Digital transparency in POME-biofuel supply chains

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1 Introduction

1.1 Increasing the transparency of renewable fuel supply chains with digital systems

In the transition towards a bio-based and circular society, the use of wastes and residues from industrial processes is becoming more prevalent for the production of renewable fuels and downstream green chemicals. In the Netherlands in 2024, the majority of biofuels used in transports were produced from residues from palm oil processing, called Palm oil mill effluent (POME).[1]

In Europe, the system implemented to verify compliance is organised around certification on an administrative level.[2] This 'before the fact' approach implies that economic operators or products are certified against a defined set of principles and criteria. Traceability and oversight of raw material along the biofuel supply chain are followed via a mass balance system, which has a less strong link with the original physical presence of sustainable material. This contrasts with compliance systems in other parts of the world, where stronger links between verification and the actual physical presence of sustainable material. RenovaBio in Brazil mandates that certifiable feedstock needs to be segregated from non-certified material. Moreover, the California Low Carbon Fuel Standard (CLFS) in California, United States, only allows mass balance when specifications and physical characteristics of batches are the same. For example, batches from different sources, such as used cooking oil (UCO) and vegetable oil, cannot be combined and require physical segregation.

At the same time, the European's digital agenda includes the ambition to introduce business wallets for European companies within the framework of global developments based on the United Nations Transparency Protocol. The business wallet offers the possibility to make visible the certification status of organisations in the supply chain and other relevant information thereby improving transparency. Furthermore, a digital product passport contains information about the product, which could be related to the information recorded on a Proof of Sustainability (PoS). With the use of these business wallets, it is possible to make agreements for transactions in a protocol or template for specific sections of the supply chain. With introducing encryption of data this information can be turned into verifiable credentials. These possibilities within the digital trust agenda are under ongoing investigation in an innovation project developing the Clean Fuel Protocol, started by the Dutch ministry of Infrastructure and Water management (I&W). This innovation project is carried out by RVO, TNO and NEN with sector parties, which investigates how such digital solutions can be used for passing sustainability information to end users. In this present project, we investigate how the use of digital tools supports the verification of residue oils further upstream in the supply chain, starting at the point of origin.

The use of residue streams can provide many advantages for instance by addressing environmental challenges, providing alternatives to the use of new virgin fossil oils and generating additional income in regional economies. However, in the case of palm oil, it can also provide an incentive for the use of pure palm oil if the residue is worth more than the palm oil itself in the food chain. In 2025, a Transport and Environment (T&E) report was published with concerns that POME-based biofuel use in Europe is reaching the limit of POME production potential.[3] Also the International Energy Agency (IEA) has published about how the mobilisation of waste oils and fats worldwide is reaching limits of availability.[4] The Netherlands Platform Renewable Fuels published in response to the

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[1] NEa 2025. Rapportage Hernieuwbare Energie voor Vervoer 2024.
[2] IEA Bioenergy 2022. Improvement opportunities for policies and certification schemes promoting sustainable biofuels with low GHG emissions, page 82, 93.
[3] Transport and Environment 2025. Palm oil in disguise? How recent import trends of palm residues raise concerns over a key feedstock for biofuels: https://www.transportenvironment.org/uploads/files/202504_POME_fraud_Report.pdf
[4] Unpublished conference presentation IEA (2023), Liquid biofuels – Feedstock Forecast, also taken into account in this Platform presentation (2024) about biomass mobilisation (see here: https://cdn.prod.website-files.com/643691764f0ee351ea1022aa/65a5255edfb0002a48dea1ff_24_0111_PHB_Knotter_Introduction%20to%20BioMOB%233.pdf.

concern of Transport and Environment an analysis that showed that biofuels released to the European market based on palm oil mill residues would fall within expected waste potentials and concluded that monitoring would be recommended. In this project we look into how the use of verifiable credentials (i.e. in systems based on distributive ledger technology)[5] could strengthen transparency and support the certification system and perhaps could contribute to monitoring.

1.2 Goal of the study

In this study, commissioned by RVO (the Netherlands Enterprise Agency), the aim is to investigate how digital traceability and the link to the Clean Fuel Protocol can contribute to better verification and transparency in biofuel supply chains.

Once fully operational, the central EU-wide system for biofuels, the Union Database for Biofuels (UDB) will improve the information position about the traceability and sustainability of biofuels. We take therefore into account the relation with the Union Database.

For this project, we focus on the specific case study of residual flows generated by palm oil mills, which subsequently are used as feedstock for POME-based biofuels, however these technologies could be applied equally to other raw materials where there is a desire for more traceability. We explore how the Clean Fuel Protocol and Digital Traceability Events[6] could be applied at the start and along the POME supply chain. For this, we must explore whether key data points at the start the POME supply chain can support the verification of the raw material and can be incorporated in such a protocol. Ultimately, the aim is to understand whether this could contribute to strengthen public oversight and private audit tasks by bringing forward recommendations on the governance and data management including the link to the UDB.

In this project, we aim to answer a number of questions which are the following:

- How can the use of encrypted data and verifiable credentials, the Digital Product Passport and Correlated Digital Traceability Events (DTE) (tools within the United Nations Transparency Protocol - UNTP)[7] improve transparency in the POME-oil based biofuel supply chain?
- What (additional) data points can we identify that support the verification of the residue oils?
- Can the use of the UNTP interoperability protocol and decentralised data architecture help to improve public oversight and private audit tasks?
- What does this mean for governance (organisational aspects) including the link with the Union Database for Biofuels?

This study was conducted in consultation with several experts namely: Harmen van der Kooij from Fides Lab (UNTP interoperability protocol expert), Wolter Elbersen, expert biomass supply and sustainable production chains from Wageningen University and Research (WUR), Reena Macagga (expert at verification scheme ISCC), Marieke Brevé-Bullens (Argent Energy), an operator of a palm oil refinery and palm oil mill. Timo Gerlagh and Max Delissen were involved, representing the Netherlands Enterprise Agency (RVO) who commissioned this study. In this study, we focus on the certification guidelines of residues oils from palm oil mill by ISCC as one of the sustainability certification schemes approved by the European Commission to ensure compliance with sustainability criteria set in the Renewable Energy Directive (RED) as described in Article 29. Article 30 in the RED describes how verification of compliance is to be assured, using voluntary national and international schemes.[8] It is important to note however that other certification schemes than ISCC are recognised by the European Commission but have not been studied in this project. Although this project focuses on POME as a specific case study,

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[5] https://www.hernieuwbarebrandstoffen.nl/post/t-e-palm-oil-in-disguise-how-recent-import-trends-of-palm-residues-raise-concerns-over-a-key-feedstock-for-biofuels-2025 on basis of studio Gear Up, 2025 Current POME-based biofuels in EU fall within current production potential.
[6] Digital Traceability Events (DTE) are core of the UNTP and relate to a collection of identifiers that specify information on the "what, when, where, why and how' of a product and facilities that constitute a value chain.
[7] See https://spec-untp-fbb45f.opensource.unicc.org/docs/specification/.
[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001

the study is reflecting upon the question whether the methodology can be applied more widely to other residues-based fuels and whether this can contribute to a broader strengthening of the European certification and supervision system.

In this report, we first describe briefly relevant current practices of residue oil at palm oil mills (chapter 2) followed by a chapter on the key concepts of digital transparency and the Clean Fuel Protocol. Thereafter we describe in chapter 4 the compliance system in Europe which includes the voluntary certification system and the Union Database for Renewable gaseous and liquid fuels, including biofuels. In chapter 5, we discuss some key data points that improve the verification of raw materials. We would like to stress that this concerns an exploratory study. In a workshop with stakeholders, we discussed key findings, including whether the use of digital transparency protocols would fit in a context of the (central) Union Database, whether adding additional data points for verification based on a physical test at one or multiple points in the supply chain would be useful and to what extent this requires to rethink the design choices of the compliance system, which currently stools on administrative compliance via a voluntary certification system. In the last chapter, we provide conclusions and recommendations for further innovation and knowledge development.

2 Current practices of residue oils at palm oil mills

Palm oil mills[9] are the point of origin of palm oil mill effluent (POME), one of the by-products resulting from crude palm oil (CPO) extraction. When fresh fruit bunches (FFB) are processed, several by-products are derived (Figure 1). Of the residuals products of crude palm oil extraction, mesocarp fibre, POME and empty fruit bunches (EFB) contain residue oils.

POME is often directed to open ponds outside to the mill where the residue oil can be recovered from the surface by skimming it. Multiple techniques are possible to recover those which includes pressing, skimming, 'bubbling' technology or extraction with hexane. Depending on the recovery method, it can be estimated how much oil can be extracted from these three different types of palm oil residues. Not all mills are equipped to recover the residual oils from CPO.

Over the course of the project, several stakeholders have mentioned that it is common practice for the different residual oil streams to be mixed into the same container. POME labelled batches can then often contain a mixture of sludge oil, condensate oil, which are commonly agreed to be POME oil, but also including EFB oil, which is commonly categorised separately. The volumes for the different products are then distinguished on a mass balance basis, which is allowed under ISCC certification guidelines (these guidelines are further discussed in Chapter 4.1).

[9] Palm oil mills operate in palm producing countries typically found in tropical zones with the largest palm producers being by far Indonesia and Malaysia, followed by Thailand, Colombia and Nigeria. Over the course of this study, we have heard accounts of practices from palm oil mill in Indonesia and Colombia.

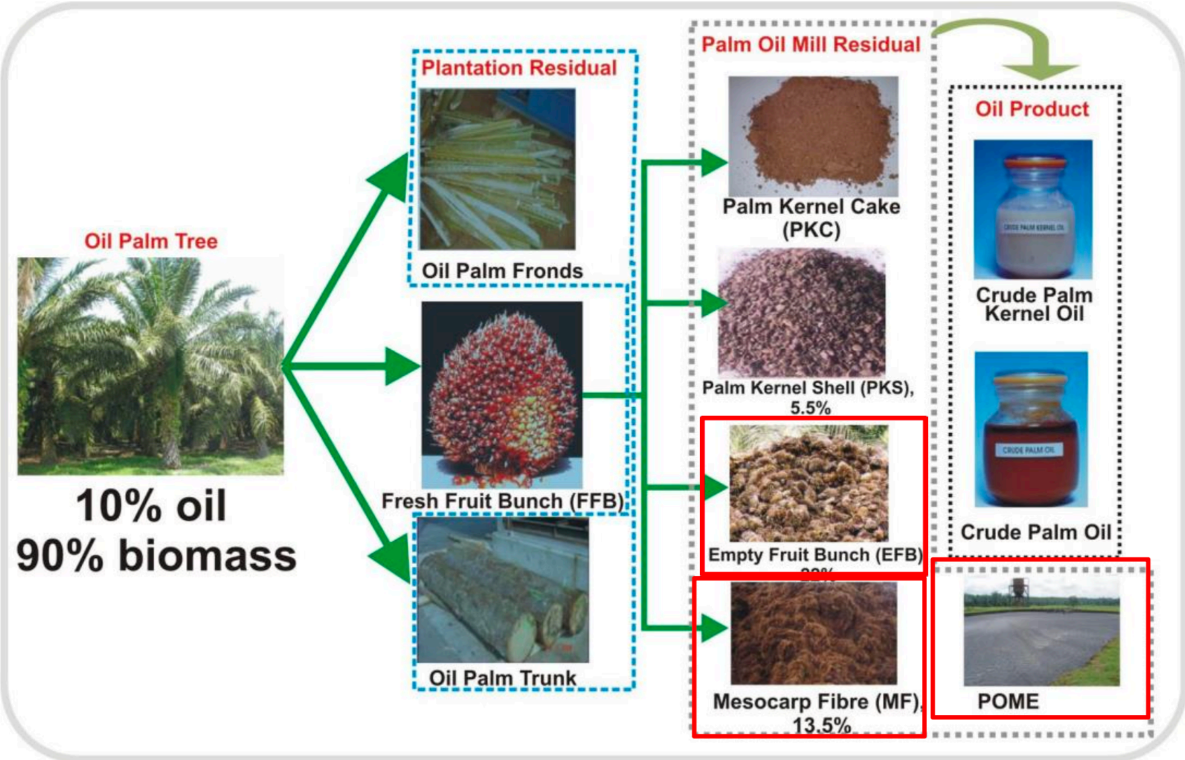

Figure 1. Diagram of the palm oil production process and the by-products derived from it (Source: Malaysian Palm Oil Board).

Indonesia is the largest palm oil producing country and has more than 2000 operating palm oil mills.[10] Although these mills differ in size, practices and resources, their main goal is to extract as much valuable product from the palm fruit and therefore, do not necessarily have the equipment to carry out advanced tests such as fingerprint analysis to measure the composition of residue oils.[11] Contrastingly, the handlers of palm products further down the supply chain, will want to ensure a certain quality of product to minimise refining or processing costs. Therefore, sampling and testing is more common at collection points and refineries. Tests to ensure quality are also common practice for palm oil directed towards the food market which must meet certain product specification regarding Free Fatty Acid (FFA) and moisture content.[12] In refineries processing residue oils, samples are taken on a daily basis as a quality check to verify the composition of the batches and detect the presence of unwanted compounds. For instance, phosphorus is one of the most important organic compounds to check as it can make feedstock hard to handle. At one of the refineries that we have looked at, analyses are made with ICP (Inductively Coupled Plasma) equipment, a spectrometer technique for chemical elemental analysis.

In Colombia, it is common practice for mill operators to regularly take samples of their batches and conducting test on the different palm oil streams. These samples and monitoring play an important part in understanding the daily yields and losses that are not going towards CPO. Overall, it appears that Colombian mills have the possibility to conduct more test and generally benefit from more lab facilities. As Colombian industry players are newer entrants to the palm oil market, they position themselves as more open to share information.

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[10] Distribution of Indonesian palm oil plantation companies in 2024 according to https://databoks.katadata.co.id/en/agroindustry/statistics/68b5450a231da/distribution-of-indonesian-palm-oil-plantation-companies-in-2024

[11] Interview with managing director of PT Yuni Bersaudara Sejahtera in Indonesia, a palm oil and residue oil processing business.

[12] Palm oil for food market must meet PORAM (Palm Oil Refiners Association of Malaysia) specification

3 Digital transparency and the Clean Fuel Protocol

3.1 Clean Fuel Protocol

In the Netherlands, a public-private consortium is developing the Clean Fuel Protocol (CFP), which is aimed at providing a solution to ensure the efficient and reliable recording and exchange of information about renewable fuels. This protocol is a collection of technical, semantic and management agreements that must be complied with by the parties involved and their systems.

The basic principle is that it is not a completely new system, but that it makes use of the already certified EU Renewable Energy Directive (RED) data registered in the Dutch Registry for Energy in Transport (REV) of the Netherlands Emission authority (NEa)[13] and makes that verified information available for end users. Parties involved can largely continue their existing ways of working, and with little adaptions be compliant with the protocol. It is aiming for interoperability with different information systems in use. Although the Clean Fuel Protocol is primarily developed for the end of the biofuel chain to inform end-users in the market, the protocol has been designed to be generic and can therefore also be applied to other stages of the chain.

3.2 United Nations Transparency Protocol

The Clean Fuel Protocol is derived from the United Nations Transparency Protocol (UNTP). UNTP is a global framework designed to improve supply-chain transparency and integrity through interoperable digital records and verifiable data. It is a generic protocol that enables information about products, transactions, and sustainability claims to be shared securely and consistently across different systems. It explicitly is not a separate system, but rather an interoperability protocol.[14] According to this protocol, data is managed federatively (or decentrally), meaning that ownership of data remains at the level where the data is created. The UNTP framework prescribes that supply chain events and other data is to be recorded as encrypted and verifiable credentials. Through this, the UNTP supports traceability and trust across supply chains without requiring a single central database.

The advantage of using UNTP is that it will increase interoperability within international (global) chains and between different domains. This means that it will be easier to exchange verifiable, machine-readable, linked data. The same data can be reused more easily for multiple purposes, even in the case of complex chains spanning different continents and sectors.

3.3 Digital Product Passport and Digital Traceability Events

Digital tools such as Digital Product Passport (DPP) and Digital Traceability Events (DTE) play an essential part in the UNTP and in the Clean Fuel Protocol that is being developed by Dutch parties. The Digital Product Passport consists of a digital record containing information of every serialised product item as well as its sustainability and environmental performance. A product passport is issued by the shipper of goods and is linked to the product as it travels along the value chain. This in turn ensures transparency and accountability.

The product passport also contains links to traceability events which allows to follow the transformation of a product and trace it back to its point of origin. Digital Traceability Events (DTEs) refer to a collection of information on a product and facility that constitute the value chain. The traceability events specify the "what, where, why and how" information of a traded product. Five different types of DTEs are distinguished:

- **Transformation Events**: These are arguably the most critical for traceability because they record manufacturing processes where input materials are consumed to create new outputs. For example, a biorefinery hydrogenation process in which POME oil is processed with hydrogen into Hydrogenated Vegetable Oil (HVO).

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[13] See https://www.emissionsauthority.nl/topics/renewable-energy-for-transport/registry
[14] UN Transparency Protocol, Transparency at Scale (see presentation: https://untp.unece.org/assets/files/UNTP-Presentation-92d5c3bc42d8473aaa08f6e327541575.pdf)

- **Association Events**: These record the physical joining of independent items. This can be the addition of a specific chemical tracer or additive to a batch for "fingerprinting" purposes. The event identifies a "parent" (the batch of feedstock) and a "child" (the specific additive)
- **Aggregation Events**: These describe grouping or ungrouping items for logistics, such as the grouping of several individual POME oil batches from multiple suppliers into a single large container for international shipping.
- **Transaction Events**: These track the change of ownership or responsibility between different parties or organizations, such as the sale of goods from a supplier to a buyer.
- **Object Events**: These capture specific actions or observations performed on an item, such as an annual sustainability audit on a facility, or a laboratory test on the POME oil.

Instead of using a centralised database, DTEs typically function within a decentralised architecture, allowing users to navigate a linked-data "graph" that represents the entire history of a product. Technically, these events are issued as Verifiable Credentials, which ensure that the data is secure, tamper-proof, and can be shared selectively.

The approach is also inherently platform-agnostic in the sense that the same "event" could be recorded in multiple systems, for example across different compliance markets.

Figure 2 (on next page) shows examples of different supply chain events along the POME supply chain and how these would be recorded as Digital Traceability Events.

3.4 Verifiable identities and data

The current renewable fuel value chain is largely based on traditional documents, such as PDFs, Excel files and paper statements. These formats are not always machine-readable and difficult to verify automatically. Furthermore, technological developments, including generative AI, make it easier to manipulate or falsify such documents. To enable reliable automation and oversight, a shift from document-based to verifiable data is needed.

In order to use verifiable data reliably, it is also necessary that the organisations that publish, manage and use this data can also be identified in a verifiable manner. The UNTP and Clean Fuel Protocol propose specific methods to ensure that organisational identities and data are verifiable.

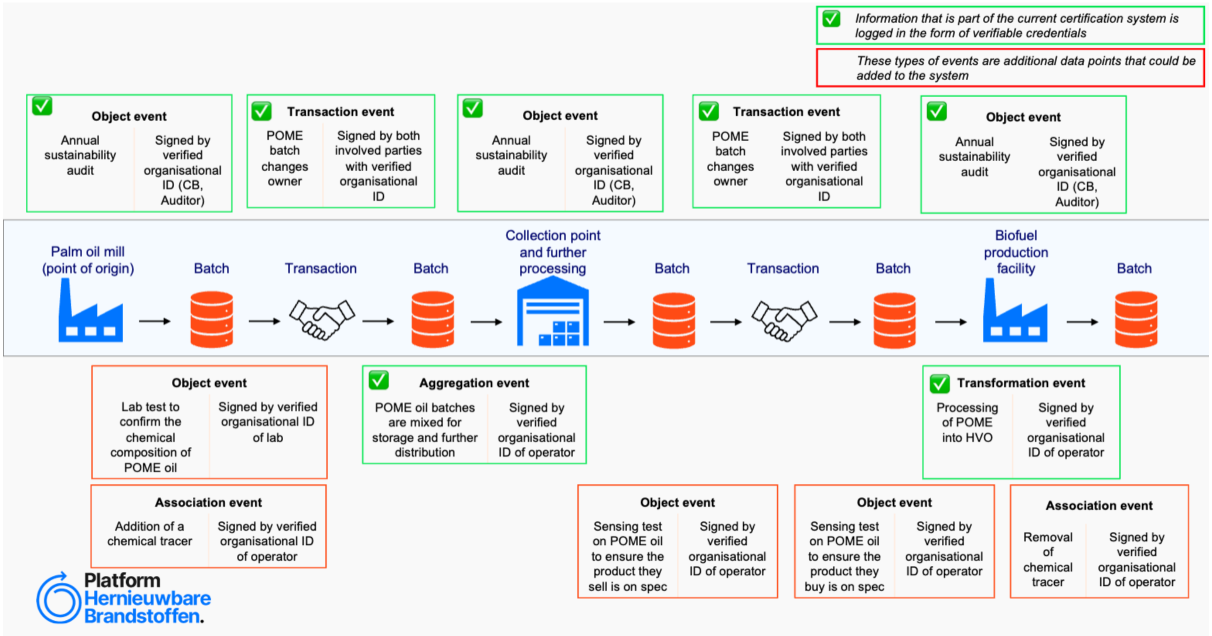

Figure 2. Illustrative representation of the events taking place along the POME supply chains and how they would be recorded as Digital Traceability Events (event categorisation taken from the UN Transparency Protocol.15

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[15] See https://untp.unece.org/docs/specification/DigitalTraceabilityEvents

Some important aspects include:

- that data is presented in a structured manner and that it is machine-readable so that data can be easily processed and interpreted by the system
- that data is cryptographically signed with an organisational ID that can be traced back to a legal entity to prove who issued the data and that the content has not been altered
- that data is suitable to use for Linked Data which allows individual data point to be linked together in a way that is consistent and scalable.[16]

Linking data provides a possibility to combine and analyse data. We will return to this functionality in chapter 4.

3.5 Business wallets

Business wallets, or organisational wallets, are an essential part of a digital transparency solution. They allow organisations to create, receive, store and present verifiable data. Business wallets are likely to become widely applied in the EU in the coming years. The European Digital Identity (eIDAS 2.0) Regulation[17] aims to create a framework for digital identity and authentication to create confidence in electronic interactions and promote seamless digital services. This Regulation introduces, a European business wallet, the European Digital Identity Wallet. It also prescribes Member States to integrate zero-knowledge proof technology into the European Digital Identity Wallet, which allow parties to validate whether a certain statement is true without revealing any data on which that statement is based. In this way verification of claims can be drastically improved without compromising the privacy of users of the business wallet system.

4 The EU compliance system

The compliance system that Europe has implemented is based on administrative certification. In this chapter, we elaborate upon the different elements that make up the compliance system. In the POME supply chain, palm oil mills are certified on a yearly basis after rigorous audit procedures have been carried out by recognized certification schemes. Thereafter, palm oil mills handling waste and residues can issue Sustainability Declarations (SD), which are linked to a physical flow of outgoing POME batches. Information collected in a Sustainability Declaration and thereafter in the Proof of Sustainability (PoS) issued by biofuel producer is uploaded onto the Union Database for Biofuels (UDB).

4.1 The certification system

4.1.1 Certification and audit of palm oil mills handling wastes and residues

Certification for Palm Oil Mills (POMs) generating waste and residues like oils from the Palm Oil Mill Effluent (POME), Empty Fruit Bunches (EFB), or the pressing of mesocarp fibers (PPF) is subject to specific rules for compliance. Rules of certification are formulated in the European Renewable Energy Directive which sets sustainability criteria that are then translated into guidelines in voluntary certification schemes. ISCC is one of the approved schemes that we use as an example in this project but other schemes most likely have similar requirements. ISCC requirements state that all palm oil mills generating and supplying waste and residues such as POME oil, EFB oil, and PPF oil as sustainable materials must be individually certified as a Point of Origin, and accordingly, must be audited on-site annually.[18] This requirement means that the group auditing approach, where only a sample of operational units is audited, cannot be applied to palm oil mills dealing with these wastes and residues.

This more rigorous approach to certification is driven by the fact that POME oil is categorized as an "advanced" raw material under Annex IX Part A of the EU Renewable

[16] These properties form the core of the W3C Verifiable Credentials Data Model developed by in the Clean Fuel Protocol and are therefore also in line with the United Nations Transparency Protocol (UNTP).
[17] See https://www.european-digital-identity-regulation.com
[18] ISCC 2024. Guidance: Waste and residues from palm oil mill

Energy Directive (RED II). The Point of Origin is a critical element in the supply chain as this is where the raw material's classification as a waste or residue is determined. This is determining the raw material's value for application in regulated markets, and therefore, a point where fraud risks, such as deliberate production or contamination to meet the definitions of waste and residue, have to be mitigated.

The auditor must verify several critical aspects related to the mill's operation, material flow, and compliance with the criteria set by the European Commission that are translated in the ISCC requirements.

The most important aspects an auditor must verify are checks that determine if the operation is technically capable of generating the claimed amounts and if those amounts are plausible given the mill's specific process setup:

1. **Production Data and Capacity**: The auditor must confirm the annual production capacity of crude palm oil (CPO) and the total amount of Fresh Fruit Bunches (FFBs) processed by the POM in the 12 months prior to the audit.
2. **POME Recovery Methodology**: The auditor must determine how the POME oil is recovered. Specifically, whether it is recovered from the pond (through "skimming off") or through a more efficient pre-treatment step (e.g., using a centrifuge) prior to the POME being discharged to the pond. This affects the expected POME yields.
3. **Sterilizer Type**: The type of sterilizer used (horizontal or vertical) must be checked, as this affects the expected yields.
4. **Verification of Equipment**: If POME oil is recovered before being discharged to the pond, the auditor must visually inspect and verify that the technical equipment and infrastructure used for recovery (e.g., centrifuges) and storage are available, functional, and operational.
5. **Plausibility Check of Amounts**: A crucial step is verifying the plausibility of the amount of POME oil generated and sold. In the ISCC Guidance Document, this check uses indicative figures, recognizing that the plausible amount recovered depends heavily on the recovery methodology (recovery from the pond is less efficient than pre-treatment). If the generated amount exceeds the established thresholds in the guidance, the POM must provide specific evidence to the auditor justifying the higher yield.
6. **Treatment and Losses**: If the recovered POME oil is further treated (e.g., purified or cleaned) at the POM, the auditor must ensure that losses from this treatment process are appropriately taken into account when determining the final amount of recovered oil sold.

Furthermore, auditors carry out checks to mitigate the risks of fraud. Auditors must verify that the material being claimed (POME oil) meets the definition of a "waste" or "residue" and is not a (co-) product or primary aim of the production process. It must be ensured that the POME oil is not produced or generated deliberately or intentionally contaminated to meet the definition of waste or residue. Crucially, labelling other oils (such as Palm Fatty Acid Distillate) as POME oil is considered a critical and fraudulent violation of EU requirements which are subsequently included in the ISCC schemes.

The collection logistics also need to be reviewed by the auditor: they will check the number of recipients of POME oil in the previous year and the frequency with which POME oil was collected, based on verification of delivery documents and contracts.

Finally, the auditor must check if the POM delivers POME oil under other voluntary or national sustainability certification schemes to prevent double accounting of POME oil volumes under different systems.

In sum, the sustainability requirements set by the European Commission and translated in the ISCC certification guidance for Palm Oil Mill residues are robust. In principle, the annual auditing provides evidence of the physical volumes.

4.1.2 Sustainability Declarations and Proofs of Sustainability

To ensure transparency and regulatory compliance, information about the origin and sustainability of raw materials and fuels must be communicated correctly, particularly to prevent double claims. Various means are used to communicate sustainability information, some of which are required by regulators to demonstrate compliance with the rules.

A Proof of Sustainability (PoS) is a document that provides specific evidence that a certain volume of fuel or raw material complies with the sustainability and greenhouse gas requirements laid down in the Renewable Energy Directive. PoSs can only be issued by economic operators that are certified within the framework of a voluntary scheme approved by the European Commission (e.g. ISCC-EU).

In their certification guidelines, ISCC makes a differentiation between the Proof of Sustainability (PoS) and the Sustainability Declaration (SD). Under ISCC, a PoS only refers to a document issued for a product that is a final fuel, ready for consumption. For sustainable products that are used as a feedstock for fuel production, certified economic operators can issue Sustainability Declarations.

The PoS is normally required by regulators as proof that a renewable fuel meets the sustainability requirements and greenhouse gas emission reduction criteria laid down in the RED (Articles 25.2 and 29).

Information recorded in Sustainability Declarations or Proofs of Sustainability

Sustainability Declarations must contain general information on the individual transaction between supplier and recipient. This information is not forwarded throughout the supply chain. Additionally, Sustainability Declarations have to include certain product specific information on sustainability and GHG criteria that needs to be forwarded through the supply chain.

General information on the specific transaction:

- Name and address of the supplier
- Name and address of the recipient
- Related contract number
- Date of dispatch of the sustainable material
- Address of dispatch/shipping point of the sustainable material (e.g. processing unit, storage facility) – applicable if different from the address of the supplier
- Address of receipt/receiving point of the sustainable material (e.g. processing unit, storage facility) – applicable if different from the address of the recipient
- Name of the certification system and certificate number of the supplier
- Date of the issuance of the Sustainability Declaration
- The number of the group member (in case of group certification) – Not applicable to the POME supply chain
- Unique number of the Sustainability Declaration

Product-related information – only listed if relevant for POME or POME derived products:

- Type of product (e.g. raw material, crude oil, biodiesel, HVO, etc.) – This has to reflect the product group
- Raw material (e.g. POME oil, UCO, crude glycerine, etc.)
- Country of origin of the raw material: country where the point of origin is located i.e. where the waste/residue was generated (for waste/residues and products derived from waste/residues)
- Scope of certification of raw material:
    - Statement that the raw material complies with the relevant sustainability criteria according to Art. 29 (2)-(7) of the RED III”
    - Statement that the raw material meets the definition of waste or residue according to the RED III
- Quantity of delivered sustainable product in metric tons or m^3 at 15°C
- Statement that the entire upstream supply chain is certified under a voluntary scheme recognized by the Commission under the framework of the RED.
- Chain of custody option (i.e. mass balance or physical segregation)
- Information if for the production of the fuel or fuel precursor support was received and if so, type of the support scheme

- GHG emission information
    - A statement that total default values are used, OR
    - A statement that disaggregated default values are used (for specific elements of the calculation), AND/OR
    - A statement of an actual value in kg CO_2eq/ton (for specific elements of the calculation)

In the current certification system, the documentation of information that needs to be forwarded through the supply chain is based in a paper trail. This means, that information is taken from a paper (or PDF) document (the sustainability declaration) and with that information new sustainability declarations are created. This paper system leaves room for mistakes and misuse, which leads to misreporting of e.g. products, volumes or GHG performance.

Using the Digital Product Passport as a means to record the data that is now recorded on sustainability declarations and Proofs of Sustainability, could largely eliminate this risk. The same type of information would be recorded on the Digital Product Passport, with the addition that it includes a link to previous Digital Traceability Events. In this way, a trail is created that can be traced back, increasing traceability and integrity of the system.

4.2 The Union Database for Biofuels

The Union Database for biofuels (UDB) is a central EU-wide system designed to ensure the traceability and sustainability of biofuels, bioliquids, and biomass fuels placed on the European market. The UDB is supposed to help prevent double counting, fraud and the use of non-sustainable material, by enabling economic operators to record and verify the movement of consignments along the supply chain. The UDB is not yet fully implemented, and still subject to change, which creates uncertainties about the value of the system to contribute to better verification and transparency in the POME supply chain.

The UDB will digitally link and record consignments and transactions through the supply chain from the Point of Origin of the raw material to the point where fuels are released to market. Economic operators will not be able to see the full upstream trade history of a consignment in the sense of seeing previous sellers or buyers. Operators will be able to see and manage their own transactions as well as the specific data elements that are transferred with the consignment. Essentially, this is in line with the type of information that needs to be forwarded in the supply chain on the Sustainability Declarations and Proofs of Sustainability, as described in the previous chapter.

At the system level, transaction data of consignments is linked. Each time a consignment is traded, a unique Proof of Sustainability (PoS) identifier is generated that links to the previous sustainability declaration and includes details such as the volume quantity, greenhouse gas data and origin. This linking of data allows auditors, certification bodies and competent authorities to reconstruct the full supply chain in cases of fraud suspicion. There is not yet sufficient clarity on when a reconstruction of the supply chain can be carried out. It is now understood that only when suspicion of fraud is raised, certain system users can get access to the transaction data of the respective supply chain. This would mean that the system cannot be used to detect fraud, only to verify fraud suspicions. It is uncertain how this will work in practice, since suspicion is mostly raised at end use for compliance but related to the first part of the chain, where other countries and parties are involved.

While the UDB will record transaction history of a product as it moves through the supply chain - and offers a possibility for system users to map out the product's trajectory - it differs from the framework of (Correlated) Digital Traceability Events as defined by the United Nations Transparency Protocol (Figure 3). The UDB is a single centralised database used only for the regulatory traceability and compliance for biofuels under EU law, while DTEs are a protocol and data model that records supply chain "events" in a way that interoperable, extensible and machine-readable. This makes the approach platform-agnostic, the same event model could be implemented in many different systems.

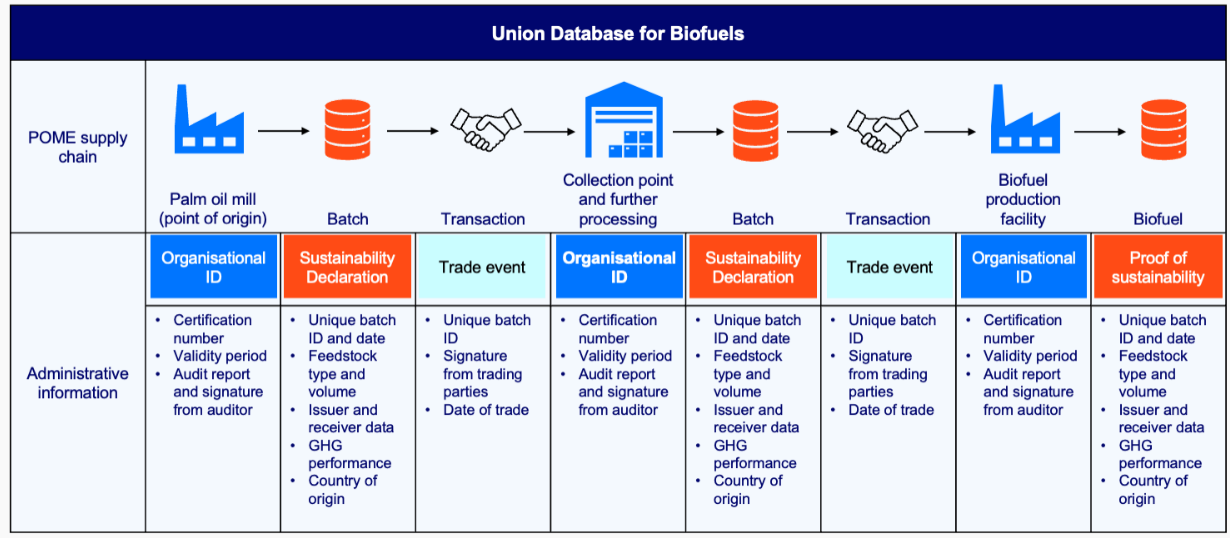

Figure 3. Overview of the information collected in the Union Database from POME supply chains combining administrative information found in business wallet, sustainability declaration and trade event.

It is important to note that access to UDB functionalities and data is restricted to authorized users based on the "need to know" principle. This means access rights are determined by the system owner based on a risk assessment, considering factors like information sensitivity.

Who has access to what information in the UDB?

The UDB distinguishes between several categories of information relating to Economic Operators. While these categories are not further elaborated, they likely include:

- **Organisation information**: The core identity and administrative details of an Economic Operator, such as the legal entity name, registration details and contact information, which establish who the operator is in the system.
- **Transaction data**: This covers records entered in the UDB, related to specific individual transactions (trades) between two economic operators.
- **Certificate identification and validity information**: This consists of the certificate number associated with an Economic Operator and the corresponding validity period, enabling users to verify whether the operator holds a valid certification at a given point in time.
- **Certificate scope details (sites, scope and materials)**: This includes the detailed content of the certificate, specifying which sites are covered, which activities are authorised under the certification, and which materials or fuels fall within its scope.

Table 1 below (next page) provides an overview of which users of the UDB can access what types of information.

While the Commission has shared some information on who has access to what information in the Union Database on their website, it is still unclear as to whether there are constrictions to when system users have access to what information.

Specifically, regarding the transaction data, it is important to know whether supervising Member State authorities, and European Commission system users have access to the full history of transaction data of all economic operators, or whether this is limited to specific situations. Moreover, there have been signals that transaction data can only be accessed for economic operators that are subject to a suspicion of irregular data reporting. These questions are relevant to understand what can be done by regulators or supervising authorities with the data that is collected in the Union Database.

Table 1: Access rights Union Database of Biofuels[19]

User Role	User description	Organisation Details	Transaction data	Certificate ID & Validity	Certificate Site/Scope/Material?
EC Admin / User	European Commission officials	✅ **Yes** Full access to view the registered legal entity and organisation profile for all Economic Operators.	✅ **Yes, for authorised personnel only** visible only to people with specific transaction-related roles/rights within EC.	✅ **Yes** Certificate identifiers and their valid timeframes.	✅ **Yes** Full detail: what activities or locations are covered and what materials are certified.
Member State authority (MS)	Member State authorities managing supervision	✅ **Yes** Can view organisation details of EOs relevant for their Member State.	✅ **Yes, for authorised personnel only** visible only to Members of national competent authorities with transaction rights	✅ **Yes** Certificate ID & validity.	✅ **Yes** Full certificate scope and material coverage to enforce compliance.
Voluntary Scheme (VS)	Voluntary Scheme representatives	✅ **Yes** Can view organisation details of EOs registered under their scheme.	❌ **No** Cannot see transaction history at all.	✅ **Yes** Certificate ID & validity.	✅ **Yes** Can see certificate-specific details such as sites covered, scope and materials.
Economic Operators themselves	Economic Operators themselves, with access to their own registered information	✅ **Yes** Can view own organisation profile.	✅ **Yes** Can view own transactions in the system.	✅ **Yes** Can see own certificate ID & validity.	✅ **Yes** Can see own certificate details (sites, scope, materials).
Other Economic Operators	Economic Operators who cannot access other operators' data, maintaining confidentiality	❌ **No** Cannot view another EO's organisation info.	❌ **No** Cannot view another EO's transactions.	⚠️ **Planned** Intended future feature to allow visibility of certificate IDs of other EOs.	❌ **No** No access to other EO's certificate details.
TSO/DSO/LSO	Transport and distribution operators	❌ No Cannot view organisation profiles of EOs.	❌ **No** Cannot view transaction histories.	✅ **Yes** Certificate ID & validity.	❌ **No** Cannot view certificate scope or materials.
Certification Bodies (CBs)	Certification Bodies that audit Economic Operators	✅ **Yes** Can view organisation details for EOs they audit.	✅ **Yes, as part of audit** Can see transactions related to their audit scope.	✅ **Yes** Certificate ID & validity.	✅ **Yes, as part of audit** Can view certificate scope/materials for validation purposes.
Service Provider	Entities appointed by EOs to act on their behalf, such as providers of software that has links with the UDB	✅ **Yes (appointed by EO)** Only for EOs that have explicitly appointed them.	✅ **Yes (appointed by EO)** Only transactions for the EO that appointed them.	✅ **Yes** Can see certificate identifiers for all EOs they are connected with.	✅ **Yes (appointed by EO)** Only full certificate details for those they serve.

4.3 The treatment of POME and other palm oil residues in the EU regulatory framework

Within the EU renewable energy regulatory framework, both palm oil mill effluent (POME) and empty fruit bunches (EFB) are explicitly recognised as waste- and residue-based feedstocks eligible for advanced biofuel production. Under Directive (EU) 2018/2001

[19] Adapted from a table in the Public wiki by the European Commission on Union Database for Biofuels (https://wikis.ec.europa.eu/spaces/UDBBIS/pages/121442625/Security)

(RED II) and its subsequent amendments, these materials are included in Annex IX, Part A, point (g), which covers residues from palm oil production such as POME and EFB.

Feedstocks listed in Annex IX, Part A benefit from enhanced policy support, including higher contribution towards renewable energy targets, reflecting their status as wastes or residues that do not drive additional land use. Importantly, the regulatory framework does not differentiate between POME- and EFB-derived oils in terms of eligibility, sustainability status, or incentive level. Both are treated equivalently for the purposes of compliance, certification, and target accounting, underscoring that they belong to the same regulatory feedstock category despite differences in their physical origin within the palm oil mill process.

5 Potential data points for verification of a raw material

The administrative chain of custody system adopted in Europe for the sustainability verification of raw materials is on its way to provide better transparency and trust in biofuel supply chains. Extensive data points are already being collected at palm oil mills and further down the supply chain during everyday operation and yearly audit procedures. The UDB acts as an attempt to better record a number of these data points and improve the traceability of raw materials along the supply chain.

Nevertheless, this administrative verification system is not intended to provide information on the physical reality on batch level. Annual audits check for certain parameters at the palm oil mills, such as the type of steriliser used, the processing set-up and the used equipment, to give an indication of the expected annual volumes of POME oil, as well as other palm oil residues. It, however, does not provide a verification that the physical reality of individual batches reflects the administratively issued volumes recorded on sustainability declarations.

In this section, we first explore the samples and test that are taking place at the palm oil mill and downstream points. Furthermore, we explore how the information on the composition of individual POME batches can further improve the administrative chain of custody information to strengthen the information position of actors along the supply chain.

5.1 Physical samples and testing taking place along the POME supply chain

At the palm oil mills, the first point in the supply chain that gets individually audited and certified, physical sampling and testing is generally not a standard current practice carried out across all geographies. There are indications that at some palm oil mills in Colombia, it is common practice to carry out physical sampling and analysis on a daily basis as part of the standard operations. They do so especially for checking the quality of their main product, crude palm oil, for the food market. Whether or not this is standard practice across the South American region is uncertain.

Contrastingly, stakeholders in Indonesia indicate that physical sampling and analysis is not commonly applied at the palm oil mills They say that it would be technically possible for palm oil mills to carry out such tests, but that in the current practice it remains an unnecessary cost to do so. Specifications of their product are estimated more roughly and on basic parameters that can be established without the need for advanced methods and equipment. They also highlight that the purchase of proper equipment to generate quick and reliable results can be a large expense for small palm oil mill operators.

All stakeholders downstream from the palm oil mill in the supply chain are likely doing some kind of physical sampling and analysis for the purpose of monitoring and managing quality of the feedstock. This is especially the case when feedstocks are refined to improve the quality of the feedstock or are processed into biofuels. Operators further downstream are likely to have more advanced equipment and procedures, whilst operators directly after the palm oil mills can show larger variation in the type of tests carried out on the products they handle and the equipment they use.

During the audit process, auditors are authorised to take samples in case of doubt, however it is not a requirement. In the working session organised for this project, ISCC indicated that an analytical method for used cooking oil to analyse the typical UCO composition is being developed. ISCC indicates that a similar method will most likely be developed for POME, in case the pilot for UCO is successful.

5.2 Fingerprinting of POME samples

Palm oil mill effluent often consists of a mixture of oils originating at the palm oil mills. Oils can be distinguished from other palm products, such as the crude palm oil in terms of their organic compounds such as free fatty acids, oil types, or vitamins and inorganic compounds such as chloride or iron.

This idea of an additional physical confirmation can be implemented in two distinctive ways.

Physical traceability via an (artificial) fingerprint

A first approach is to introduce a physical verification mechanism at the point where POME oil data on batch level is recorded in the certification system and are entered into the UDB. This physical verification concerns any point where sustainability declarations for a specific batch are issued, and could be applicable at any stage of the supply chain up to (and potentially beyond) processing into fuel. Testing for the recurrence of specific physical composition profiles at different points in the supply chain can allow to physically trace specific batches along the supply chain. The possibilities of such tracing will need to be studied more extensively. As organic profiles change over time and in storage and transport, it is perhaps better to not rely on the natural chemical composition of POME, but rather use a chemical or isotopic tracer, deliberately added at the point of origin and traced along the supply chain.

This tracer would act as a unique physical fingerprint that accompanies the POME through storage, transport, and aggregation, enabling verification that the material corresponding to a given UDB entry is physically present and unchanged. The tracer could be designed to be:

- Detectable at multiple points in the supply chain;
- Resistant to dilution or substitution;
- Removable or neutralised during fuel processing, ensuring no impact on the final fuel product or downstream sustainability criteria.

Moreover, comparing test results of the natural chemical compositions of outgoing batches and receiving batches would allow to signal if abnormalities have occurred and allow to detect where in the supply chain tempering of raw material took place.

By linking UDB entries to a verifiable physical marker, this approach would reduce reliance on administrative controls alone and make deliberate mislabelling, double counting, or substitution materially more difficult. Trust would no longer depend solely on documentation integrity but would be reinforced by a tamper-resistant physical signal embedded in the product itself. The cost and benefits of this option need to be further discussed. The choice of implementing such a solution touches upon the principles of design choice for the sustainability certification system. Adding a verification step on a physical sample may move away from a mostly administrative evidence-based approach.

Confirmation of composition at point of origin

A second, more targeted approach is to apply physical verification only at the point of origin, with the aim of confirming that the material registered as POME is indeed POME. This would be achieved by analysing the natural chemical composition of the material and verifying that the recorded volume corresponds to a profile that is consistent with typical POME characteristics.

This verification step provides additional assurance that:

- No other oils, residues, or by-products are incorrectly labelled as POME at the source;

- The declared volumes are physically plausible given the composition and expected yields of POME.

Once the authenticity of the material is confirmed at origin, the administrative tracking system that is in place for the EU biofuel market should ensure that no tempering with data happens downstream. With the full implementation of the UDB, and possible additional digital traceability solutions, such as creating verifiable credentials, such as described in this report there should be sufficient safeguards to ensure that no subsequent tampering, substitution, or misreporting occurs along the remainder of the supply chain.

This approach therefore front-loads physical verification while maintaining a proportionate level of complexity and cost, using physical testing to validate the starting point and administrative systems to preserve trust thereafter. It also stays much closer to the existing administration-based system, only adding a physical verification at the point POME oil data on batch level is first entering the certification system.

Testing methods and equipment

Different technologies exist for these types of fingerprinting. Chemical analysis is often too costly and time consuming while sensing technology can provide a faster and cheap solution for fingerprinting. For instance, optical sensing technologies allow to fingerprint solid and liquid samples in terms of their chemistry. Infrared and Raman spectroscopy allows to fingerprint in terms of organic molecules such as fats and acids. Fluorescence spectroscopy is another optical technique which is more sensitive to minor components such as vitamins, polyphenols, carotenoid, chlorophyll, and secondary oxidation products as well.

Both proposed solutions would require an additional financial investment and potentially expertise from the operators of the palm oil mills at the point of origin, as it is not common practice that they do physical sampling and analysis. By making it a mandatory requirement for supply to the EU market, it likely does not lead to any competitive disadvantages for palm oil mills.

6 Conclusion and recommendations

This project allowed us to look at the following questions:

- How can the use of encrypted data and verifiable credentials, the Digital Product Passport and Correlated Digital Traceability Events (DTE) of UNTP[20] improve transparency in the POME-oil based biofuel supply chain?
- What (additional) data points can we identify that support the verification of the residue oils?
- Can the use of the UNTP interoperability protocol and decentralised data architecture help to improve public oversight and private audit tasks?
- What does this mean for governance (organisational aspects) including the link with the Union Database for Biofuels?

This chapter combines the conclusions of the project and discusses any associated recommendations, structured along these research questions. In the sub chapters, five key recommendations are drawn which are summarised in the figure below (Figure 4).

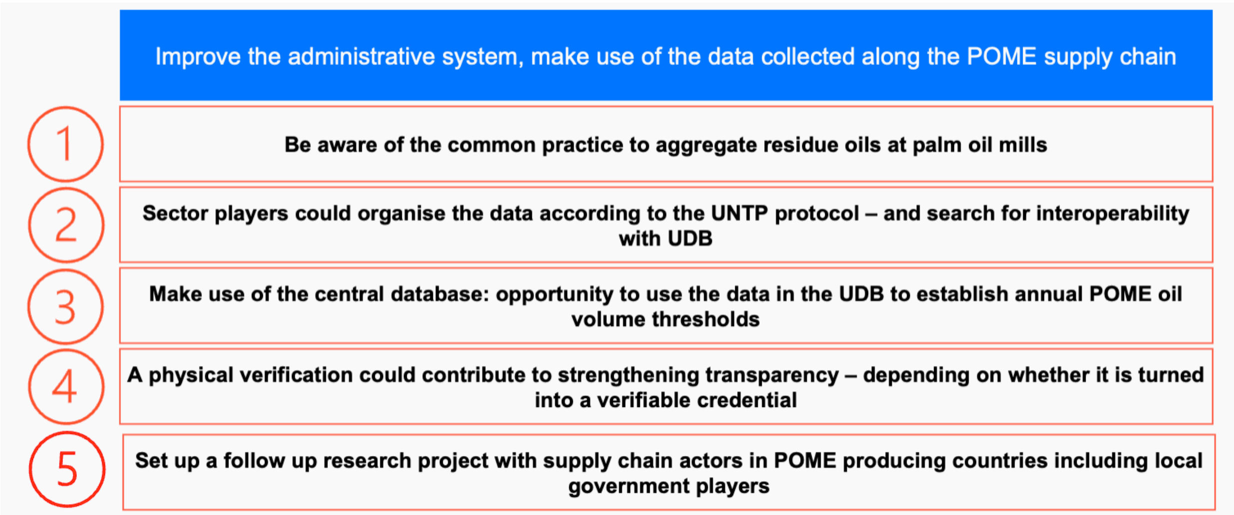

Figure 4. Five key recommendations have been drawn from the project.

While most of the recommendations and conclusions of this research relate directly to the POME oil-based supply chain, many of them can equally apply to other (high-risk) feedstock supply chains.

6.1 Use of the Digital Product Passport and Correlated Digital Traceability Events (DTE)

We explored the benefits of some core principles of the United Nations Transparency Protocol (UNTP), which are also being incorporated in the Clean Fuel protocol, an innovation project in the Dutch renewable fuel context. We specifically assessed the benefits for verification in the POME supply chain of implementing a Digital Product Passport (DPP) and correlated digital traceability events (DTEs).

The Digital Product Passport consists of a digital record containing product information, including sustainability and environmental performance, and is linked to the product as it travels along the value chain. The product passport also contains links to traceability events which allows to follow the transformation of a product and trace it back to its point of origin.

Digital Traceability Events (DTEs) refer to a collection of information on a product and facility that constitute the value chain. The traceability events specify the "what, where, why and how" information of a traded product. DTEs are issued as verifiable credentials, which ensures that the data is secure, tamper-evident and can be shared selectively.

[20] See https://spec-untp-fbb45f.opensource.unicc.org/docs/specification/.

Typically, DTEs function within a decentralised infrastructure, allowing users to navigate a linked-data “graph” that represents the history of a product.

Market parties in the POME-oil supply chain could benefit from adopting the DTE approach to record supply chain actions as verifiable credential data. This approach facilitates interoperability, allowing connectivity to different compliance systems including the Union Database. This prevents a lock-in into the UDB system and ensures that operators do not have to double record information for different compliance markets. Business Wallets are an essential tool to issue and manage such verifiable credential data.

The digital product passport could be used to increase trust in the recording of information that is already made available in current sustainability certification systems. This concerns the product-related information listed on a sustainability declaration that is passed on through the supply chain, such as product type, country of origin, raw material, and GHG information. The use of DTEs makes it possible to trace specific batches and to create a linked-data trail, providing insight into inspections, transactions, and transformations that altered the product’s state. All of such supply chain events can then be traced back to a verified legal entity. This provides better transparency in the system but also creates more opportunities for accountability of actions. The value of using DTEs and a decentral data management approach lies in the opportunity to link to the data from the point of origin which improves supply-chain transparency.

6.2 Additional data points supporting verification of raw materials

The current EU compliance system is stooled on voluntary administrative certification systems. The scrutiny on the supply chain palm oil, but also of its associated residues such as POME oil, as well as EFB oil, has intensified. Palm oil mills always have to be individually certified, which includes an annual audit procedure. The ISCC Guidance on the certification of these palm oil residues is very comprehensive. This creates a great number of valuable data points at the palm oil mills which could be recorded as verified credential data in the form of digital traceability events. Additionally, the administrative certification system includes more valuable data points, which are part of sustainability declarations, including data on volumes, sustainability compliance, and greenhouse gas performance.

Nevertheless, there could be value in additional data points that reflect the physical reality at certain points in the supply chain.

Verification in the form of physical tests on samples can be complementary to administrative data by providing information on the chemical composition of batches. Two options to add physical verification were identified. The first option is to confirm the chemical profile of POME at the point of origin and further rely on the strengthening of the chain-of-custody that is created by the Union Database for biofuels. This would further improve the quality of the data entered into the administrative system and the UDB (Figure 5). The second option is that all operators take a chemical profile of the product to see if these profiles match as the product moves along the supply chain, potentially achieving the best results through the use of an intentionally added chemical tracer that can be filtered out at the point of conversion to fuel. Both of these options would have to be further investigated for feasibility and cost-effectiveness.

6.3 Implications for public oversight and private audit tasks

Firstly, the implementation of DTEs for supply chain actions on facility and individual batch level could improve trust and substantially reduce transaction costs. Verifiable credential data ensures that any supply chain event can be traced back to a verified legal entity. This could make public oversight and private audit tasks quicker, simpler and more effective.

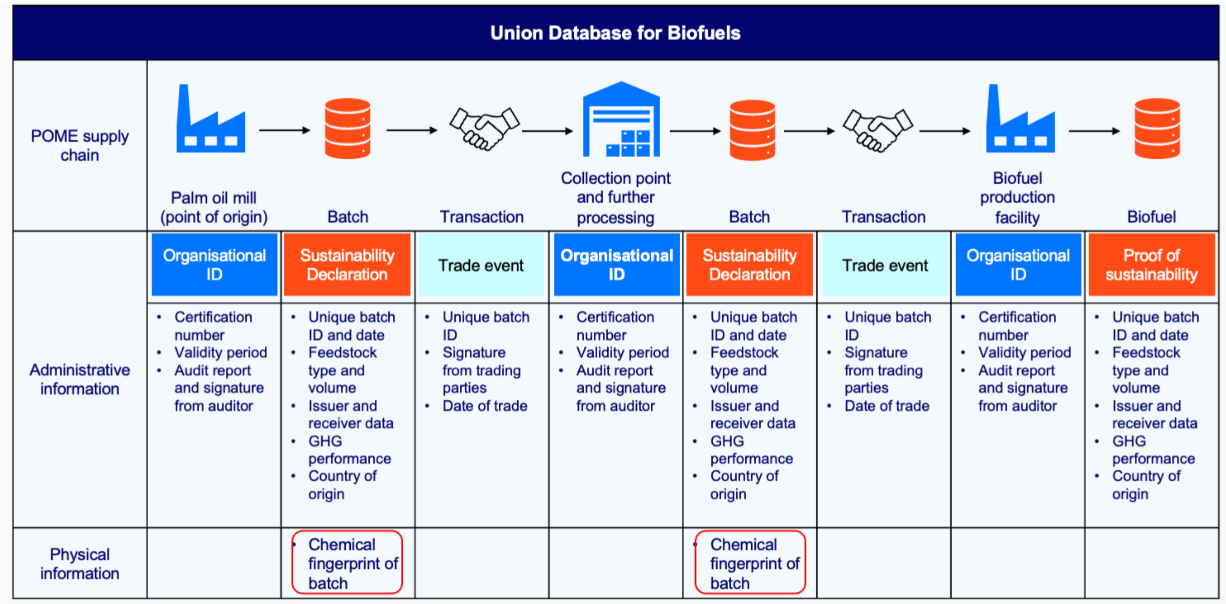

Figure 5. In this project, we explore the possibility of adding physical information on a batch level which could occur at several points along the supply chain and uploaded to the UDB.

Secondly, decentral data approach could improve monitoring by providing the possibility to linking data. The voluntary certification systems require a lot of information to be checked during annual audits. Specifically, auditors must check that the issued sustainable product of a palm oil mill falls within a specific expected range, based on process parameters such as steriliser type, POME recovery method and recovery equipment used. This is very useful information that could be used to calculate an annual threshold reference for POME oil volumes. This threshold would represent the estimated volume of POME oil, or all residue oils, that could reasonably be produced by palm oil mills certified under an EC-recognised voluntary scheme.

Comparing this threshold with the actual volumes for which sustainability declarations have been issued, would provide supervising bodies and auditors with a tool to detect anomalies or potential fraud. It would also serve the sector parties to refute claims that there is fraud at substantial scale, made by external stakeholders critical of the sector.

There are two key challenges to this proposed solution. One is that the mill-specific technical data needed to establish accurate thresholds is currently accessible only to the voluntary schemes under which the mills are certified. A second challenge is that currently there is no overview of the volumes for which sustainability declarations are issued.

Both of these challenges could be overcome if market players start recording such information as data credentials verified by the auditor. The palm oil mill can then allow this data to be used for analysis while respecting its confidential nature. The Union database (UDB) is likely also creating a data-overview that has the potential to overcome the second challenge, but it is uncertain whether the UDB can be used as a data source for such purposes, as access rights are not fully certain. This would require further investigation and is beyond the scope of this project.

6.4 Governance implications and the role of the Union Database

The Union Database for Biofuels collects a large amount of information, but current access rights do not allow for systematic analysis of the data. Only in cases of fraud suspicion can transaction data for specific operators be viewed. This limits the ability to proactively analyse volumes released to the European market.

Using the UNTP framework, including Digital Traceability Events, ensures that data are issued in the form of verifiable credentials that can be traced back to verified legal entities. This offers opportunities to link data sources and analyse datasets. It is, however, an entirely different approach to data management. Data are federated, meaning ownership remains with operators, and verifiable credentials can be used as input for different compliance systems, including the UDB. This approach prevents system lock-in and increases flexibility to adapt to technological advancements.

Implementing this approach in the biofuels supply chain would require an obligation to use Business Wallets for the management of data. The data stored within such business wallets can then serve as an input source for the UDB. Such an obligation could be introduced by certification schemes or by the European Commission through regulation of voluntary schemes.

This requires a fundamental change at the architectural level of how sustainability is ensured. Europe has decided to introduce an administrative system for the sustainability chain of custody for biofuels, and has introduced a central database to improve public oversight and traceability. At the same time the administrative system could fit well with the decentral data management that the UNTP offers, including verifiable and encrypted data, managed from business wallets. This would, however, mark a fundamental shift in the organisation of sustainability certification. Hybrid approaches can also exist, where a decentralised data management by market players can inform the central database used by supervising authorities, but will likely lead to inefficiencies and increased system costs.

6.5 Additional insights

Finally, the project identified that it is common practice at palm oil mills that empty fruit bunch (EFB) oil is frequently stored and handled together with POME oil. In practice, these streams are often physically mixed immediately after retrieval, making a strict administrative distinction difficult to maintain and verify. This could lead to situations where different residual oil streams are labelled under one category, whether intentional or unintentional, whereby EFB oil is reported as POME oil. This may contribute to apparent POME feedstock volumes that exceed what reasonably can be expected to be available from palm oil mills.

From a regulatory perspective, there may be limited justification for maintaining a separate administrative classification, as both POME oil and EFB oil fall under the same feedstock category listed in Annex IX, Part A, point (g), and are therefore incentivised equally. Requiring a formal distinction between two physically co-mingled streams that receive identical policy treatment adds unnecessary complexity to verification systems without delivering additional environmental integrity and may increase the risk of reporting errors. By eliminating this potential source of inconsistency, focus can be directed towards suspicions of fraud that may have additional environmental consequences, while also reducing disputes and reputational risks across the biofuel supply chain.

6.6 Recommendations for future research

In this project, we have brought together insights from four systems: practices of residue oils at palm oil mills, the ISCC certification system, digital transparency solutions as provided by the UNTP and the Clean Fuel Protocol along with the development of the Union Database for biofuels. In order to further develop and test the insights generated in this project, we recommendation to set up a follow up research project with supply chain actors in POME producing countries including local government players. This type of research project would provide better insights on the feasibility of implementing digital traceability solutions as well as the possibility of adding a fingerprint to the as a physical verification of the composition of batches.

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