed into biofuels and other products. As such, PFADs are associated with similar impacts on deforestation as conventional palm oil and their conversion to biofuels is estimated to reach up to 230 gCO_{2e}/MJ in the worst case [15], more than twice the emissions of fossil diesel and quite close to the emissions of palm oil biofuels [16].

Market data show that the consumption of PFAD biofuels has increased by close to 30% since 2020, in particular in countries such as Sweden and Finland, reaching almost a third of all palm biofuels in 2022 according to T&E analysis [2]. However, such palm derivatives consumption is not directly reported by EU Member States in the RED because PFAD is not directly listed in Annex IX. It is thus very hard to assess their official consumption and complicated to evaluate if some of the volumes are being reported in some of the Annex IX categories or not.

Some countries such as Germany, the Netherlands or Sweden do not classify PFADs as a residue under their national RED implementations and therefore PFAD volumes should not be reported in any of the Annex IX categories. However, it is not the case for most EU countries and subcategories with particularly high volumes such as industrial waste (Part A (d)), POME (Part A (g)) or "other compliant biofuels" may include PFADs.

Position and recommendations

Unlike crude palm oil and PFAD, **POME** and **EFB** are residues of the palm oil industry and are therefore not directly associated with deforestation in South-East Asian countries. But their uses in EU biofuels should be avoided and prioritised for local uses where they can help decarbonise producing countries, especially with emerging alternative uses such as biogas or fertiliser production.

2.2. Part A: Forestry residues and other derivatives

Description and current uses

Forestry residues are part of the Annex IX Part A (o) sub-category and include many products from the forest industry: bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil. Other sub-categories such as tall oil pitch (h) or *other ligno-cellulosic material except saw logs and veneer logs* (q) are also derivatives of the wood or paper industry considered as advanced feedstocks in the RED. Recently added *raw methanol from kraft pulping stemming from the production of wood pulp* (s) is also an indirect residue from the woody and forestry materials.

Primary forestry residues are defined as residues generated inside the forest and most are currently either left on the ground to maintain biodiversity and forest soil fertility or used by various industries. Bark is for instance used for mulch or energy, pre-commercial thinnings are usually left to the soil or used as materials for wood panels or paper, while fine wood debris such as leaves, needles and twigs are essential for forest regeneration [17]. Tree tops and branches constitute the largest volumes of forestry residues and have been traditionally used for fuel wood. But as much as possible of these coarse woody debris should stay in forests for climate and biodiversity purposes [17].

The forestry methods used to produce the wood also make a big difference to its climate and biodiversity impact. Unlike conventional practices relying mostly on clearfelling, where most if not all the woody biomass is removed from the logging area, continuous cover forestry can prevent soil erosion and maintain forest soil health [18]. This considerably limits biodiversity losses and climate damages from the harvesting process. However, sustainability criteria included in the RED for woody biomass do not guarantee at all that more sustainable forestry methods are used [19].

Secondary forestry residues, defined as residues generated by any wood transformation taking place outside of the forest, can include saw dust and cutter shavings which are mostly used for paper, wood products or energy. Black and brown liquor, fibre sludge and tall oil are all derivatives from the pulp and paper industry and can be used for energy or as raw materials for the chemical industry.

In 2022, around 140 ktoe of biofuels produced from forestry residues (Annex Part A (o)) were reported by EU Member States, equivalent to less than 5% of Annex IX Part A volumes, with nearly two thirds of volumes used in Sweden. The consumption of materials classified in Annex IX Part A (h) and (q) were close to zero the same year.

Availability and projected competing uses
Current uses of wood residues are estimated to be around 2.4 EJ, the equivalent of 130 Mt of dry wood per year in the EU[7] of which one quarter are primary residues and three quarters secondary residues, according to a study by Material Economics commissioned by the European Commission [20]. While primary residue volumes may slightly increase with higher removal rates from forests, the study concludes that any growth in the supply of forestry residues will rapidly create risks for carbon cycles and biodiversity. It must be noted that the land carbon sink in the EU has already been in rapid decline since 2010 due to overlogging partly driven by bioenergy, as well as the climate and biodiversity crisis, and that increasing woody biomass extraction from forests will likely worsen the situation [21] [22].

Emissions and other environmental impacts
While forestry residues are often promoted as sustainable feedstocks for the production of advanced biofuels, their uses can raise several environmental concerns. First of all, wood burning emits at least as much greenhouse gases and numerous pollutants at combustion point than fossils, and it takes many years for tree growth to sequester again the carbon that was lost in a few minutes or hours. For this reason, all uses of woody biomass create an initial carbon debt compared to the continued use of fossils, and in the case of whole trees[8] this debt can be counted in decades or even centuries [23].

Primary forestry residues such as tree tops, leaves or needles are indeed essential to preserve forests' soil health and biodiversity, as forestry residue removal decreases soil quality and affects wood productivity [24]. Similarly, pre-commercial thinnings are young trees, presumably extracted to create more growth space for other trees, but their promotion for biofuels production in the RED risks increasing the felling of young trees beyond sustainability limits. This would worsen the decline in European mature forests, despite tall and old trees storing more carbon and being key biodiversity safeguards [25].

[7] Assuming an average energy density of 18 GJ/t for wood products.
[8] Due to market incentives enabled by the RED, many whole trees that do not have a higher economic value as something else than an energy source can be logged for energy production.

While global tree cover has already fallen by 12% since 2000 [26] and tall European forests have lost 3% of their area since 2001 [27], wood consumption appears to exceed local forest supply in many European countries [28] with on average three quarters of EU forest net growth being already harvested [20]. Incentivising the use of forest residues beyond current supply levels would further increase pressure on forests and damage carbon sinks and biodiversity.

Finally, diverting forestry residues that have existing uses towards biofuels may also cause indirect emissions, if current applications would start using more emitting materials. Figure 5 shows total emissions from forestry-based advanced biofuels, highlighting the high uncertainty around some residues and the absence of any emissions savings for others. While biofuels derived from **secondary residues** such as sawdust or black liquor could bring savings compared to fossil fuels after some time[9], the displacement of current uses could lead to an additional demand for primary wood in material uses (e.g. particle boards) or natural gas in the case of energy uses[10].

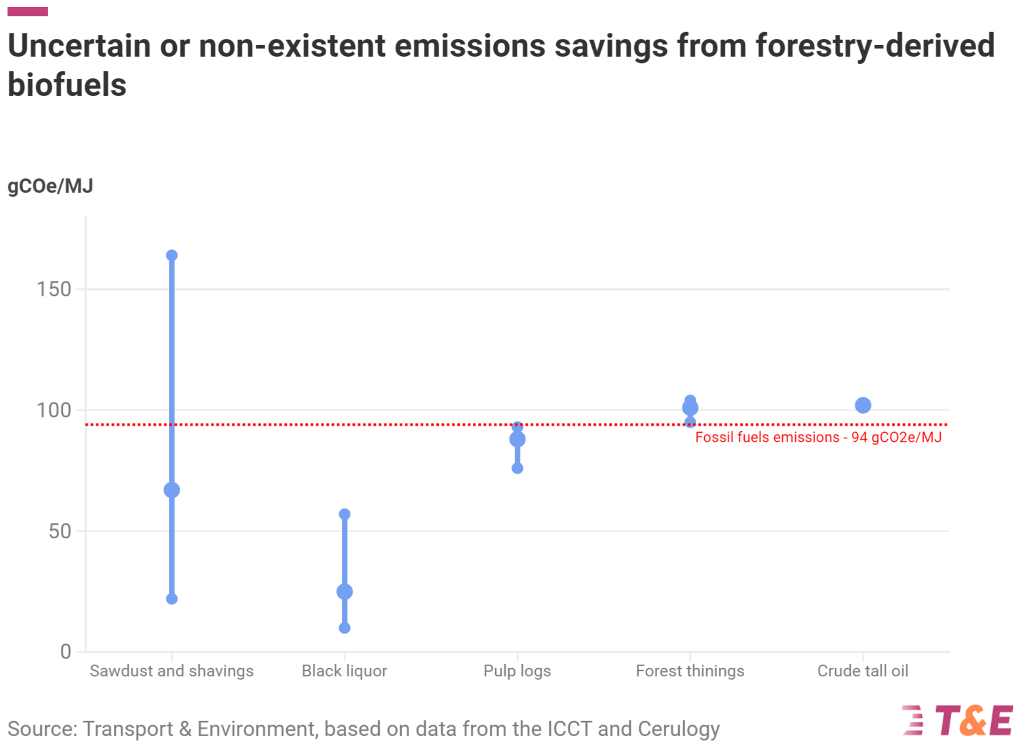

Figure 5: Direct and indirect emissions of forestry-based biofuels

Position and recommendations

- With forests already suffering from high harvesting rates, **forestry residues** should not be used for biofuels production and particularly primary residues which are essential to forest regeneration and biodiversity.
- Following the cascading principles, the use of sustainably collected woody biomass should be prioritised in long-lasting, high economic-value yielding applications such as biomaterials rather than bioenergy, in order to maximise carbon storage cycles.

[9] Respectively 30% and 70% compared to fossil fuels on average, according to Cerulogy [29].
[10] Increased wood consumption to replace existing uses of forest residues could lead to additional wood harvesting, which could have an impact on forest carbon stocks, depending on forest management practices, and therefore lead to indirect emissions [13, 29].

- Because of existing uses and uncertainties around their actual emission savings, secondary residues produced from the transformation of wood should also be avoided.

2.3. Part A: Biodegradable fraction of municipal and industrial waste

Description and current uses

Waste-to-fuels technologies are considered in the Annex IX Part A of the RED through different feedstock categories. For instance, it includes the **biomass fraction of mixed municipal waste**, which corresponds to organic household waste that has not been collected separately (Part A (b)), unlike **biowaste from private households subject to separate collectio**n (Part A (c)). While the biomass fraction of mixed municipal waste has been historically landfilled, such treatment currently only processes a quarter of waste volumes, as does incineration, with recycling and composting representing nearly half of waste treated [30].

Moreover, Annex IX Part A (d) includes the **biomass fraction of industrial waste** that is not fit for use in the food or feed chain, including materials from the agro-food and fish industry but excluding feedstocks listed in Annex IX Part B. This very broad category could include industrial organic waste such as waste paper, cardboard, food waste occurring at the production stage. Most of this industrial biowaste is already either recycled, composted or used for biogas production [31]. Other materials such as brown grease, which is a mix of fats recovered from grease traps in different industries, may also fall within this subcategory, as it is very likely the case today in Spain[11].

Reported consumption of biofuels made from biowaste collected separately from households was around 200 ktoe in 2022, while biofuels made from mixed MSW were around 20 ktoe. On the other hand, biofuels from industrial biowaste were the largest contributor to the Annex IX Part A with more than 1300 ktoe reported, equivalent to around half of all advanced biofuels.

Finally, whether it is gasification or pyrolysis pathways, the maturity of waste-to-fuels technologies remains uncertain as MSW carbon content and other properties can vary a lot and be complex to deal with, especially for jet fuel production which needs to meet very specific standards [34] [35].

Availability and projected competing uses

While the biomass fraction of mixed municipal waste is available in large quantities today, the prevention of waste generation as well as increasing reusing and recycling rates will constrain the available volume over time. In their 2021 study, the ICCT estimated that the biomass fraction of MSW available for biofuels production was around 78 Mt[12] in 2020 and will progressively decrease to 67 Mt in 2030 and 37 Mt in 2050 in the EU [36].

Given that part of the energy generated through the incineration of mixed municipal waste is currently recuperated for urban heating or to produce electricity, biofuels from this stream may face some competition with existing waste-incinerators. However, energy recuperation from incinerators suffers from low conversion efficiencies [37] and converting the biomass fraction of municipal solid waste to fuels could thus potentially lead to greater emission savings [38]. In addition, waste incineration is associated with air pollution and can destroy non-hazardous resources that could be reused or recycled in another form. Landfilling waste can also be used to produce methane from the anaerobic

[11] Spain lists such feedstock as advanced and double-counted, with around 23% of its 2022 biodiesel consumption reported to be brown grease according to national statistics [32] [33].
[12] On a dry basis.

decomposition of the biomass fraction of mixed waste, but potential methane leaks and local soil contamination do not make this solution sustainable in the long-term without very efficient capture technologies and the EU aims to phase out landfilling of organic waste [39].

Emissions and other environmental impacts

Converting municipal solid waste to fuel can avoid emissions from landfilling and thus provide emission savings. However, municipal solid waste potentially includes fossil waste such as plastic. Therefore, the biomass waste fraction needs to be high enough to meet the RED emissions savings threshold, as a high fossil fraction can lead to emissions worse than conventional fossil fuels [40] (Figure 6). Because it does not seem realistic to fully sort biowaste from fossil waste[13], using separately collected materials would minimise the risk of having too high fossil fractions and ensure the highest emission savings. This would also align with the EU mandate for separate collection of biowaste starting in 2024 [42].

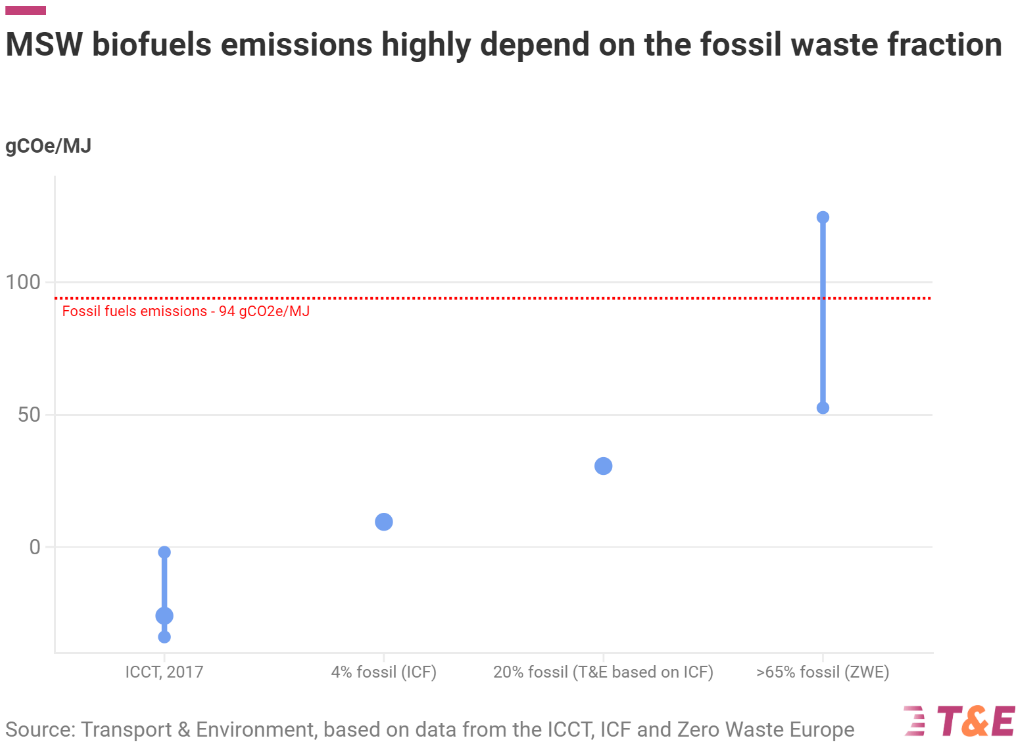

Figure 6: Emissions of municipal solid waste biofuels

However, incentivising MSW for fuel production might compete with increasing recycling rates and slowing down the reduction in waste production in the first place, in particular food waste from households or from the food industry. There is also a risk of lock-in effects for waste-to-energy projects that could prevent higher recycling rates, as it has been seen with 20 or 30 years long “put or pay” contracts in the US which force municipalities to pay for the waste treatment even if volumes are reduced [43].

Position and recommendations

- Using the **biodegradable fraction of waste** as biofuels feedstocks can provide climate benefits but only if it is collected separately from other fossil waste, in accordance with the separate collection obligations.

[13] Municipal Solid Waste sorting efficiency is on average around 80% [41].

- **Unsorted mixed waste** should not be used directly as biofuels feedstocks, as it will always contain fossil-derived materials.

2.4. Part A: Intermediate and energy crops

Description and current uses

Intermediate crops are crops that are grown outside the main growing season, such as catch crops and cover crops that are for instance cultivated during winter. These can include legumes (e.g. varieties of clover, peas, vetch or other beans), brassicas (e.g. rapeseed, carinata or mustard), grains (e.g. oats, rye or winter wheat) and other crops (e.g. silage maize, sudangrass or millet). Currently, intermediate and cover crops typically occupy around only around 3-8% of European arable land [44] [45] and are mostly used for fodder and animal feed production as well as soil fertilising. In tropical regions with more than one growing season, such as in Brazil, intermediate crops are often food and feed crops.

Intermediate crops are defined in a recent delegated act as "*crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest*" [7]. Such feedstocks could be converted to biofuels and have been added to the RED Annex IX with the conditions that "*their use does not trigger demand for additional land, and provided the soil organic matter content is maintained"*. If used to produce biofuels for the aviation sector, intermediate crops are classified in the Part A (t) sub-category, while they are included in the Part B (f) for other transport sectors. The current definition seems to indicate that intermediate crops that are food and feed crops are not eligible.

Energy crops grown on severely degraded land are also included in the Part A (u) of Annex IX. Explicitly excluding food and feed crops, the RED defines "*severely degraded land*" as "*land that, for a significant period of time, has either been significantly salinated or presented significantly low organic matter content and has been severely eroded"*[14]. It is however very unclear how this will be verified in practice.

Additional energy crops such as **other non-food cellulosic materials** are also included in the Annex IX Part A (p). Referring to crops grown solely for bioenergy production, such category includes cellulosic energy crops or grassy energy crops like miscanthus, switchgrass, giant cane, sorghum or hemp grown as main crops. These energy crops are grown on agricultural land, and are perennial, unlike intermediate crops.

Availability and projected competing uses

On top of current uses for animal feed, intermediate crops and other energy crops can be used as biomaterial, for instance for insulation in the construction sector. They are also digested and converted to biomethane, even though such use may face environmental challenges because of the high warming potential of methane leaks [47].

The availability of **intermediate crops** is hard to estimate because of poor data and uncertainty around the requirements for intermediate crops to be beneficial. As an illustrative example, the ICCT estimates that only 10% of land used for annual crops may be dedicated to intermediate or cover crops in 2050 as the compatibility of cover crops with common European crops may also be challenging [48], leaving a limited space for any growth compared to current harvested areas. Moreover, the availability of **energy crops** in general is also hard to assess as it highly depends on the accessibility of marginal or abandoned land, the competing uses for this land and the obstacles to grow crops there (e.g. droughts).

[14] Annex V C.9 of the Renewable Energy Directive [46].

Emissions and other environmental impacts

Intermediate crop biofuels could also cause indirect deforestation in a similar way that food crop biofuels currently do and lead to indirect land use change (ILUC) emissions if their increased consumption globally triggers demand for additional land [49]. While it is explicitly mentioned in the Annex IX that such impact should be avoided, the demand for additional land can be quite indirect and hard to monitor, without robust criteria and verification.

As flagged in the Commission's assessment study, ILUC emissions could in particular happen in the case of intermediate crops grown outside the EU, such as in Brazil, where cover crop practices are already widespread and for which a diversion from traditional food and feed uses could require additional land to satisfy new demand for biofuels [14] [50]. While this case seems to be implicitly excluded from the RED definition, intermediate crops grown in Europe for biofuels could still indirectly impact negatively other regions if global demand for such feedstock and market prices increase significantly, potentially leading to ILUC emissions. Safeguards currently in the Annex IX do not give any guarantee that there will be a strong system put in place to ensure this risk is mitigated, and this is particularly problematic considering that there is no limit in Part A on these feedstocks. Intermediate and cover crops have also been classified as high risk for fraud in the Commission's assessment study [14].

Furthermore, while growing intermediate crops can enhance soil health by reducing soil erosion and nutrient leaching, it can also increase the needs for pesticides and irrigation, especially in arid regions. Incentivising their use for biofuels in the RED can create pressure for high yields that would push farmers into practices that harm the environment and the climate. Depending on the cases, growing intermediate crops could thus have negative impacts on biodiversity and could even compete with sustainable practices such as fallow land and other non-productive areas.

The definition of **energy crops grown on severely degraded land** does not include additional safeguards to ensure that there are no negative impacts on biodiversity, soil and water from growing these crops. According to the Commission's assessment study, most of the degraded land in the future is expected to be located in countries outside the EU, with additional challenges for verification. This is why this study classifies such feedstock as subject to high risk of fraud. Moreover, environmental benefits of growing energy crops on degraded land seem very uncertain as fertilisers, pesticides and irrigation could be largely needed to counterbalance the poor soil quality of such areas [51]. Degraded land could be rewilded and given back to nature with more benefits for the climate & the environment [1].

Indirect land use change emissions of **other energy crops** are likewise very uncertain given the very few studies covering this aspect, and could range between -20 gCO_{2e}/MJ and +45 gCO_{2e}/MJ for perennial grasses, miscanthus and switchgrass depending on the ILUC model used and how effectively forests are protected at the same time[15]. Finally, despite **damaged crops**' definition excluding crops that would be intentionally modified or contaminated, verification will likely be hard to implement, making such feedstock potentially subject to fraud.

Position and recommendations

- In order to bring some local benefits for the soil fertility and minimise their biodiversity impacts, **intermediate crops** should use neither fertilisers or pesticides and they should not compete with fallowland and other non-productive areas that are essential for biodiversity, but current rules do

[15] The GLOBIOM model optimistically assumes that energy crops cannot be grown on high-carbon stock land [52].

not provide certainty that such criteria will be respected. If intermediate crops fulfil the above environmental criteria, they should be prioritised for non-energy uses, such as for production of food and animal feed or use in biomaterials.

- Converting **energy crops** to biofuels is a very inefficient use of land as more climate and biodiversity benefits could be obtained if the land were rewilded [1]. The land could also be used for growing crops for food & feed uses instead of energy. Energy crops grown on agricultural land should thus not be incentivised for biofuels use.
- In the absence of strong sustainability safeguards and because of uncertain environmental impacts, **energy crops grown on severely degraded land** should not be promoted for biofuels. Vague definitions in the RED will also likely make these feedstocks subject to fraud as it will be hard to verify that biofuels produced are actually using crops coming from degraded land [14].

2.5. Part A: Agricultural residues

Description and current uses

Many residues from the agricultural sector are promoted for advanced biofuels production in the Renewable Energy Directive, such as straw (e), animal manure (f), bagasse (j), grape marc and wine lees (k), nut shells (l), husks (m) or cobs cleaned of corn kernels (n).

Agricultural residues could in theory be converted into liquid biofuels through cellulosic ethanol technologies (e.g. for straw) [53] or through more advanced and non yet commercialised biomass to liquid technologies such as hydrothermal liquefaction (e.g. for manure) [54] or other ethanol processes (e.g. wine lees) [55].

Most of these residues, however, have existing uses. Straw, for instance, is commonly employed as a soil amendment, for animal bedding and fodder, as a mulch for vegetable and mushroom production, as well as for energy production. Other residues are also used for soil enhancement (e.g. animal manure, wine lees or corn cobs), for food derivatives production (e.g. alcoholic beverages from grape marc), or for energy and material uses (e.g. animal manure for biogas, bagasse for sugarcane on-site heat and power) [56]. Items recently added to the Annex IX, such as alcoholic distillery residues (r), can be processed in the chemical and pharmaceutical industries or turned into biogas [57].

Availability and projected competing uses

Despite being sensible to yearly variability, significant agricultural residue volumes are being produced in the EU. In terms of total volumes, straw (which commonly includes cereal straw, maize stover and oil crop residues) and animal manure are by far the most important agricultural residues.

While **straw** production is estimated to range around 300 Mt per year in Europe[16] [36, 58], an average of at least 4 t/ha or more than two thirds of residues should be retained on the field for soil health [59]. The availability of straw for liquid biofuels is further limited by economic constraints such as underdeveloped supply chains, uncertain extraction rates depending on local conditions and the necessity to adapt farming practices [53]. In addition, straw has other uses such as for biogas, biochemicals and could be more widely used as insulation material in the building sector [20].

Moreover, the total amount of **animal manure** generated in the EU and the UK is around 1400 Mt per year, more than 90% of which is re-applied to soils as organic fertiliser [60] and the remaining manure is currently prioritised for biogas production [61]. However, in practice, manure is difficult to transport and

[16] On a dry basis.

is generally processed on-site at farms [62]. As in the case of straw, underdeveloped supply chains will limit the availability of manure for liquid biofuels. In addition, the gas produced from manure can be combusted in an on-site boiler, delivering power for farm operations.

Emissions and other environmental impacts

Straw and other residues left in the field are important to create and maintain a high soil organic carbon content [59]. In addition, straw can improve the soil structure, supporting soil organisms and thus prevent erosion, thereby counteracting the negative consequences of industrial farming [63]. Straw can also reduce evaporation from the soil surface, provide water filtration and retention capacity, benefits that are increasingly needed in the context of more frequent droughts [64].

Animal manure used as fertiliser can substitute a part of mineral fertilisers, increases soil carbon stocks, promotes plant growth, provides nutritious food to soil organisms, and improves physical soil properties [60]. At the same time, nitrates from livestock manure are a major source of water pollution in Europe [65] and using manure gas for on-site power generation could be cost effective with moderate incentive value while providing emissions reductions [62]. When used to produce biogas, emission savings from manure biomethane however vary widely depending on practices [66] and such material rely largely on industrial farming which is responsible for significant impacts on the environment [67].

Position and recommendations

- In the absence of the implementation of strong criteria to ensure crop residue harvest does not exceed what is needed to create and maintain soil health, **agricultural residues** should not be promoted for biofuels. While the RED mentions that these residues can count towards transport targets "*only where operators or national authorities have monitoring or management plans in place in order to address the impacts on soil quality and soil carbon*", it remains very unclear how this will be implemented. The text does not offer strong enough safeguards to ensure sustainable harvest of agricultural residues and does not factor in their many existing and potential competing uses.
- Similarly, the use of **animal manure** as fertiliser should be prioritised over biofuels production, with a view to enhance soil biodiversity. This should be done while remaining within sustainable limits, to avoid reliance on unsustainable large scale farming and pollution.

2.6. Part A: Other feedstocks

The Annex IX Part A of the Renewable Energy Directive also includes other feedstocks with either more uncertainty or more limited volumes than for the materials detailed in the previous sections.

Crude glycerine (Part A (i)) is a by-product of biodiesel production[17]. While glycerine is produced at around 10% the rate of biodiesel [68], it is already widely used today in chemical and pharmaceutical applications. Direct and indirect emissions of glycerine-derived methanol are estimated to be around 28-42 gCO_{2e}/MJ [29] and would thus be higher if additional methanol-to-fuel conversion steps would be accounted for [69]. Given the risk of indirect emissions related to existing competing uses, crude glycerine does not appear as a sustainable feedstock for biofuels production. Moreover, the projected slowdown in FAME production due to road transport electrification will further limit waste glycerin availability in the future.

[17] Fatty Acid Methyl Ester (FAME).

Sewage sludge resulting from wastewater treatment facilities presents the advantage of being a steady and abundant supply with about 10 Mt dry matter generated each year [70]. When treated to prevent any health risk, sewage residues can be used as fertiliser given its high nitrogen and carbon contents. In addition, sewage sludge is already partly used for biomethane production in Europe [61, 71]. Innovative technology pathways, such as thermo-catalytic reforming could also be used to convert such feedstock into biofuel [72], [73], but scalability of such processes still needs to be proven.

Finally, novel feedstocks such as **algae** (subcategory (a)) or recently added **cyanobacteria** (v) have been promoted for many years as third-generation biofuels. However, most research projects looking into these feedstocks seem to face many technical and financial challenges preventing them from scaling up beyond laboratory [74]. Such feedstocks thus appear very uncertain to supply significant biofuels volumes [75].

2.7. Part B: Used cooking oil

Description and current uses

Used cooking oil (UCO) is one of the most mature waste feedstock incentivised in the RED as part of the Annex IX Part B (a), as its conversion to biofuels uses conventional technologies such as FAME or HVO. Such waste can be collected in restaurants or in households and it can be used to produce biofuels but also as a chemical input for soap and fertiliser production or in some cases for animal feed[18].

As shown in Section 1, UCO is the largest Annex IX feedstock consumed in the EU with more than 3 Mtoe of UCO-based biofuels reported by Member States in 2022. However, around 80% of the UCO volumes used in EU biofuels are currently imported from non-EU countries, with China accounting for 60% of the imports [2].

Availability and projected competing uses

Based on the European potential from restaurants, households and the industry sectors, it is estimated that up to 1.5 Mt of UCO could be collected each year in the EU [76]. While the ICCT estimates the potential for UCO collection in Asian countries to be around 8 Mt [77], with more than 5 Mt in China, these volumes may be better used to decarbonise the producing countries' transport sector [78] and are therefore not considered as available for the EU needs.

On top of that, T&E's recent commissioned analysis suggests that EU UCO collection has been around 0.8 Mt in recent years with most of the professional sectors' potential already tapped. While some capacity for increased collection in EU households remains, feasibility and logistics complexity may limit any major growth potential [79].

Finally, UCO is almost exclusively converted to conventional FAME biodiesel today, making it available for road transport despite direct electrification being more sustainable. However, airlines and fuel suppliers are more and more promoting waste feedstocks and UCO in particular to produce Sustainable Aviation Fuels (SAF), showing how the competition for such limited material is already happening.

Emissions and other environmental impacts

While direct and indirect emissions of UCO biofuels are estimated to be on average 74% lower than fossil fuels' emissions[19], the environmental impacts of UCO remain unclear with regards to high fraud

[18] Such use is prohibited in the EU according to Regulation (EC) No 1069/2009, but is allowed in other regions.
[19] 24 gCO_{2e}/MJ, taking into account RED direct emissions of 11.2 gCO_{2e}/MJ and indirect emissions of 13.2 gCO_{2e}/MJ from the ICCT [80].

concerns. Recent increased imports of both raw UCO and UCO-based biodiesel from China and Malaysia as well as increased imports of palm oil from Indonesia to China indeed raise suspicions over palm oil being mislabelled as UCO [2, 81]. Discrepancy between Malaysian collection and export figures also suggests that fraud is happening at scale in the country [82]. For all of these reasons, the Commission's assessment study classifies UCO as high risk for fraud [14].

Given the link between palm oil and deforestation, opening back-door entries to palm oil through incentivising UCO or other waste feedstocks would reduce the benefits of EU countries progressively phasing out palm oil biofuels.

Position and recommendations

- **Used cooking oil** collected in the EU could be a sustainable feedstock for biofuels production but the available volumes will remain limited.
- With high concerns over an increased reliance on fraudulent imports, imports should not be incentivised and UCO collected in other producing countries should be used to decarbonise their own economy.
- While UCO feedstocks are at the moment mainly used for biofuels in the road sector, these biofuels should eventually be used in hard-to-decarbonise sectors such as aviation, while road transport is being electrified.

2.8. Part B: Animal fats

Description and current uses

Animal fats are a by-product of industrial meat production. Just like UCO, they can be processed into biofuels using mature technologies. Animal fats are classified in three categories depending on the risk they pose for human consumption and disease transmission. While **animal fats categories 1 and 2** are associated with high and medium risks, **category 3** is considered to have the lowest risk and is fit for human consumption. Categories 1 and 2 fats are thus included in the Annex IX Part B (b), while category 3 fats are falling under the "other compliant biofuels" which are not subject to specific incentives.

Animal fats categories 1 and 2 have been traditionally used for heating and energy applications and category 3 fats are being used for pet food production and in oleochemical industries. Most of categories 1 and 2 fats have already been diverted to biofuels production [83], with more than 800 ktoe of biofuels reported by EU Member States in 2022.

Availability and projected competing uses

The ICCT estimates that only 0.75 Mt of animal fats biofuels would be sustainably available in 2030 [48], excluding category 3 fats because of competition with other uses. However, data from the renderers industry show that the current European supply is closer to 0.5 Mt [84].

Emissions and other environmental impacts

Direct emissions of animal fat biofuels are estimated to be around 15 gCO_{2e}/MJ in the RED [46]. However, because of competing uses, diverting animal fats to biofuels may lead to displacement effects and indirect emissions if unsustainable materials, such as palm or soy oil, are replacing their current uses. Indirect emissions are estimated to be around 35 gCO_{2e}/MJ for biodiesel derived from category 1 and 2 fats [80] and range between approximately 20 gCO_{2e}/MJ and 140 gCO_{2e}/MJ for animal fats category 3 biodiesel [85], potentially making animal fats category 3 biofuels emissions up to 1.7 times those of conventional fossil fuels.

In addition, data mismatch between supply and consumption data of categories 1 and 2 animal fats suggests that some fraudulent practices may be happening, with for instance category 3 fats being mislabelled as categories 1 and 2 fats, which are highly incentivised. Recent developments in Norway seem to confirm that such fraud is happening, with Esso accused of misclassifying animal fats [86]. Increasing imports of animal fat biofuels are, similarly to UCO, more prone to fraud risks.

Position and recommendations

- Biofuels produced from **animal fats categories 1 and 2** collected domestically, that have the least competing uses, may be considered as a sustainable feedstock. However, the availability of such feedstocks is limited and current trends suggest that current consumption already exceeds sustainable levels, highlighting increasing risks of fraudulent practices.
- **Animal fats category 3** should not be used for biofuels, because of existing uses as animal feed or in the oleochemical industry and high risks of indirect emissions.

2.9. Part B: Other feedstocks

As part of the expansion of the Annex IX list, several feedstocks have been added to Part B. As mentioned in previous sections, **crops grown on severely degraded land** and **intermediate crops** that are not used in the aviation sector are now fully part of the Part B, under subcategories (e) and (f) respectively. Such feedstocks should not be used for biofuels production for the many concerns raised in Section 2.4.

Moreover, **damaged crops** that are not fit for use in the food or feed chain have been included in the Annex IX Part B (c) and could for instance correspond to crops rendered unusable because of poor weather conditions or affected by diseases. Despite the explicit exclusion of materials purposefully modified, strict controls will be hard to implement and these feedstocks will likely be subject to fraudulent practices. It will indeed be complicated to verify that biofuels produced will not use food and feed crops or that they actually come from damaged crops, as it is already the case for UCO and animal fats category 3.

Finally, **municipal wastewater and derivatives other than sewage sludge** have been included in the Part B (d) subcategory. This category being very broad it is hard to assess the availability, current uses and sustainability impacts of these feedstocks for biofuels production.

2.10. Other compliant feedstocks

In addition to food and feed crops and to advanced and waste feedstocks included in the Annex IX, other biofuels feedstocks can still be counted towards the RED transport targets. Despite not being explicitly listed, such materials could include **Palm Fatty Acid Distillates** (PFAD)[20], which are associated with deforestation, or **animal fats category 3** that have many competing uses[21]. Feedstocks from this category have been limited to 3% of aviation fuel in the ReFuelEU mandates [87]. In addition to that, PFADs, palm and soy derivatives, non-Annex IX intermediate crops and soapstocks and derivatives have been explicitly excluded.

[20] See infobox in Section 2.1 for more details.
[21] See Section 2.8 for more details.

Molasses, which are residues from the sugar industry, would also fall under this category. Such feedstock is already widely used today as livestock feed or input for the fermentation industry, for instance to produce alcohol or yeasts. Diverting molasses to fuel ethanol production would thus lead to indirect emissions, with emissions savings estimated to range between 43% and 63% compared to fossil fuels according to the ICCT [88]. This feedstock would therefore not meet the RED GHG threshold and should not be used for biofuels.

Finally, **soapstocks and derivatives** are by-products of vegetable oil refining, such as palm and soy oil, and could also be used for biofuels production. However, they are currently used for animal feed and diverse industrial uses, making their indirect emissions potentially close to those of PFADs [89]. Soapstocks and derivatives should therefore not be used for biofuels.

3. Overall availability of sustainable biofuels

Assessing the availability of biofuels feedstocks is a complex exercise that can be very sensitive to the assumptions taken. Within that context, we have decided to focus on the availability of materials that Transport & Environment considers as truly sustainable, i.e. with the least competing uses and proven emissions savings compared to fossil fuels.

As detailed in the previous sections, only very few feedstocks can be considered sustainable as of today. These include used cooking oil collected in the EU, animal fats categories 1 and 2 as well as the biomass fraction of municipal solid waste if it is collected separately and sewage sludge materials, to ensure the highest emission savings and limit fraudulent practices.

What about other availability studies?

Many studies have been trying to assess the volumes of biomass feedstocks that could be available for bioenergy production. For instance, the Imperial College of London's *Sustainable biomass availability in the EU, to 2050 [90]* report concludes that between 71 and 176 Mtoe of biofuels could be produced from "sustainable" biomass for the EU and the UK in 2050. However, such research does not thoroughly examine the environmental impacts of using certain feedstocks for bioenergy.

As an example, forestry materials are estimated to represent more than 40% of all bioenergy materials in Europe according to the ICL study, with more than half of it coming from stemwood. However, stemwood is basically wood obtained from the core tree trunks and using this for biofuels would be the least sustainable practice. It would essentially mean cutting down forests to produce energy, ignoring the vital role of forests as carbon sinks and as biodiversity hotspots. Primary and secondary forestry residues are likewise considered as available despite their respective fundamental role in forest ecosystems and many existing uses - as explained in Section 2.2.

Similarly, the potential for used cooking oil and animal fats is assessed to be respectively around 7.7 Mt and 2.2 Mt in the EU27 and UK in 2050, despite maximum domestic supply being at most a quarter of this potential[22]. Reaching such volumes would imply increasing even more our current reliance on UCO imports from Asian countries for UCO, regardless of high fraud suspicions, and ignoring the needs of producing countries. Likewise, such high volumes of animal fats would require diverting animal fats category 3 from their current uses with the risk of pushing these existing uses towards less sustainable materials, as detailed in Section 2.8.

Using the different sources mentioned in the respective sections and converting the available volumes to biofuels and more specifically to biojet, Figure 7 shows the advanced and waste biofuels potential for the decades to come[23]. It relies on existing mandates for biofuels adopted under the RED but also ReFuelEU aviation. FuelEU maritime is a regulation that will also drive biofuels into the shipping sector, but it is not part of our analysis. Sustainable advanced and waste biofuels are estimated to be around 7.4 Mtoe in 2030 and 5 Mtoe in 2050, with a slight decline over the year thanks to improved recycling and reusing rates of municipal solid waste. However, these estimates only represent a theoretical potential as significant uncertainty remains around the scalability and ramp-up rates of waste-to-fuel technologies.

Compared to a high traffic scenario in the aviation sector, sustainably available advanced and waste biofuels appear to cover up to 13.8% and 7.5% of the projected jet fuel demand in 2030 and 2050 respectively. In the perspective of reduced traffic and managed demand, bioSAF could then replace up to 14% and 8.8% of fossil jet fuel in 2030 and 2050.

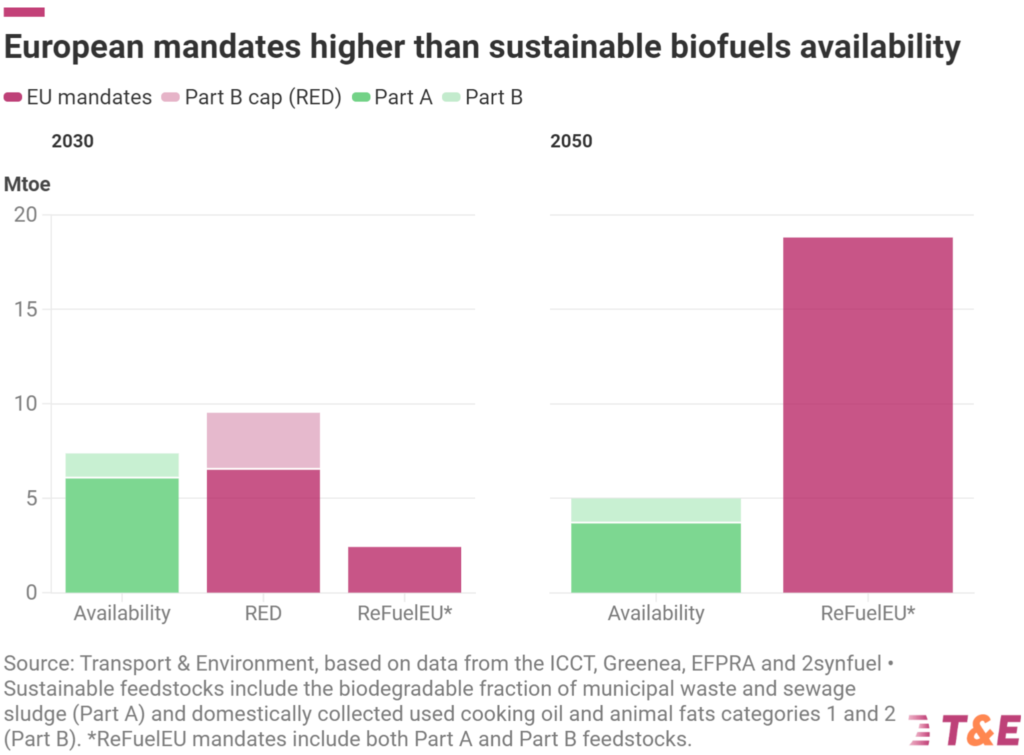

Figure 7: Sustainable biofuels availability vs EU RED and ReFuelEU mandates

Finally, as explained in Section 1, the 2030 RED target for advanced biofuels (Annex IX Part A) converts into 6.6-7.9 Mtoe depending on the share of biofuels that are consumed in the aviation and shipping

[22] As explained in sections 2.7 and 2.8.
[23] See Annex 2 for assumptions and details.

sectors. Comparing the availability figures presented above, this leads to the conclusion that the 2030 target will be very challenging, given the limited volumes of sustainable feedstocks and the uncertainty around the technology scale up for waste-to-fuels.

Position and recommendations

- Because of constrained volumes of feedstocks with proven environmental benefits as of today, current European mandates will likely drive the consumption of unsustainable feedstocks, especially beyond 2030.
- Unsustainable waste feedstocks that have been excluded from ReFuelEU such as PFADs, non-Annex IX intermediate crops, soapstocks and derivatives as well as palm and soy derivatives should also be excluded from the RED and FuelEU maritime targets.
- ReFuelEU and FuelEU maritime should limit the contribution of biofuels to their targets after 2030 and focus on scaling-up RFNBOs.
- As a result, the use of RFNBOs should be prioritised and go beyond the 1% minimum 2030 target in the RED to reach 2%, to ensure that European mandates are fulfilled with truly sustainable materials.

4. Risks of fraud and Union database

The risk of fraud is a major issue for Annex IX advanced and waste biofuel feedstocks. Civil society organisations [82], industry stakeholders [91] and EU member states [92] have expressed serious concerns regarding fraud and its implications for the environment and, for economic operators, the EU biofuels industry.

Fraud is incentivised by a number of factors, including a higher market value for Annex IX feedstocks, evading customs duties and a higher value of emissions credits. There are two main known types of fraud: administrative fraud where a biofuel producer claims and sells more emissions credits than they are entitled to (most common) and feedstock fraud whereby feedstocks that do not qualify for inclusion in Annex IX are reported as waste-based or advanced feedstock (less common) [14].

The highest category of fraud risk is associated with feedstocks whose physical nature cannot be easily identified or when classification of co-product, residue or waste is unclear. Currently there are four Annex IX feedstocks that can be classified as high risk [14]: intermediate and cover crops, biomass from degraded lands, palm oil mill effluent (POME) and used cooking oil (UCO).

The key mechanism proposed by the European Commission to fight fraud is the **Union Database for Biofuels (UDB)** [93]. The UDB is an online registry that aims to improve supply chain traceability by replacing paper-based chain of custody documents with digital consignments, mitigating the risk of double or multiple claiming, irregularities and fraud. However, despite having the potential to digitise and improve the traceability of the biofuels supply chain, proving the authenticity of products registered on the UDB is still reliant on product certification, which is where much of the inherent problems with fraud lie.

Advanced and waste biofuel feedstocks are verified by independent certification bodies that are licensed by select EU-recognised voluntary, government and certification schemes. The first limitation of certification is that the system in which certification bodies operate is market-led, meaning that the primary ambition of relevant economic operators is not driven by environmental concerns, but by the possibility of increased market access and sales. Secondly, the certifying bodies that verify feedstocks are independently selected by economic operators. There are many variations of certification bodies and the licensing schemes governing them, each with different geolocations, auditing mechanisms, quality of standards and implementation. Economic operators can therefore select a certifying body at their own discretion, based on their own needs, which can be to the benefit of nefarious actors.

Despite the UDB being touted as a solution to fight fraud, weakness derived from the certification process means that it is unlikely to prevent fraud alone and that further action is required from the EU and Member States to effectively fight fraud, such as a dedicated RED fraud investigation unit.

5. Policy recommendations

According to Article 29, paragraph 6, of the Renewable Energy Directive, additions to the Annex IX list should be based on an analysis of the potential of the raw material as feedstock for biofuels. The addition should also take into account several criteria, such as the principles of circular economy, waste hierarchy, the need to avoid significant distortive effects on markets, the need to avoid creating additional demand for land or the potential to deliver substantial greenhouse gas emissions savings compared to fossil fuels [46].

As shown in the previous sections of this report, most of the feedstocks in the Annex IX list are not respecting these criteria. T&E recommends changes at different regulatory levels to ensure that policy support goes only to sustainable feedstocks and that appropriate sustainability safeguards are put in place on the advanced and waste feedstocks.

5.1. Reinforce the sustainability safeguards

Several additional sustainability safeguards should be put in place at the EU level. Firstly, indirect emissions should also be taken into account when designing policy support to certain feedstocks. These emissions stem from displacement effects that happen when the waste hierarchy principle and the cascading principle are not respected. Under this scenario, a feedstock with several traditional uses would be promoted for biofuel production. The result of these competing uses is that the industry that traditionally used this feedstock now needs to find alternatives that can in some cases lead to higher emissions[24].

Regarding emissions, it is necessary to ensure that real GHG emissions are used for imports of feedstocks from non-EU countries (taking into account transport and distribution) instead of default GHG emissions that are currently allowed by the Renewable Energy Directive [46]. However, to ensure that these actual values can be trusted would require a complete review of the certification systems.

Moreover, in cases where policy-makers decide to include feedstocks that have important functions for preserving ecosystems, it is important to provide strict safeguards and enforcement measures and not only monitoring tools to ensure that this primary function is not endangered by biofuels' demand. This is the case with agricultural residues that are needed to create and maintain soil health and where strong measures should be put in place to ensure the crop residue harvest for biofuels does not exceed sustainable levels [56].

[24] Section 2.8 gives a good example with animal fats category 3.

Lastly, most "residues" need to comply with a criteria to avoid direct land use change and deforestation, e.g. "not be made from raw materials obtained from land with a high biodiversity value". This is the case for agricultural, aquaculture, fisheries or forestry residues but not for other feedstocks like industrial residues. To fight direct deforestation, all residues must comply with the same sustainability criteria. Moreover, certification schemes do not have to certify and trace back the upstream part of the process for residues and that is a major weakness in the system [56].

5.2. Restrict support to problematic feedstocks

In its current state, the Renewable Energy Directive does not allow removal of feedstocks, only the addition of new ones. This is very concerning considering that many of the feedstocks in the list pose environmental and climate risks, create additional demand for land, have distortive market effects, do not respect principles of waste hierarchy and circular economy and pose serious risks of fraud.

It is also necessary to modify the Renewable Energy Directive in the next revision so as to allow the possibility to also **remove feedstocks from the list**. In the meantime, Member States should explore options at the national level to restrict the support to the most problematic feedstocks, whether by removing them completely or at least putting a limit to how much they can count towards the RED targets (cf section 5.3. "Recommendations for Member States'). The feedstocks that should be removed based on the analysis above are following:

- **Forestry residues and other derivatives** because of environmental and availability concerns as well as existing uses and uncertainties around their actual emission savings (for more information please see the Section 2.2. on forestry residues)

- **Intermediate crops** notably because of a lack of clear guidelines to ensure there is no use of food or feed crops or demand for additional land but also because of competing uses and environmental concerns (for more information please see Section 2.4 on intermediate and energy crops)

- **Crops grown on severely degraded land** because of a lack of proper safeguards but also because the land could be used for other uses, like rewilding (for more information please see Section 2.4 on intermediate and energy crops)

- **Crude glycerine** because of uncertainty around the scalability of such processes, the existing competing uses and the future decreasing availability (for more information please see Section 2.6 on other feedstocks in Annex IX Part A)

- **Agricultural residues** in the absence of the implementation of strong measures to ensure crop residue harvest does not exceed what is needed to create and maintain soil health and because of many existing and potential competing uses (for more information please see Section 2.5 on agricultural residues)

- **POME and other palm derivatives** due to increasing competing uses and the importance of leaving them to producing countries to decarbonise their local economy (for more information please see Section 2.1.of part A on POME and other palm derivatives).

On top of feedstocks listed as part of the Annex IX, there are other feedstocks **that should not count** towards the targets for renewables in transport:

- **Animal fats category 3** because of existing uses in the oleochemical industry and high risks of indirect emissions (for more information please see the Section 2.7. on animal fats)
- **Palm Fatty Acid Distillates (PFAD)** because they are associated with similar impacts on deforestation as conventional palm oil (for more information please see Section 2.1. on POME and palm derivatives)
- **Molasses and soapstocks and derivatives** because diverting them from their current uses for the production of biofuels can be associated with significant GHG emissions
- **Imports of UCO and animal fats categories 1 and 2**, as well as imports of biofuels produced from these feedstocks, because of fraud risks and because the producing countries need these feedstocks to decarbonise their transport sector (for more information please see sections 2.7 on UCO and 2.8 on animal fats).

Moreover, there are also several feedstocks that should be **monitored further, such as:**

- **Unsorted municipal mixed waste and industrial waste** due to the fact that no mixed waste should be used directly for making biofuels as only the biodegradable fraction is suitable for biofuels. Hence, separate collection of the biomass fraction of the municipal solid waste would be required. In addition to this, the availability of such feedstocks should decrease overtime as waste volumes are progressively reduced (for more information please see Section 2.3)

- **Damaged crops** due to competing uses and fraud risks (for more information please see Section 2.9 on other feedstocks in Part B)

- **Fusel oils from alcoholic distillation** for their competing uses (for more information please see the Section 2.6 on other feedstocks in Part A)

- **Novel feedstocks** such as algae or recently added cyanobacteria promoted as third-generation biofuels for different technical and financial challenges they face (for more information please see the Section 2.6 on other feedstocks in Part A)

- **Municipal wastewater and derivatives other than sewage sludge** because it is currently hard to assess the existing uses and sustainability impacts of the use of these feedstocks for biofuels production (for more information, please see Section 2.9 on other feedstocks in Part B).

In addition to different measures on fixing the Annex IX list, it is necessary to also act on the quantities of advanced and waste biofuels that should be promoted across RED, ReFuelEU and FuelEU maritime. Firstly, it is essential that the **cap on Annex IX Part B biofuels remains at the 1.7% level, or is further lowered,** considering that only EU collected feedstocks should be favoured and that several of the feedstocks added to Part B are unsustainable. For example, sustainable volumes of EU UCO and animal fats category 1 and 2 would currently amount to 1.1% of all EU transport energy (with double counting), far below the current limit. The latest Renewable Energy Directive allows the European Commission to adjust the limit on Part B feedstocks based on the assessment of availability of feedstocks [94]. Given that currently it is only possible to add new feedstocks to the Annex IX list, and taking into account that new feedstocks will be added to both Part A and Part B of Annex IX, there is a real concern that the limit will be further increased, which would put additional pressure on unsustainable feedstocks.

Secondly, it is necessary to put **a limit to the contribution of Part B biofuels and several problematic feedstocks[25] in Part A of Annex IX in ReFuelEU and FuelEU maritime**. These are currently not limited

[25] Such as intermediate crops, crops grown on severely degraded land, forestry residues, etc.

and as of 2030 increasing volumes of renewable fuels will be required to meet the ambitious targets. Instead, it is important to scale up the use of hydrogen and e-fuels in these sectors and to also increase its contribution to the RED transport sub-target from 1% to 2% (with double counting).

5.3. Recommendations for Member States

Member States can go further than the EU to ensure that stronger sustainability safeguards are respected when using advanced and waste biofuels.

It is crucial that the Member States **identify their domestic availability** of advanced and waste feedstocks before deciding to incentivise them for renewables targets in transport. They should pay special attention to competing uses with other sectors and hence put the priority to the waste hierarchy and cascading use principles. The waste hierarchy clearly indicates the hierarchy regarding waste prevention and management: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; and (e) disposal. The cascading principle emphasises that feedstocks should first be used for the production of durable products before being used for bioenergy. Countries should conduct an impact assessment of the potential consequences of the policy, including market distortion effects but also impacts on biodiversity and ecosystem services [56].

T&E calls on Member States to **act on the current sub-target for advanced biofuels and RFNBOs** of 5.5% with double counting, of which at least 1% needs to be supplied by RFNBOs (e-fuels and green hydrogen). It is necessary to reach the **5.5% target for advanced fuels with 2% RFNBOs and 3.5% advanced biofuels Annex IX Part A**. By doing so, the RED III ambition will stay in line with the previous 3.5% target set in the previous RED revision in 2018, even though the volumes needed to reach the target will be higher with the expansion of the denominator to the shipping and aviation sectors [95].

There are already several Member States that acted on **limiting or excluding problematic feedstocks from counting towards renewable targets**. For example, France further restricted both used cooking oil and animal fats category 1 and 2 in Part B of Annex IX (at 1.1% instead of 1.7% at EU level). It also restricted Crude Tall Oil in part A of Annex IX which is currently not limited at EU level (France put the limit of 0.1% for this feedstock) [96]. Some countries have excluded feedstocks outside of Annex IX from counting towards the RED targets, as is the case with Italy excluding PFAD from counting towards their renewable energy targets [97]. A recent legal analysis commissioned by NGOs points out that there is currently no legal basis that would prohibit Member States from excluding or restricting individual substances in Annex IX[26].

5.4. Ensure better compliance and more efficient measures against fraud

According to Article 30 of the Renewable Energy Directive, Member States need to ensure compliance of biofuels with the sustainability and greenhouse gas emissions savings criteria that are laid down in Article 29 of the Renewable Energy Directive. They need to take measures to ensure that economic operators submit **reliable information** regarding the compliance with these criteria and they can require additional information from economic operators if needed, such as the data that was used to develop such information. This has already been requested by France, for example [99]. In addition to this, article 30 also requires **more transparency per fuel supplier** on the websites of operators, suppliers and the relevant competent authorities [77].

[26] See legal analysis prepared by the law firm GEULEN & KLINGER on behalf of DUH, NABU, RFN and T&E [98].

There are also several measures that can be taken to fight fraud. In the European Commission's own assessment on Annex IX feedstocks [14], several feedstocks were identified as carrying a high fraud risk: intermediate and cover crops, crops grown on severely degraded land, POME and UCO. There were other feedstocks identified with medium or low risk. The study suggested as a key measure to fight fraud the **creation of a dedicated fraud investigation unit** specifically for the RED, equipped with necessary resources and specially trained staff that could work with national governments, industry and customs authorities to investigate suspected fraud cases. In addition to this, we recommend a complete review of the certification system for biofuels, moving away from independent, industry-led voluntary schemes in favour of more stringent EU and national regulation[27].

5.5. Focus on cleaner alternatives

To ensure a full decarbonisation of the transport sector, cleaner and more scalable alternatives will be needed, in parallel to decreasing overall energy demand. Direct electrification must be the preferred option wherever it is possible and T&E supports a dedicated credit mechanism for rewarding the use of renewable electricity in transport [100]. For sectors that are harder to electrify, like aviation and long-distance shipping, hydrogen-based fuels - renewable fuels of non-biological origin (RFNBOs) - will play a key role. Regarding RFNBOs, T&E recommends slightly higher ambition compared to the current RED targets but also a clearer targeting at aviation and shipping [101].

For these fuels too, the traceability and proof of sustainability will be a major challenge and something that needs to be closely scrutinised.

[27] For more information please refer to our latest briefer on Used Cooking Oil [82].

Annex 1. List of biofuels feedstocks in the Annex IX of the RED

Part A:

(a) Algae if cultivated on land in ponds or photobioreactors;
(b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC;
(c) Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection as defined in point (11) of Article 3 of that Directive;
(d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex;
(e) Straw;
(f) Animal manure and sewage sludge;
(g) Palm oil mill effluent and empty palm fruit bunches;
(h) Tall oil pitch;
(i) Crude glycerine;
(j) Bagasse;
(k) Grape marcs and wine lees;
(l) Nut shells;
(m) Husks;
(n) Cobs cleaned of kernels of corn;
(o) Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil;
(p) Other non-food cellulosic material;
(q) Other ligno-cellulosic material except saw logs and veneer logs.

Feedstocks recently added in the Delegated Directive (EU) 2024/1405 [7]:

(r) Fusel oils from alcoholic distillation;
(s) Raw methanol from kraft pulping stemming from the production of wood pulp;
(t) Intermediate crops, such as catch crops and cover crops that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land, and provided the soil organic matter content is maintained, where used for the production of biofuel for the aviation sector;
(u) Crops grown on severely degraded land, except food and feed crops, where used for the production of biofuel for the aviation sector;
(v) Cyanobacteria.

Part B:

(a) Used cooking oil;
(b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009

Feedstocks recently added in the Delegated Directive (EU) 2024/1405 [7]:

(c) Damaged crops that are not fit for use in the food or feed chain, excluding substances that have been intentionally modified or contaminated in order to meet this definition;
(d) Municipal wastewater and derivatives other than sewage sludge;
(e) Crops grown on severely degraded land excluding food and feed crops and feedstocks listed in Part A of this Annex, where not used for the production of biofuel for the aviation sector;
(f) Intermediate crops, such as catch crops and cover crops, and excluding feedstocks listed in Part A of this Annex, that are grown in areas where due to a short vegetation period the production of food and feed crops is limited to one harvest and provided their use does not trigger demand for additional land and provided the soil organic matter content is maintained, where not used for the production of biofuel for the aviation sector.

Annex 2. Methodology to assess the availability of sustainable biofuels

As described in Section 3, sustainable advanced and waste biofuels availability is estimated with feedstocks that have the lowest environmental and climate risks. These include domestically collected used cooking oil and animal fats categories 1 and 2, as well as the biodegradable fraction of municipal solid waste that is collected separately and sewage sludge. Table 1 below shows the estimated volumes and the underlying assumptions used.

Feedstock	Feedstock volumes	Biofuels technology	Conversion efficiency	SAF output	SAF volumes
Animal fats cat 1 & 2	0.5 Mt [84]	HEFA	0.89 $kg_{fuel}/kg_{feedstock}$ [48]	66% [68]	0.3 Mt
UCO	1.5 Mt [76]	HEFA	0.89 $kg_{fuel}/kg_{feedstock}$ [48]	66% [68]	0.9 Mt
Biodegradable fraction of MSW[28]	66.8 Mt (2030) [36]	Fischer-Tropsch gasification	0.1 $kg_{fuel}/kg_{feedstock}$ [102]	75%	5.0 Mt
	36.7 Mt (2050) [36]				2.8 Mt
Sewage sludge	10 Mt [70]	Thermo-catalytic reforming	0.08 $kg_{fuel}/kg_{feedstock}$ [73]	-	0.8 Mt

Table 1: Assumptions and estimated volumes of SAF produced from sustainable advanced and waste biofuels

[28] A more recent sensitivity analysis conducted by the ICCT shows that these volumes may be up to twice lower if energy recovery from incineration proves to be more efficient than converting and using bio-SAF.

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