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Roundtable on Sustainable Biomaterials
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BioLedger

Blockchain Database for Sustainable Biofuels:

A Case Study

March 2021

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A joint publication by the Roundtable on Sustainable Biomaterials (RSB) and Bioledger, this report summarises the results of a project which ran between January and November 2020. The project was made possible by a grant from the ISEAL Innovations Fund, which is supported by the Swiss State Secretariat for Economic Affairs (SECO).

Executive Summary

The growth and integrity of the sustainable biofuels industry, as well as the interests it seeks to protect, are in jeopardy due to the vulnerabilities in methods it currently uses for tracking transaction claims and verifying their authenticity — as identified by recent biofuel fraud investigations in the Netherlands.

Bioledger and the Roundtable on Sustainable Biomaterials (RSB) explored a solution to this risk, leading to the development of a highly innovative, simple, and secure centralised database for tracking the data generated by biofuels transactions, utilising the powerful and incorruptible capabilities offered by blockchain technology.

The results generated and lessons learnt from the project are shared in the accompanying case study document and are summarised below.

The parameters for building and running the database were identified through consultations with stakeholders, including used cooking oil (UCO) collectors, biodiesel producers, traders, EU policymakers, industry associations, certification bodies, and auditors, and are summarised under the following three themes:

1. Improvement of data integrity and security.
2. Execution of business processes and compliance.
3. Governance method and business model for the database.

To evaluate the efficiency and applicability of the database, a prototype was piloted by four partners: Greenergy (UK), Europe's largest waste-based diesel producer; Rexon Energy (Singapore), an exporter of UCO to the EU; Bensons Products (UK), a UCO collector; and Valley Proteins (USA), a UCO collector and exporter.

The database application enabled three distinct user roles — namely 'first collector driver', 'first collector administrator', and 'trader' — to process a total of 1,927,906 litres of feedstock, accurately representing real-life commercial and operational processes.

During the piloting of the database, it was demonstrated that a significant number of transparency and accountability issues in the UCO biofuel market can be resolved by the technical solutions that a blockchain database offers — either exclusively or in a far superior manner to the typical data management methods currently used in the supply chain, such as paper and digital transactional documents, spreadsheet programmes, and relational databases.

New solutions, such as verifiable proof of origin, secure consignment creation, process simplification, audit efficiency, data integrity, and central governance were developed through this blockchain prototype, and the following recommendations and observations were made:

- A full blockchain database solution ensures true decentralisation and transparent governance of trades with blockchain nodes hosted by trusted regulators and stakeholders.
- The system should be designed to enable stakeholders to easily integrate data using new digital interfaces or existing data systems, while these interfaces need to be carefully managed to control data quality.

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- This solution had business rules developed in line with the specific use case (biofuel markets using the EU RED Voluntary Scheme), but a scalable solution should include the development of a configurable business logic layer to account for different markets.
- To increase the strength of evidence and minimise the risk of errors and fraud at data point of entry, the blockchain solution should include the use of biometric authentication, photos, signatures, and geolocation.
- A full blockchain solution should record all mandatory data points from EU RED requirements within its data architecture, in order to replace the currently ubiquitous paper-based chain of custody documents.
- Existing legal agreements between supply chain companies and their auditors, certification bodies, and voluntary schemes already provide the necessary protections to allow private disclosure of sensitive commercial data within the blockchain database.

The project recommendations are made with acknowledgement of the fact that a major hurdle in the development of a blockchain database for sustainable biofuels will be the cost involved in building a solution which captures the complex requirements of the biofuel regulations and their international supply chains. However, these same legal frameworks provide a firm foundation to define digitised compliance logic, governance roles, actions and responses that are permitted within the blockchain database. The pilot project is an example of how blockchain technology can be used to develop a commercially viable solution to meet industry and regulatory requirements on scalability and security within a limited time period and budget.

The database initiative and the recommended features for improving transparency and control in certified sustainable biofuel supply chains were welcomed during presentations to several European Union member state biofuels regulatory agencies, including the EU Renewable Fuels Regulators Club (REFUREC), the UK Department for Transport Renewable Transport Fuel Unit, the Dutch National Emissions Authority (NEA), and the Irish National Oil Reserves Agency (NORA).

The blockchain database prototype was also included in a scoping study conducted by Navigant on behalf of the European Commission Directorate-General for Energy (DG Energy).

RSB and Bioledger continue to engage with industry and regulatory stakeholders towards ensuring that the technical capabilities to mitigate fraud, restore trust, and build transparency — as outlined in this report — are integrated into industry standards and digital platforms such as the RED II database for renewable road transport fuel or international sustainable aviation fuel.

Bioledger is further developing the lessons gained from the pilot project to provide a new blockchain database for the biofuels market.

RSB and Bioledger are committed to building upon the lessons learnt through this project and making such a database — based on the principles of transparency, sustainability, and good governance — a reality. In particular, the project partners acknowledge the need to maintain dialogue and consideration of the global waste biofuel feedstock supply chain when developing technical solutions intended for every day, manual use. The integrity and liquidity of any biofuels database depends on adoption by the diverse upstream supply chain.

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Glossary of acronyms

BLE	Federal Office for Food Agricultural (Germany)
BOS	Biofuels Obligation Scheme (Ireland)
BSS	Business Support System
CB	Certification Body
DLT	Distributed Ledger Technology
EBB	European Biodiesel Board
EBOTA	European Bulk Oil Traders' Association
ePURE	European Renewable Ethanol Association
EU RED	European Union Renewable Energy Directive
EWABA	European Waste-to-Advanced Biofuels Association
FuelsEurope	European Petroleum Refiners Association
IoT	Internet of Things
KYC	Know Your Customer checks
MVO	Netherlands Oils and Fats Industry
NARA	North American Renderers Association
NBB	National Biodiesel Board (US)
NEA	National Emissions Authority (The Netherlands)
OSS	Operations Support System
ROS	RTFO Operating System
RSB	Roundtable on Sustainable Biomaterials
RTFO	Renewable Transport Fuel Obligation (UK)
UCO	Used Cooking Oil
VSS	Voluntary Sustainability Scheme

1. Introduction

Investigations conducted by the Government of the Netherlands indicate[1] that almost one third of the volume of biodiesel in the country reported as sustainably certified could have been declared using fraudulent documentation created by one company in 2015 and 2016. This means that biodiesel claimed to be made from Used Cooking Oil (UCO) could have been made with virgin oil (e.g., palm oil) instead.

On top of the significant environmental impact — such as deforestation and continued transport emissions — unsustainable and fraudulent biofuels illegally embezzle public funding intended for the development of a green economy. This deception undermines the credibility of and support for sustainably certified biofuels which policy makers are relying on to reduce transport emissions in the immediate and long term.

The European Renewable Energy Directive (EU RED) requires that all biofuels sold and traded in the EU are regularly audited and certified by independent, third-party auditors according to a recognised voluntary sustainability standard. Despite these stringent requirements being applied, some fraudulent claims have still managed to enter the system without being detected through the normal auditing processes.

Sustainability data associated with physical consignments in the chain of custody for biofuels is usually recorded with paper documentation, exposing the process to risks including forgery, unwarranted replication, and concealment — allowing fraudulent claims to be created without the auditor being able to adequately review them in the participating operator's accounts. Furthermore, the auditor's access to information during audits is also limited by time constraints and a lack of transparency.

A blockchain database solution that records transactions in an immutable ledger and integrates a waste origin verification mechanism has the potential to solve these issues.

To prove the feasibility of such a solution, RSB and Bioledger joined forces to carry out a project between January and November of 2020, with the support of the Swiss State Secretariat for Economic Affairs (SECO) through the ISEAL Innovations Fund. The project builds on a previous project led by RSB called 'The Blockchain Revolution: Application to Sustainably Certified Supply Chains', also funded by the ISEAL Innovations Fund, and finished in 2018 — which concluded that blockchain technology was suitable as a *single source of truth* (SSOT) in chain of custody tracking but that more testing in a real-world scenario was required.

[1] https://www.ilent.nl/actueel/nieuws/2019/05/20/fraude-met-certificering-duurzame-biodiesel

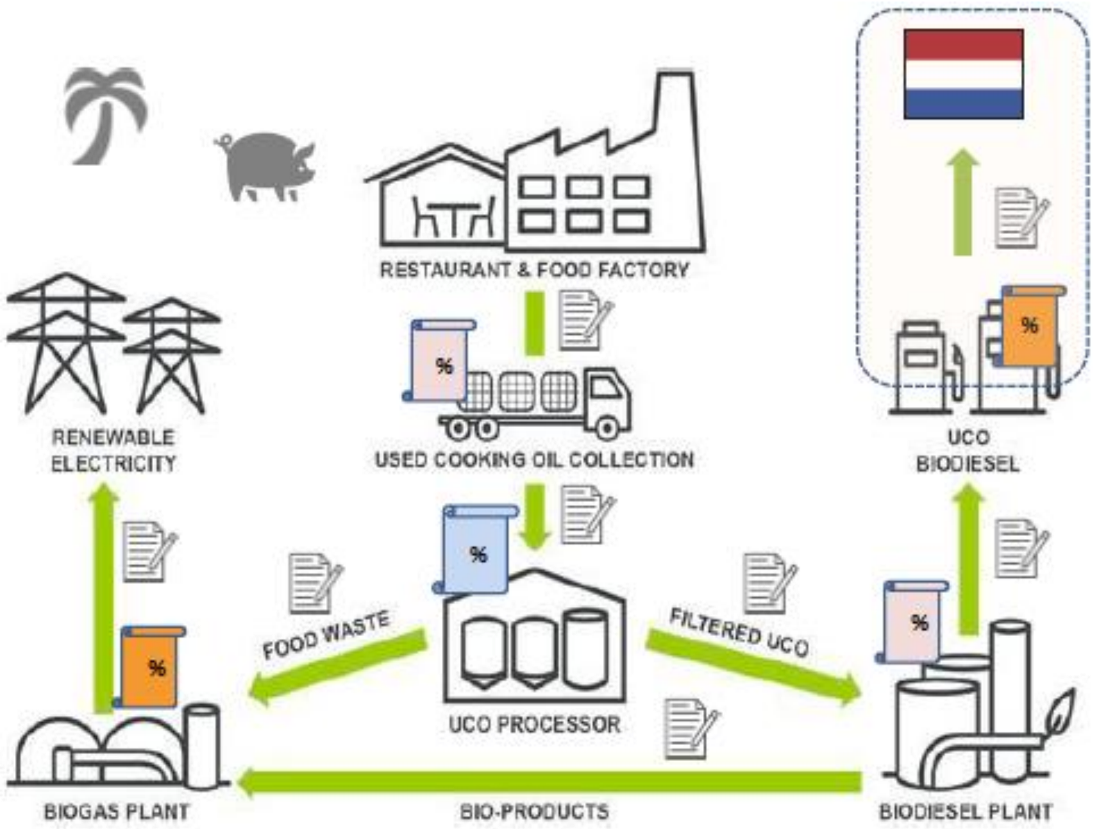

Figure 1: Example of a UCO biodiesel supply chain

1.1. Project partners

This project was led by Bioledger and RSB, funded by the ISEAL Innovations Fund, tested with data provided by four pilot partners, and received further support from seven other industry entities.

Bioledger

Bioledger Ltd. is a software development company formed by biofuel industry stakeholders in response to the risk of fraud and noncompliance in the certified sustainable biofuels market in 2019. By combining a world-class design and development team with biofuel industry experts, Bioledger embeds a deep understanding of biofuel and feedstock trading, operations, and compliance into technical solutions which meet the specifications of both regulators and industry.

The Bioledger team, based in Ireland, the UK, Poland, and India, bring together a group of highly skilled and experienced developers of distributed ledger and blockchain solutions. Team members have previously worked on database solutions for biofuels compliance and Enterprise Resource Planning (ERP) systems for blue chip clients in the pharmaceutical, vehicle manufacturing, and oil industries.

Bioledger's founder, Patrick Lynch, helped develop and deploy some of the first voluntary schemes for sustainable biofuels under the RED (in particular for sugarcane ethanol and UCO biodiesel) as well as the recent EWABA Standard of Transparency, during his role as Head of Sustainability at Greenergy, Europe's largest waste biodiesel producer and the UK's largest biofuel blender.

Bioledger aims to support efforts to mitigate climate and ecological emergencies by making sustainable commodity verification and compliance easier, safer, and more valuable so that every stakeholder contributing to sustainable commodity supply chains is protected from fraud and rewarded fairly. Its process requires deep consultation with users to identify and resolve material problems with precise solutions.

RSB

The Roundtable on Sustainable Biomaterials (RSB) is a global, multi-stakeholder organisation that offers advisory as well as membership and certification services for the bioeconomy — on a global scale. Together with its partners, members, and certified projects, it represents best practice in sustainability and proactively drives the development of a sustainable bioeconomy.

The RSB Principles and Criteria are the most robust and comprehensive indicators of why a biomaterial is sustainable. They are a solution for sector pioneers who need guidance in developing innovative products for a new world, founded on social, economic, and environmental considerations. The RSB certification system includes regulatory standards for compliance with the European Union's Renewable Energy Directive (EU RED) and ICAO's CORSIA.

RSB enjoys extensive NGO support and is aligned with the United Nations' Sustainable Development Goals (SDGs). RSB certification is recognised by WWF, IUCN, and the Natural Resources Defence Council as the strongest and the most trusted of its kind.

Visit www.rsb.org for more information.

Pilot Partners

Four private sector companies participated in the project as pilot partners, and namely:

- Greenergy (UK), Europe's largest waste-based diesel producer;
- Rexon Energy (Singapore), an exporter of UCO to the EU;
- Bensons Products (UK), a UCO collector; and
- Valley Proteins (USA), a UCO collector and exporter.

ISEAL Innovations Fund

The project was funded by the **ISEAL Alliance Innovations Fund**. ISEAL is the global membership organisation for ambitious, collaborative and transparent sustainability systems. They drive collective efforts to tackle the most pressing sustainability issues and create a world where markets are a force for good.

From climate change and deforestation to inequality and persistent poverty, the world needs scalable and effective solutions. ISEAL supports sustainability systems and their partners in delivering solutions for these critical challenges, so that companies and governments can meet their sustainability commitments and the UN Sustainable Development Goals. Visit www.isealalliance.org for more information.

Other Contributors

Other key stakeholders who provided support and contributions to the project are the MVO (Dutch Oils and Fats Industry), the EWABA (European Waste-to-Advanced Biofuels Association), the EBB (European Biodiesel Board), the European Commission, Peterson Control Union, SCS Global Services, and Oracle Consulting Services.

1.2. Project overview

The project was developed in the following four phases:

Phase I: Requirement Gathering

The first phase was dedicated to gathering detail on the business and compliance requirements of stakeholders that would be used to develop the blockchain database prototype in the following phase. A comprehensive database of nearly 400 companies, associations, and policy makers that play a role in the biofuel (especially biodiesel) sector in Europe was developed. Each stakeholder was assigned a category — **auditor**, **certification body**, **industry association**, **ISEAL member**, **policy**, or **supply chain**. Stakeholders were identified from Bioledger's list of contacts in the international biofuel supply chain.

Stakeholders were asked to respond to an online survey relating to:

- **Risks**. Identification of the key risks to data integrity in a sustainable biofuel supply chain.
- **Data**. Specification of the sustainability and product data requirements for integration in the database.
- **Database governance and funding.** Identification of who should be responsible for managing and monitoring the data, and for governance of the system, including finding solutions to fund development and the ongoing management of the database.

During this phase, user interviews were conducted with the pilot project industry partners in order to understand the requirements of a biofuels database from commercial and operational perspectives as well as to identify user roles at the different stages in each business and the supply chain.

Phase II: Prototype Development

During the second phase, Bioledger developed the design, infrastructure and user interfaces for the blockchain based biofuel database.

A suitable architecture for the private, permissioned blockchain database was chosen based on the functionality and governance specifications identified by the industry partners in the survey and interviews, as well as those requirements defined in the Voluntary Schemes Chain of Custody standards and the project budget.

Bioledger identified three different user roles, namely First Collector Driver, First Collector Administrator, and Trader, and designed a reactive mock-up of a specific User Interface (UI) for each role to deliver the common requirements.

The blockchain code, supporting database, and web-based interfaces were built by Bioledger developers and hosted in a dedicated Oracle Cloud environment which is accessible at https://www.bioledger.ltd/rsb-blockchain-pilot-2020.

Phase III: Pilot Study

During the pilot phase, the blockchain database prototype was piloted by the four pilot partners Greenergy (UK), Europe's largest waste-based diesel producer; Rexon Energy (Singapore), exporter of UCO to the EU; Bensons Products (UK), UCO collector; and Valley Proteins (USA), UCO collector and exporter.

Bioledger identified stakeholders who represented the entire supply chain from first collection to end consumption of biofuel and who would also be willing to contribute the minimum 10 days required to complete the pilot project design, testing and analysis.

Greenergy, Rexon, Valley and Bensons were keen to support the project with the contribution of effort and expertise, due to their ongoing commitment to improving trust in the sustainable biofuels supply chain in which they are commercially active. Greenergy, in particular, have been a pioneer in the development of biofuels sustainability standards, including the first EC approved voluntary scheme for Brazilian sugarcane ethanol.

In 2013, all four of the pilot project partners worked with the founder of Bioledger in developing the first audit requirements for UCO traceability. They recognise that digitisation of biofuel sustainability compliance is a logical next step in strengthening the veracity and efficiency of supply chain evidence.

By contributing to this project, the partners want to improve the standard of evidence throughout the supply chain to protect their operations from risk but also to raise the minimum requirements for the rest of the market where the perception of risk is significant.

In total, 1,927,906 litres of feedstock were recorded in the prototype database at the point of origin (representing a First Collector Driver at a restaurant) and then aggregated and transferred downstream into the accounts of a First Collector Administrator and then a Trader.

Pilot partners were able to apply their real-life commercial and operational scenarios, and inspect deliveries from First Collector Drivers or suppliers, observe current available stock, and split or aggregate same-type consignments and transfer them to their downstream customer.

Phase IV: Knowledge Sharing

The results and lessons from the project are shared in this case study document as well as a series of webinars hosted by RSB and Bioledger[2].

The project's blockchain database prototype was also included in a scoping study conducted by Navigant on behalf of the European Commission Directorate-General for Energy (DG Energy). As contributors to that project, Bioledger and the project partners participated in very comprehensive stakeholder discussion forums to identify the key challenges and potential solutions in delivering a useful and acceptable biofuel sustainability database which is mandated by the EU Commission in Article 28.2 of the recast Renewable Energy Directive II (RED II) for implementation in 2021.

That scoping study cites lessons from this project and recommends many of the Bioledger design features for the eventual European Commission database.

Sustainable biofuel industry associations, including the European Waste-to-Advanced Biofuels Association (EWABA), the European Biodiesel Board (EBB) and the Netherlands Oils and Fats Industry Association (MVO), were helpful contributors to the Bioledger project, by hosting demonstrations and discussions with their members — culminating in a joint working document on the industries' preferred technical and governance specifications for a biofuels database.

The project was also presented in several European Union member states to biofuels regulatory agencies, including the EU Renewable Fuels Regulators Club (REFUREC), the UK Department for Transport Renewable Transport Fuel Unit, the Dutch National Emissions Authority (NEA), and the Irish National Oil Reserves Agency (NORA) — with the initiative and recommended features for improving transparency and controls on certified sustainable biofuel supply chains welcomed by the participating states.

[2] Webinar recordings are available on request

2. Blockchain Technology

One of the principal problems that the project sought to resolve is that of fraud and trust in the sustainably certified biofuel ecosystem. As such, a solution was required which not only provided a reduction in manual and paper-based audit trails — which could have been accomplished by a standard cloud-based database — but rather one which provided the users with greater confidence that the data they were receiving was irrefutably true from the point of entry and thereafter.

In simple terms, a blockchain database is a network of synchronised copies of a cloud-based database, shared in different locations, which each have secure access to read, write to, and validate the database, and which all store the identical information in an identical sequence. This makes it different to a centrally managed database, as no single entity is the master, and it is therefore impossible for a bad actor to tamper with the information or its sequence without all entities in the network observing the change.

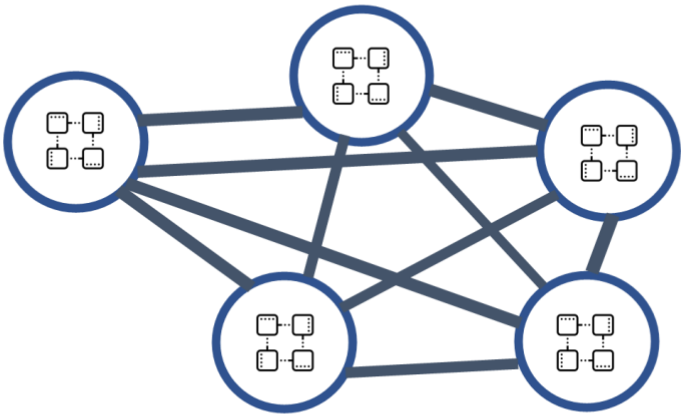

Figure 2: A blockchain database is a network of synchronised copies of a cloud-based database.

The chronological series of immutable records of data are referred to as “blocks”, and each block is secured and bound to each other using cryptographic principles (“chain”).

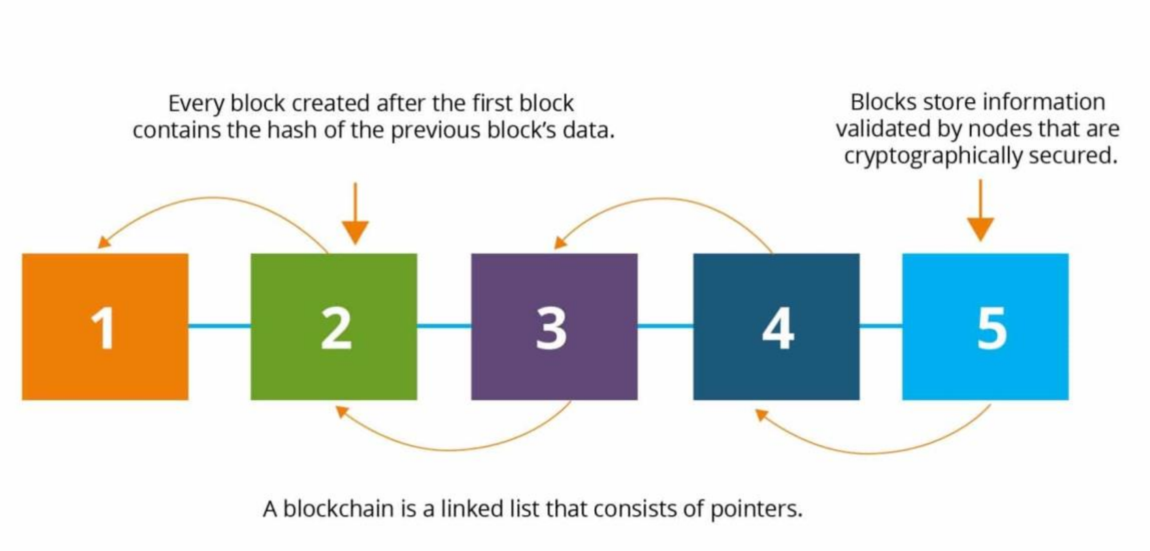

Figure 3: The chronological series of immutable records of data referred to as “blocks"

What makes blockchain relevant for sectors prone to fraud and double accounting is that all data is recorded in a shared and immutable ledger, where information is shared in a transparent way and no central authority has the power to tamper with or change any of the data or transactions.

Falsifying one record would mean having to simultaneously falsify the same records over millions of blocks across every distributed copy of the ledger, which is virtually impossible (as opposed to entering a regular database or Excel sheet and falsifying a record that is stored on one single machine or server) and would in any case be immediately visible to each of the entities hosting a copy of the ledger.

Information held on a blockchain exists as a shared — and continually reconciled — database.

As with any record, the data within it can only ever be as accurate and complete as the data first entered. An advantage of a blockchain solution is that it can be configured to demand that a specific set of logical functions must be satisfied before a transaction is allowed to be recorded in the database, improving the completeness and quality of evidence available to auditors of biofuel transactions in a blockchain database.

As with any record, the data within it can only ever be as accurate and complete as the data first entered. An advantage of a blockchain solution is that it can be configured to demand that a specific set of logical functions must be satisfied before a transaction is allowed to be recorded in the database, improving the completeness and quality of evidence available to auditors of biofuel transactions in a blockchain database.

To ensure that a First Collector Driver has indeed been given the oil type they are expecting (i.e. UCO instead of virgin palm oil), the Bioledger prototype demands that a Collector Driver must capture additional evidence (GPS location, photos, and signature) to prove that each consignment meets the requirements of the biofuel sustainability standards.

The control of unevidenced, fraudulent data at any point in the supply chain (i.e. false generation of oil or changing the feedstock type or volume of a consignment) is automatically managed by the supervising nodes in the blockchain database: when the Network automatically identifies a rogue change in one version of the ledger, the application will identify the error immediately and irrefutably, enabling the fraudulent consignment to be eliminated from the supply chain and the Supplier to be subjected to the agreed governance procedures.

Finally, in the type of blockchain used in this case study (permissioned private blockchain) different stakeholder roles can be provisioned which can then be assigned to Users. For a system user to execute a transaction, the role access rights need to be validated by the blockchain to ensure it is not a rogue request, providing another layer of security.

For example, an auditor who has been hired by a trader to perform a certification audit can be assigned the right to only read the data within their client's account within a specified time limit for the purpose of conducting their audit, or a UCO Collector Driver role could be the only role in the system that can record new consignments of used cooking oil in the ledger. Giving users a specific capability could be dependent on, for example, the user demonstrating that they are certified by a voluntary scheme and certification body to perform this type of transaction.

By working with the developer in the design stage of a blockchain database, stakeholders can build a system of consensus and embedded trust by defining the requirements and capabilities for each user role, defining the compliance logic for new transactions, and establishing who the trusted keepers of the distributed ledgers should be.

2.1 How Do Blockchain Transactions Work?

A blockchain transaction is based on a consensus mechanism — a set of rules and procedures translated into an algorithm which maintains a coherent set of facts among participants. It is a method of authenticating and validating a transaction on a blockchain, based on commonly agreed rules, and without the need to trust or rely on a central authority. There are many different mechanisms that can be used to build consensus, and programmers and companies are constantly working on new ones.

This project utilises the core functionality of blockchain, by recording transactions of sustainable biofuel consignments between Users into the blockchain — across three ledgers. The business logic of the supply chain and the compliance logic of the EU RED Voluntary Schemes are built into the network design of User accounts and blockchain code. The transaction flow is visually represented in Figure 4 below.

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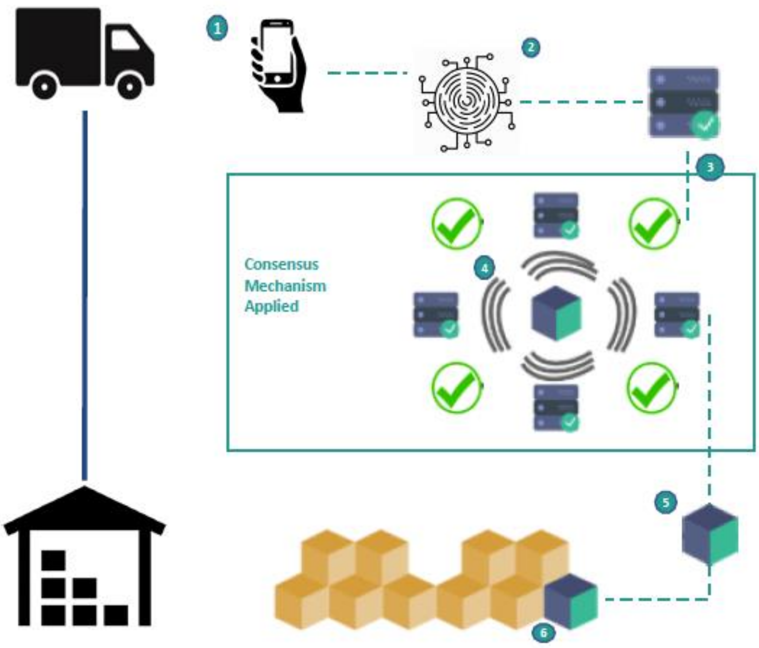

Transactions

1. A Seller delivers a consignment to a Buyer, creating transactional data.	2. Transaction data are converted into an anonymised code by an encryption key.
3. The new transaction is proposed to a network of nodes that make up the Blockchain.	4. The network of nodes validates the proposed transaction, using an agreed consensus algorithm known as a 'smart contract'.
5. A valid transaction will be permitted to execute the requested action, in this case transferring the title of the transaction data to the Buyer and creating a new Block visible to every node to	6. Only those Users authorised by business rules — in this case the Buyer and a permissioned System Administrator — can read the transaction data, using access management rules contained within the blockchain.

Figure 4: Overview of Consensus Mechanism flow

3. Results

This section summarises the main project results, including the results of the stakeholder survey, a gap analysis of the current biofuel system, advice on a preferred governance structure for the database, and finally the blockchain database design.

3.1. Stakeholder Survey

A stakeholder survey was developed in the first quarter of the project in order to collect feedback from relevant stakeholders — including used cooking oil (UCO) collectors, biodiesel producers, traders, EU policymakers, industry associations, certification bodies, and auditors — on a number of technical and governance specifications for the blockchain biofuels database.

The survey was built in SurveyMonkey and shared with nearly 400 stakeholders in April 2020, as well as on RSB's website and social media.

It included three main sections:

1. **Risks**: aimed at identifying the key data management risks in a sustainable biofuel supply chain.
2. **Data**: aimed at identifying the sustainability and product data requirements to be integrated into the database structure,
3. **Governance and funding:** aimed at hosting the preferred governance structure for the database (allocation of responsibilities regarding managing and monitoring the data), and the willingness of stakeholders to pay for the database.

A summary of the key results can be found below, and the full research results can be provided upon request. Survey results were used to inform the gap analysis of the UCO biodiesel sector (see section 3.2), database governance structure options (see section 3.4), and the data structure of the blockchain biofuels database (see section 3.5).

3.1.1. Survey Respondents

The survey was completed by a total of 103 people. The figures below show industry and geographical representation.

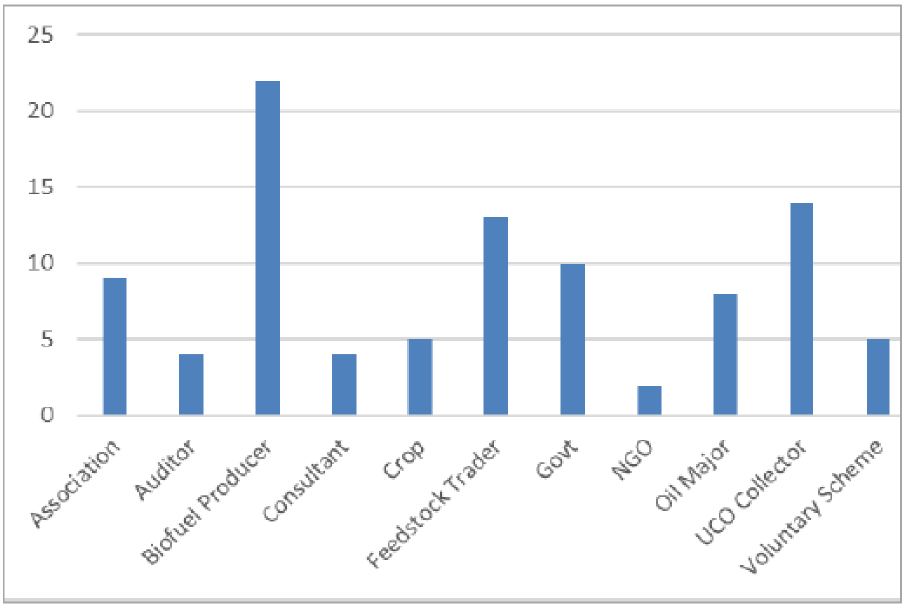

Figure 5: Stakeholder survey respondents' industry affiliation

Figure 6: Stakeholder survey respondents' geographical location

3.1.2. Project Relevance

To the question "How important is it that the current chain of custody processes and controls are improved to mitigate the risk of fraudulent claims of biofuel sustainability?", respondents selected an average of 86 on a scale from 0 (not at all important), to 50 (somewhat important), and up to 100 (critical).

Comments on project relevance included:

- *"This is critical as there are clearly loopholes being used by a few wrongdoers. Their action casts a shadow over the whole industry which requires public support to thrive."*
- *"It is critical to maintain public trust in the system to ensure government support as the industry develops and matures."*
- *"Sustainability has become a market label for many, and it has been booming due to that it opens market opportunities. That is why is important to keep a record of the actual sustainability along the production chains, to avoid greenwashing and misleading information, resulting in anti-competitive practice and unethical promotion, that can greatly damage our environment."*
- *"It is essential that chain of custody processes and controls are there, because fraudulent claims undermine the whole potential for sustainability."*
- *"Current systems are not strong enough to deal with fraud"*

3.1.3. Risk Points

Respondents were asked both which operations in the supply chain are most at risk of data corruption, as well as which components of the independent sustainability verification process are least reliable due to the risk of data corruption. Their answers are reflected in the colour-coded table below.

Risk level				
Low ---------- Medium --------- High				
1	2	3	4	5

Figure 7: Key of perceived risk level

Supply Chain Step	**Risk level**
Creation of volumes of waste at Points of Origin	4
Collection of crops from designated land areas	2
Collection of waste by a First Collector	4
Sales of waste from a First Collector to a Waste Processor / Aggregator	4
Sales of waste between waste traders	4

Sales of waste to a biofuel production plant	3
Sales of waste biofuel from a production plant to a biofuel trader	3
Sales of waste biofuel between traders and oil companies	3
Reporting of waste biofuels by an obligated oil company to a national biofuel regulator	2

Figure 8: Levels of perceived risk at each supply chain step

It is clear from the results that the highest perceived risks are at the beginning of the supply chain. In other words, respondents believe it is easier to corrupt data at the point where UCO claims are first created, and mass balance is applied by the First Collectors and Aggregators in the origin countries, than it is when the feedstock is processed at biofuel plants and distributed to consumers. That said, respondents confirm that there is hardly any step in the supply chain that is totally free of risk — indicating the need for a more robust mechanism for tracking sustainable biofuels from the Point of Origin. This perception also contrasts with the major fraud investigation in the Netherlands which is focused on the downstream supply chain from the biodiesel production plant onward through biodiesel trading.

Reliability level				
Low ---------- Medium --------- High				
1	2	3	4	5

Figure 9: Key of perceived reliability level

Sustainability Verification Step	**Reliability Level**
Self-declarations from Point of Origin to First Collector	2
Administration of self-declarations at First Collector	2
Mass balance accounting at First Collector	2
Declarations between First Collector and Trader	3
Yield calculations	3
Purchases from Certified Traders	3

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Audits at First Collectors	3
Audits at Biofuel Production Plants	4
Audits at Traders	3
Audits at Obligated Parties	5

Figure 10: Levels of perceived risk at each sustainability verification step

3.1.4. Data Transfers in a Blockchain Database

The survey identified the typical data points that are transferred between the supply chain companies to represent a transaction. These are transferred along the chain of custody on documents such as the proof of sustainability, bill of lading, contract, invoice, or customs documents.

Respondents prioritised these data points into those which were most and least important for inclusion in the scope of this blockchain prototype as well as a database for biofuels traceability in general. They also preferred to include the mandatory data points for compliance with the voluntary schemes for RED compliance (feedstock name, certification status, country of origin, and carbon intensity) and basic data points representing the physical consignment transfer (quantity, origin, destination, and date).

Some respondents highlighted that data points of a lower priority should be kept out of the scope, as they were not required for RED compliance and excluding them protected confidential data from any risk of disclosure to competitors from this system.

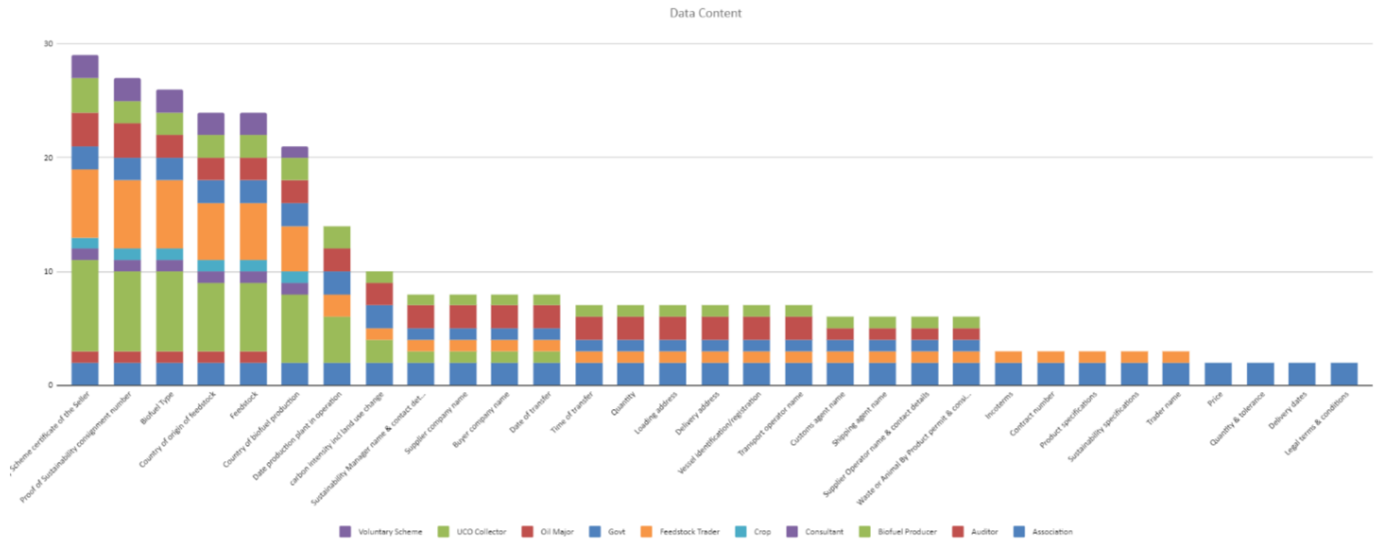

Figure 11: The types of data that should accompany data transfers, according to survey respondents. A full size version of this table is available here: https://rsb.org/wp-content/uploads/2021/03/The-types-of-data-that-should-accompany-data-transfers-according-to-survey-respondents.pdf.

Q17 Select the contract data that should accompany transfers of material between Supplier and Buyer within a blockchain database.

Answered: 41 Skipped: 62

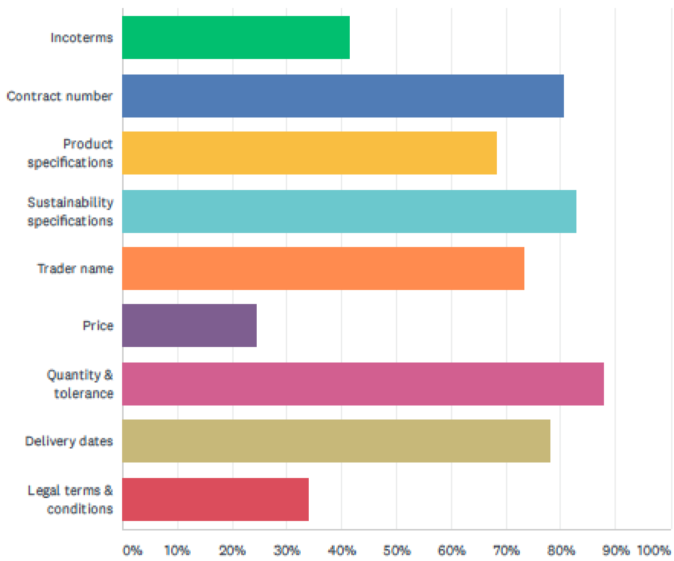

Figure 12: Survey respondents' choice of the type of data that they believe should accompany transfer of data within the blockchain database

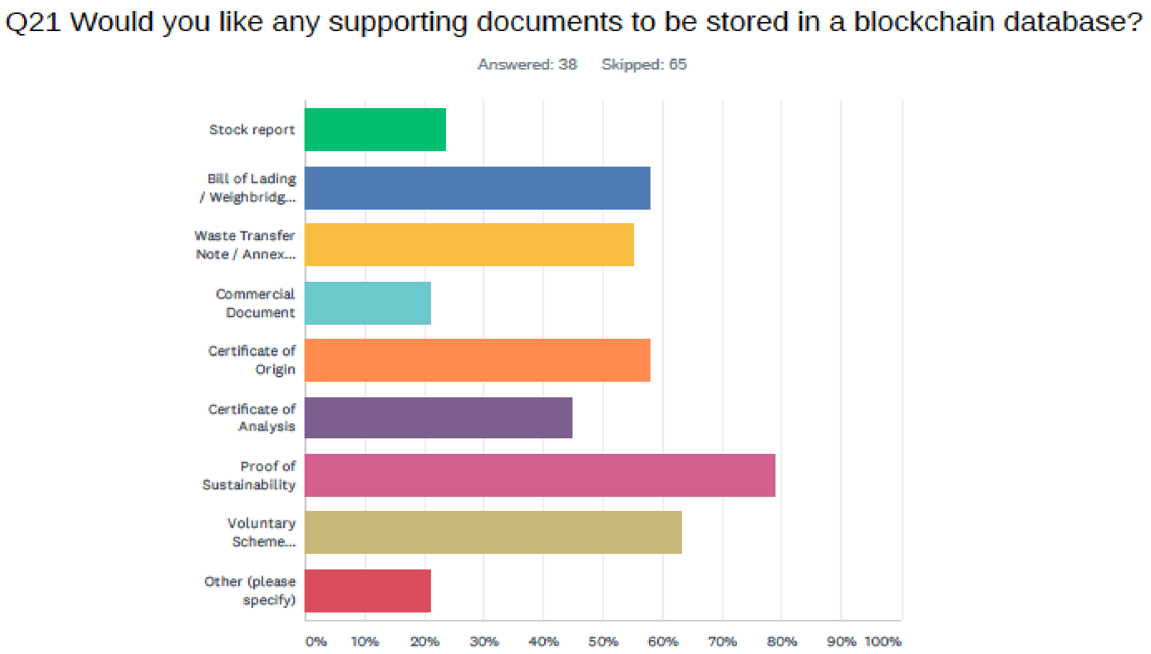

Figure 13: Survey respondents' choice of the types of supporting documents they believe should be held within the blockchain database

3.1.5. Governance Options

Since regular databases are typically centrally managed by a private sector company or regulator, determining the governance structure of a blockchain database that aims to become an industry-trusted solution for chain of custody transparency and accountability is of critical importance.

To solve this challenge, survey respondents were asked who should be responsible for key activities (presented as a list of tasks related to the database design, management, financing and monitoring), and to assign 'primary responsibility' or 'oversight function' to each activity for each stakeholder — providing insight into what role industry thinks the key biofuels stakeholders should play in the development, management, and monitoring of the database.

The stakeholders identified as candidates are:

- **Certification bodies**: namely the companies responsible for auditing companies against the preferred voluntary sustainability scheme
- **Voluntary sustainability schemes**: namely the organisations developing the sustainability standards that are recognised by the targeted sector
- **National biofuel regulators**: namely those EU Member State agencies responsible for EU RED compliance and reporting, i.e., the UK's Renewable Transport Fuel Obligation (**RTFO**), Germany's Federal Office for Agriculture and Food (**BLE**), the Netherlands' Emissions Authority (NEa), and Ireland's Biofuels Obligation Scheme (BOS)
- **Industry Associations**: representing businesses active in the biofuel feedstocks, production, and trading supply chains, i.e., Europe's Waste-to-Advanced Biofuels

Association (EWABA), the European Biodiesel Board (EBB), the European Renewable Ethanol Association (ePURE), the European Bulk Oil Traders' Association (EBOTA), the European Petroleum Refiners Association (FuelsEurope), and the Netherlands' Oils and Fats Industry (MVO), as well as the North American Renderers Association (NARA) and the National Biodiesel Board (NBB) in North America.

- **The EU Commission:** responsible for the regional allocation of targets and incentives to biofuels sold and traded within its territory.
- **Independent systems operators**: namely private companies and suppliers of services to the sector, such as Bioledger and other information technology (IT) providers.
- **A combination of the above**: organised within an Advisory Committee or Board.

The results in Figure 14 below indicate that the respondents have the following preferences:

- An independent private sector supplier, supported by a multi-stakeholder advisory committee or board — to design, develop, and maintain the database, as well as support with data analytics and market/industry reports.
- The European Commission takes the responsibility of paying for the development and management of the database.
- A multi-stakeholder advisory committee or board oversees the database's development, defining its due diligence requirements and governance functions.
- Certification bodies and voluntary sustainability schemes monitor the system and its supply chain user's compliance with the standards as well as support investigations of incorrect or fraudulent claims that are led by biofuel regulators.

These results guided the development of the governance framework that is explained in section 3.4.

Who should be responsible for the roles below?

Governance	Certification Body (e.g. Control Union, SGS, GUTCert)	Voluntary Scheme (e.g. RSB, ISCC, REDCert, 2BSVS)	National Biofuel Regulator (e.g. RTFO, BLE, NEA) Industry Consortium or Association (e.g. EWABA EBB, EPure)	EU Commission	Independent system operator (e.g. Bioledger powered by Oracle, another independent IT service provider)	Combination of the above within an Advisory Committee or Board (please specify)	Other (please specify)	Max
Define the design, logic and data content of the database	0	0	2	3	10	10	2	IndSysOp & AdvCom
Define the due diligence requirements for new users of the system	1	5	2	5	4	7	0	AdvCom
Pay for the development of the database	0	1	3	10	5	5	2	EU Commission
Maintain the operations of the database including deciding on new spending on improvements	0	2	2	3	14	3	1	IndSysOp
Pay for the day to day operation of the database	0	4	1	5	6	2	6	IndSysOp
Pay for further development of the database	0	2	2	8	5	5	2	EU Commission
Monitor the continued RED compliance of System Users and individual consignments in the system	8	4	2	2	4	3	0	Cert Body
Analyse the data to identify implausible, fraudulent or incorrect claims within the system	5	2	4	3	8	1	1	IndSysOp
Investigate and apply sanctions to any implausible, fraudulent or incorrect claims	3	5	10	4	1	2	0	NatBioReg
Compile regular standard reports and respond to requests from Member State Biofuel Regulators	0	4	3	4	11	1	0	IndSysOp
Report interesting statistics and supply chain stories to the public (with consent and consultation of Users)	0	1	7	4	9	3	0	IndSysOp
Any oth								
Overall								

Figure 14: Stakeholder survey respondents' governance preference

A joint publication by the Roundtable on Sustainable Biomaterials (RSB) and Bioledger, this report summarises the results of a project which ran between January and November 2020. The project was made possible by a grant from the ISEAL Innovations Fund, which is supported by the Swiss State Secretariat for Economic Affairs (SECO).

3.1.6. Willingness to Pay

Since the development of a blockchain database for biofuel traceability would be a voluntary initiative with a significant and ongoing cost, we asked respondents to identify a price point that they think is reasonable — in light of the additional security and transparency value that a blockchain database would give to the sector.

Many respondents skipped the price point question, but the roughly 25 percent of those who answered it selected an average willingness to pay 1,35 euro per metric tonne of fuel. If this fee was applied to the traded volume of the EU biofuels market for more than two years, it would justify the business case for a private developer like Bioledger to develop and provide this service.

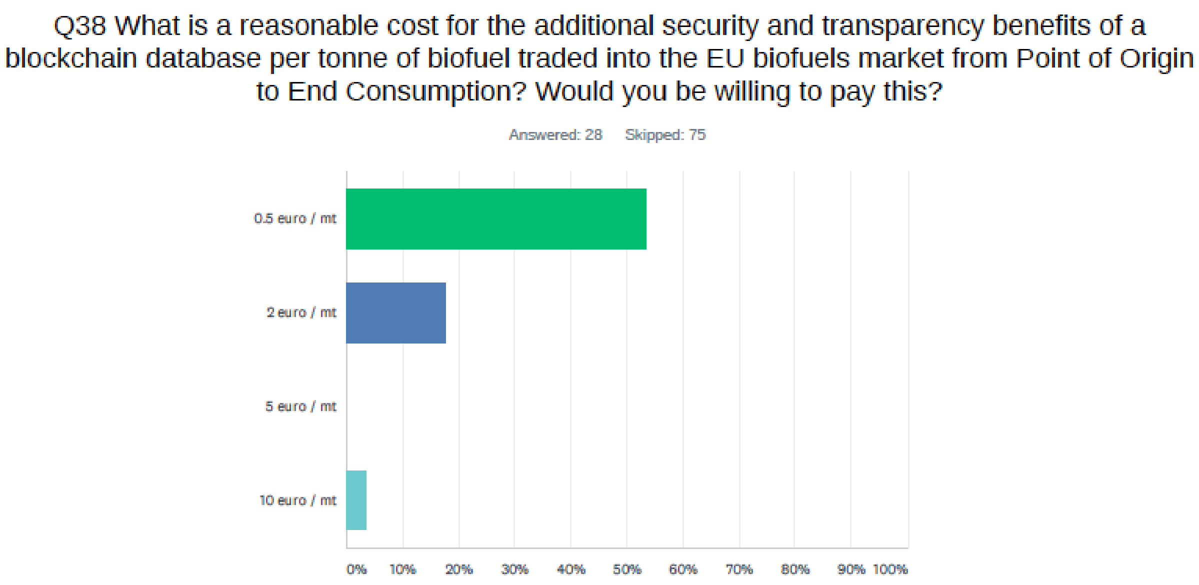

Figure 15: Average willingness to pay for a blockchain database for biofuels traceability

3.2. Gap Analysis of the Current Biofuels System

The project used the results from the stakeholder survey and combined them with the knowledge of project partners to develop a brief gap analysis of the sector, highlighting the key weaknesses within the current system and identifying potential solutions that can be provided by a blockchain database.

Key Weaknesses

- The self-declaration of sustainability using Excel templates, transferred as PDF files or paper hard copies, creates the risk that anyone can generate a new declaration or use an old declaration multiple times. Digital or paper documents can also be hidden or excluded from the declared accounts of the Seller during an audit.
- Proof that a volume of UCO or UCO biodiesel is really derived from a restaurant begins at the point of origin. The predominant voluntary schemes require First Collectors to prove that

their oil is UCO by getting signed self-declarations from the restaurant managers at the points of origin at least once per year. This can be a difficult prospect for first collectors, who can have collection networks of up to 150,000 restaurants. Additionally, UCO certified under the RED Voluntary Schemes is collected from 80 countries, but forms are typically only available in less than ten languages. Collections often take place when restaurants are closed and managers are not available — with night porters possibly being unwilling to sign a legal form without advice.

- Self-declaration of sustainability from an individual offers no substantiation that the oil matches the description on the self-declaration. When these self-declarations are audited the auditors are required to check that the papers hold the necessary information, but rarely have time to visit the restaurants and interview the signatories as well as their staff at the cooking business to verify the statement apparently issued to the First Collector within the previous 12 months. Instead, auditors must take a small sample of self-declarations and verify the existence of the corresponding restaurants through a reference such as a telephone directory or search engine entry — while not having sufficient time or access to verify with the restaurant manager that all of the UCO collected was really used to cook food and originated from that restaurant over a 12-month period.
- Supply chain businesses have become reliant on the certified status of their suppliers and therefore cannot normally provide greater transparency or a contractually secured right to audit the upstream supply chain — despite their willingness.
- Auditors must also accept the validity of a declaration and do not have right to contact the issuer of that claim to verify that it was genuinely issued by them, that they had sufficient volume of that biofuel in their stock to sell, and that it was accurately deducted from their mass balance. Additionally, auditors must trust that the customer of an auditee has received and accounted for a sale from the auditee. This lack of access to document validation with the Issuer creates a fraud vulnerability — where the receiver, the issuer, or a third party could unjustifiably generate a sustainability declaration.
- Manual checking and issuing of sustainability declarations into and out of supplier mass balances accepts that some human error or manipulation will happen and that reconciliation procedures should be implemented.
- Annual audits allow for companies to issue sustainability declarations for periods of 11 to 12 months before they are checked by an auditor.
- For efficiency, auditors attempt to take a representative sample of all of the transactions during the year. This limited sample creates a high probability of missing some noncompliance instances. This also imposes a choice on the auditor which can be influenced by time pressure. The operator may try to propose samples — resulting in missing noncompliance instances or fraud. While RSB requires that auditors must use their experience to scrutinise trades outside of the sample to achieve reasonable assurance of compliance, most voluntary schemes only require a limited assurance opinion which can be closed as soon as the sample is validated.

- Most audits are performed by only one individual, which creates time pressure during audits. Unsupervised audits also allow the potential for auditors to be corrupted or intimidated.
- Mass balances can be open for up to three months, allowing suppliers to 'go short' and issue sustainability claims that do not match with their stock, expecting to replace the shortfall with volume expected later within the three-month mass balance period. This creates the risk that a sustainability claim issued will never be fully balanced at a later date, breaking the mass balance rules and creating an invalid claim downstream in the supply chain — which cannot be recalled as it may also have been traded onward downstream. Consequently, mass balances of sustainability data must be connected to physical stock and movements at the same site. Calculations regarding yield loss, operational gains, and losses need to be reconciled against the mass balance. Checking the parallel physical and sustainability mass balances open over a three-month period is a complex process which could see inexperienced auditors overwhelmed and unable to identify manipulation while they are under pressure to complete the checklists within the allocated audit timeframe.
- Voluntary sustainability schemes and national biofuel regulators have certain powers to investigate biofuel sustainability claims within their discrete jurisdictions, but no single entity has jurisdiction over the whole biofuels supply chain — which is globally interlinked and complex. Investigations of alleged fraud are therefore isolated by jurisdiction boundaries and often end where an investigating agency is given assurance by a different voluntary scheme which was reported into a disconnected verification system.
- With no central regulator of the international biofuels supply chain and markets, and the voluntary choice of sustainability standards, it is difficult to identify liability or impose any penalties on upstream supply chains protected by voluntary scheme status or a lack of supply chain transparency. The current holder of an invalid claim is therefore the most vulnerable to liability if their claim is devalued by nonconformance or fraud uncovered anywhere in the upstream supply chain.

How Does a Blockchain Database Address These Key Weaknesses?

- **Proof of origin**: the geolocation of the driver — within a 50m radius of restaurant address — for the first collection is included.
- **Secure consignment creation:** only the driver can create consignments — preventing duplication of claims or the generation of false claims (except at the point of origin).
- **Audit efficiency:** a history of all transactions is recorded with a distributed ledger, ensuring that all incoming and outgoing claims are visible in the auditee's account, and allowing the auditor or regulator to check the lifecycle blockchain of each consignment for its origin and compliance.
- **Audit validity**: the ability to issue false or hidden claims or receipts during an audit is removed due to everything being conducted within the distributed ledger, and volumes cannot be sold more than once because consignments are accurately transferred through the blockchain with the owner title changing from seller to buyer each time.

- **Central governance**: the exact governance method is still to be defined, but in theory will see one entity having a full view of the global mass balance — for identifying where fraud or implausible claims happen, and who can then pass that on to the relevant authority for investigation and prosecution.
- **Process simplification:** the scalability, standardisation, and efficiency of the blockchain database simplifies data capture and transfer and removes human error as well as reliance on paper documentation.

3.3. Technological Solution Addressing Problem Statements

In the context of this project — which looks at the transparency and accountability issues in the used cooking oil (UCO) biofuel market — blockchain has the potential to address key risks summarised in Table 1 below.

Table 1: Used Cooking Oil (UCO) biodiesel sustainability risks that can be addressed by technical solutions presented in the blockchain case study

Current Problem	Technological Solution
Paper-based documentation from the supply chain cannot be proven as accurate.	Each transaction in the supply chain is captured in a manner that makes it technologically irrefutable.
Suppliers of non-sustainable virgin vegetable oil posing as restaurants and falsely declaring their oil to be UCO.	When the First Collector Driver collects the oil, their geolocation is recorded and compared to a stored restaurant location. This corroborates the Point of Origin data associated with a consignment to a physical location and legal entity. The work required to falsely generate location evidence is vastly more prohibitive compared to falsifying paper evidence of collection. Furthermore, the driver can upload signatures or photos of the restaurant that are linked to its geolocation at the point of collection.
Submission of fake paper evidence of UCO status, either by First Collector Drivers or further downstream by feedstock and biodiesel traders, biodiesel plants, or oil majors.	First Collector Drivers need to upload signature and photos of collection, both of which are geolocated. This information is then stored on the blockchain together with the capture of all subsequent transactions in the supply chain. Only Drivers are permitted to create new

	consignments. Traders can only transfer consignments originally collected by Drivers.
Use of the same evidence multiple times for different consignments	Evidence is captured, and geolocation is validated, digitally timestamped, and automatically connected to the blockchain. As such, it is impossible to use the same evidence (such as a photo or GPS record) twice.
Data and evidence passed along the chain of custody can be corrupted, omitted, or falsified — either by human error or intentional manipulation during the data transfer from paper-based evidence to digital spreadsheets — and declared onward to customers on paper or documents generated by the Seller.	All data and evidence captured by the solution is recorded and linked to the blockchain at creation, with rules in place to ensure all required data is captured and solutions (such as geolocation tagging) in place to minimise the risk of incorrect data entry. As such, missing, changed, or corrupted data is not possible. Furthermore, all Users of the platform will be able to access all of their information instantly upon execution of new transactions. All consignments successfully recorded in the system are compliant transactions available for instant onward transfer. Compliance checks are built into the system logic, increasing the speed and reducing the risk of noncompliant transactions by removing the need for human validation of chain of custody paperwork or transcription of data.
Paper-based audits are time-consuming and must be conducted on a representative sample (small number of consignments) and limited assurance basis, meaning that auditors may miss instances of noncompliance.	Audits can be conducted far more efficiently using a purely digital dataset, through analytics and statistical analysis. Blockchain solutions can be developed to actively support data interrogation (as their purpose is to provide trust in the data they contain), providing auditors with simple end-to-end consignment tracking abilities.
No entity has the right or capability to audit the entire market or supply chain.	Trusted stakeholders can be designated as blockchain node operators and granted permission by all users to view the global mass balance of all blockchain transactions to identify implausible trades and exclude fraudulent users.

3.4. Governance

Defining the governance method of the blockchain database is vital because this database is aimed at becoming the primary solution applied across the industry and being recognised as transparent and robust by the private sector, regulators, certification systems, and civil society. Stakeholder input via the survey confirmed that the approach originally devised by project partners — to establish a multi-stakeholder governance model that allows it to be credible and compliant with standard and regulatory requirements — would fulfil that aim.

The governance system originally devised by project partners and further confirmed by stakeholder consultation is illustrated in Figure 16 below, and has the following characteristics:

- The blockchain database is owned by a non-profit organisation that is owned by the Users, managed by an IT supplier like Bioledger, and overseen by a multi-stakeholder Advisory Committee.
- Users are biofuel companies that apply to utilise the database, and as such become shareholders of the database who pay a fee based on traded volumes and appoint one or more representatives to participate in the Advisory Committee.
- An IT supplier like Bioledger — with no role in the Advisory Committee — is outsourced to develop and provide ongoing maintenance and support to users, publish reports and facilitate access to encrypted data as required by auditors, authorities in fraud investigations, and implement the decisions of the Advisory Committee.
- The Advisory Committee is the ultimate authority over the database as a multi-stakeholder body, where each constituency is represented by one or more appointed delegates on a rotating basis that approves the database logic and protocols, and consists of:
    - one or more representatives from Users;
    - one or more representatives from Certification Bodies;
    - one or more representatives from Voluntary Sustainability Schemes;
    - one or more representatives from the European Commission; and
    - one or more representatives from national regulators.

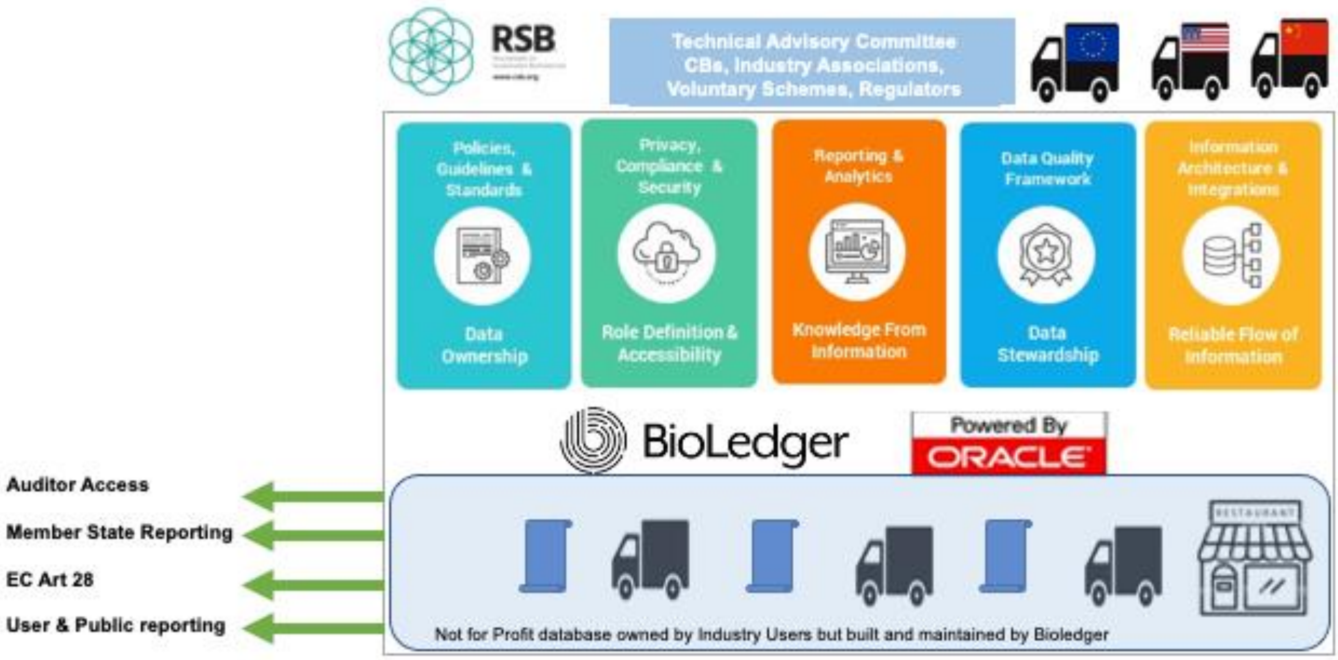

Figure 16: Potential governance structure for a multi-stakeholder biofuels traceability database

3.5. Blockchain Database Design

The blockchain biofuels database was designed using the following key components:

1. Permission issuer: assigns and validates unique capabilities to system users. Creates roles for drivers, administrator, and traders.
2. Application layer: Since users cannot write transactions using blockchain code directly into the database, the project uses an application layer in this case — a simple HTML website to capture and recall transaction data between users and the blockchain database via APIs. The website was designed to capture the necessary compliance data in a simple template familiar and useful to the industry users. Future iterations may use the same APIs to integrate data captured by other Internet of Things (IoT) applications such as weighbridges, flow meters, or handheld devices used by UCO collectors.
3. Blockchain code: ‘Chaincode’ is the term for programs that run on top of the blockchain to implement the logic dictating how users interact with the ledger via the applications. When a transaction is proposed, it triggers chaincode that decides whether the transaction is permitted and which resulting state change should be applied to the ledger, thereby creating the blocks that form the ledger. This logic sets the requirements for new collections or transactions to be written into the blockchain database.
4. Nodes: Nodes are the computers that form the infrastructure of the distributed ledger network by maintaining an identical and synchronised ledger of transactions. For this prototype, Bioledger was the key holder of a cluster of three nodes on the Oracle Cloud Blockchain

Platform. To create a decentralised single state of truth, the nodes should be distributed amongst multiple stewards of the database who can validate changes to the data.

5. Analytics: Access to a single true statement of all consignments in the market at any point in time, including a historical log of all transactions, will give regulators the ability to know exactly what has happened in the market, mitigating fraud and presenting impact reports. Bioledger illustrated this power by developing infographics which first summarise the trends of the global mass balance. Analytics and graphics presented in this project allow a regulatory user to follow the chronological blockchain record of transactions from first collection to consumption and the detail of every trade in between.
6. Ledger: blockchain data is stored in identical, synchronised and distributed databases hosted by the nodes. Data stored in the distributed ledgers must be transcribed, ordered, and stored in servers so that it can be recalled accurately at any time. This project used Oracle Cloud Blockchain Platform which uses Hyperledger Fabric to record and recall those states.

The results from the stakeholder survey and pilot partners interviews allowed the developers to find the appropriate configuration of these components. Each component and its function within the database are described in more detail in Annex A – Technical report.

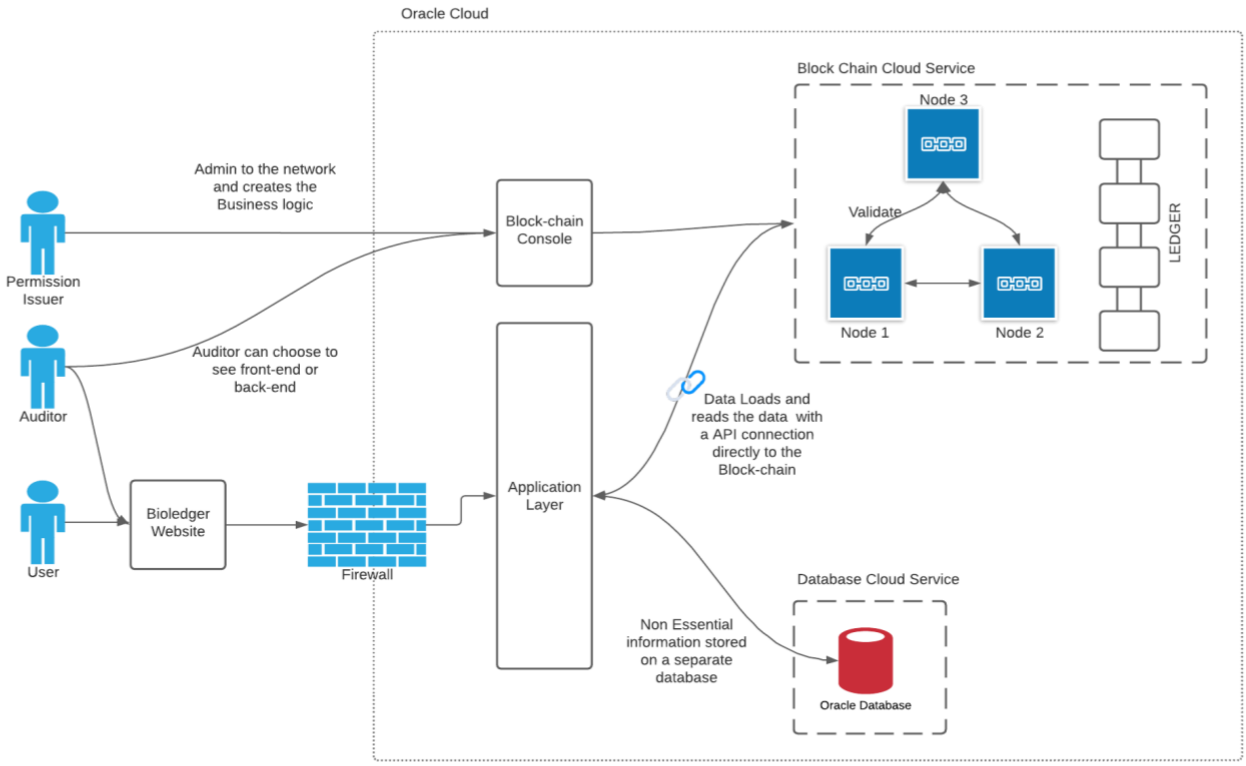

Figure 17: Key components of a blockchain database

Since a database would contain important private commercial data which should not be visible to all users, a blockchain solution involving permission partitioning for privacy purposes was chosen, as opposed to a decentralised public ledger where everyone can see all the data such as Bitcoin.

3.6. Pilot Report

During April, May, and June of 2020, this project also successfully concluded pilots with the four industry partners. Each pilot consisted of four two-hour online workshops (replacing in-person workshops, due to COVID-19 restrictions) between Bioledger and the subject matter experts from the pilot partner companies.

The four individual workshop objectives were:

1. Conducting user-experience interviews to inform the database requirements and design.
2. Presenting the first draft design.
3. Demonstrating the prototype (including live creation of consignments).
4. Giving final feedback, following two weeks of partners using the prototype.

A review of the process and findings from the pilots are finalised in this report. The database prototype can be accessed at the URL https://bioledger.io/rsb-blockchain-pilot-2020/.

The partners were given two weeks to generate consignments, using the prototype representing their normal transactions, after being provided an online tutorial on how to utilise the database. Two partners arranged additional tutorials with Bioledger within the two-week testing phase. The partners were each interviewed again to provide feedback on the prototype.

In total, 1,927,906 litres of feedstocks were recorded in the prototype database at the point of origin (representing a First Collector Driver at a restaurant) and then aggregated and transferred downstream into the accounts of a First Collector Administrator and then a Trader.

Partners represented their real-life commercial and operational scenarios by inspecting deliveries from Collector Drivers or suppliers, observing current available stock, splitting or aggregating like consignments, and transferring consignments to their downstream customer. Feedback, including recommendations for improvement, was recorded by Bioledger.

3.7. System Audit

Auditing firms Peterson Control Union and SCS Global Services were commissioned to review the prototype to assess whether it improved transparency and efficiency for auditors and reduced the risk of fraud from the perspective of a certification body performing compliance audits against the EU RED Voluntary Schemes — in particular RSB, EU RED, and ISCC EU.

A summary of their findings is found in the table below.

Table 2: A summary of the findings of the systems audit conducted by Peterson Control Union and SCS Global Services

Advantages / Things that work	**Disadvantages / Things to improve**
• Geolocation of collections. This allows an auditor to verify that points of origin are real, and that the digital transaction reflects the physical movement between mass balance sites.	• The app is currently limited to acquiring the material from points of origin. Users should also be able to acquire EU RED-compliant volumes from certified entities.

A joint publication by the Roundtable on Sustainable Biomaterials (RSB) and Bioledger, this report summarises the results of a project which ran between January and November 2020. The project was made possible by a grant from the ISEAL Innovations Fund, which is supported by the Swiss State Secretariat for Economic Affairs (SECO).

• Auditors can review the geolocation of a pick-up to check whether it coincides with the location of the restaurant. • Consignments can only be transferred from a driver to one assigned depot location/account. • Accurate transfers of data, and accurate splitting and aggregating of consignments of like materials • If volumes are input correctly, and all correct conversation factors are applied, the system can provide reliable inventory information. • Consignments with different sustainability characteristics cannot be aggregated together. • The app does record which compliance claims (e.g., RSB or ISCC) are made at the time of sale. This prevents double claims — digital claims being used more than once under different certification schemes. • Having the sustainable inventory of an entire supply chain in a single market in one app would significantly improve traceability, transparency, and trust. It would address the following gap: different certification bodies (CBs) review entities along a supply chain, and do not always have insight into the inventory, the incoming or outgoing declarations of the suppliers, or the recipients of the Operator audited — creating the opportunity for companies to omit incoming or outgoing material from their mass balances without CBs noticing. This would not be possible if the entire supply chain was visible in one system.	• Job IDs should be automatically generated to prevent multiple use of the same reference number. • Historical data is presented in one table and cannot be sorted or filtered to make more efficient audits. • No capability to record reconciliations of digital consignments with physical movements, gains, and losses, or processing yields. • Only volume is recorded, when the option and capability to record or convert to weight is also needed, with units consistently presented. • When transferring consignments to customers, GHG and country of origin data should be prepopulated from the database according to the address and geographic coordinates of the origin. • Taking photos or adding notes is not possible yet. • Not all information required for compliance with RSB/EU RED is captured at the point of origin or transferred through the accounts between traders. • The app does not track the individual GHG intensities • The system is not currently equipped to apply conversation factors such as losses from waste/ filtration of UCO. • Conversion factors are not applied. • There is still room for human error during the input of sustainability information, and drivers can record incorrect or false claims at the point of first collection, i.e., RVO may be recorded when the product is actually UCO of mixed origin (although the geolocation cannot be forged).

An important point that auditors noted is that the prototype does not allow negative balances, meaning that it reflects a continuous accounting system and not a fixed one where material is balanced every three months. Operating a negative mass balance which is reconciled within a three-month period is allowed by EU RED.

This issue was discussed during the consultation phase of the project where the pilot partners valued increased simplicity and security in operating a positive mass balance, since they could better trust compliance credits issued by their suppliers. They advised that this would not limit them from selling physical cargoes and issuing compliance credits later, after they had received a sufficient positive balance in their account.

As European biofuel regulators are currently considering further definition of the mass balance rules within the EU RED II, the project also considered appropriate consensus logic and architecture which could permit flexible mass balance allocation within the blockchain database over a three-month period. This is possible with the advantage that any consignments which are subsequently derived from a net short mass balance can be recalled from the supply chain.

Further to the list above, auditors also added the following suggestions in their feedback:

- Greenhouse gas (GHG) emissions for transport could be calculated from the geolocation data associated with each transaction.
- The blockchain database could link to the unique ID that users must assign to chain of custody documents, making auditing/cross-checking work a lot easier. For example, if the last four digits of the blockchain were used in the POS number (in Nabisy, Elna, NEa register, ISCC blue PoS).
- Certification bodies are increasingly being asked by regulators to verify compliance when a user is required to amend a claim or change transactions. As such, it would be great if users could link an auditor to their account to review ad hoc or regular changes more efficiently.
- Auditors could be granted access to review all transaction data for user audits and approve their reporting of specific GHG values.
- Something should be in place on a system admin level to deal with a possible input mistake that affects the inventory — and therefore sales for multiple operators — in a supply chain, and clarity given for who would be responsible for reviewing and approving adjustment the adjustment.

4. EU Submissions

During the month of April, Bioledger and RSB presented this project to the Biofuel Database Stakeholder Group (BDSG), chaired jointly by the European Waste-to-Advanced Biofuels Association (EWABA), the European Biodiesel Board (EBB), and the Netherlands Oils and Fats Industry (MVO), and comprising industry stakeholders concerned with the risk of fraud in the sustainable biofuels supply chain.

Bioledger and RSB also presented to Navigant Consulting (a Guidehouse company) and their working group that is tasked with informing the European Commission (EC) on setting options and identifying technical requirements for a database to track sustainable biofuels across the EU, in keeping with the EC mandate.

As part of the Renewable Energy Directive II (RED II) the EC aims to ensure that a database is put in place for the Commission to enable tracing of liquid and gaseous biofuels that are eligible for incentives and count towards RED II road transport fuel targets (namely sustainably certified biofuels).

Navigant presented a review of nine different database options including this project's blockchain prototype, during a webinar to stakeholders in May. Since Bioledger was developed specifically to understand and deliver the objectives of the Commission, industry and regulators, many of the design features of this Bioledger blockchain prototype were recommended to the Commission in the final Navigant scoping study.

The Commission continues to review options for delivering the RED II mandate, including the potential to build on the recommendations of this project. This project aims to inform any development of a technical solution that adequately protects against fraud without curtailing the supply of sustainable biofuel.

The process of stakeholder consultation undertaken in this project shows that while the diversity of the global biofuel supply chain makes design and implementation complex tasks, the industry is keen to support a well-designed solution which may facilitate increased supply.

5. Financing

Many of the recommendations made during this project would be considered critical features for the successful adoption of a compliance database.

This project's budget dictated many of the design decisions made regarding the system architecture, as well as the scale and complexity of the user interface and the new blockchain code development.

Use of the autonomous Oracle Blockchain Platform Cloud Service offered a low financial barrier to entry and enabled the prototype to host any quantity of data presented by the project partners during the course of this project. Oracle platforms provided the prototype with enterprise grade security, as a reliable base for this project budget to only add single factor authentication and minimal penetration testing.

Off-the-shelf, blockchain-for-supply chain solutions, such as IBM Food Trust and Oracle Intelligent Track and Trace, were considered but dismissed as their fixed reporting templates for supply chain traceability could not deliver the project's requirement for defining more complex consensus requirements and user permissions specific to the biofuel use case.

Developer time, rather than infrastructure, accounts for the major expense associated with this prototype. Costs associated with the design and development of a blockchain-enabled database with a complex user account management system that enables the minimum functionality required by stakeholders in this project could cost between 350,000 and 500,000 euros, and would take approximately six months to design and build a beta application.

Infrastructure costs could be minimised and scaled according to demand by using subscription-based cloud storage and transaction processing with low costs of between one- and 20-euro cents per transaction. Security features can also be configured to demand.

A User network with 4000 users, including van drivers and international clients, performing hundreds of millions of transactions per year will likely require 24/7 call centre and technical support, costing in excess of 250,000 euros per year, to ensure appropriate responsiveness for commercial users.

Translations and continuous improvements according to new supply chain risks, regulatory changes and user demand — as outlined by the stakeholder group — would likely justify a full-time development team of at least two people. Regular reports or analytics for regulators could be compiled at no significant cost.

Understanding that no political mandate or public funding is available, the funding for building a blockchain prototype to deliver the benefits of a blockchain database would need to be met on a voluntary basis by the users of the system.

If the willingness to pay 1.35 euros per ton of fuel, as indicated by stakeholders in the survey (see section 3.1.6) was applied to the traded volume of the EU biofuels market for more than two years, it would justify the business case for a private developer like Bioledger to develop and provide this service. A fee per quantity of throughput in each account could be billed to users individually.

It is important to note that, due to budget limitations, the project had to exclude specifications defined as valuable by stakeholders, which are included in the next section

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6. Recommendations

A project to demonstrate a concept can't cover all of the functionality that a full solution should. Equally, a full-scale solution would involve a balancing act between technology and cost. The results and lessons learned from the project were also shared in a series of webinars hosted by RSB and Bioledger, available on request.

Below are a few recommendations in key areas for the development of a full blockchain database:

Node hosting
This solution used Hyperledger, but all the nodes were managed by the project. For a full solution a node should be hosted by each major stakeholder in the ecosystem, ensuring true decentralisation of data and control. Such hosting would be expensive though, and a business model would therefore need to be developed to enable smaller actors to also participate.

API-based data inputs
In this project, the inputs were through mobile and web-based applications. It is likely that existing stakeholders would want to integrate their existing data systems to the platform. As such, the API developed for the mobile/web apps would act as a 'standard' for others to connect to. However, enabling others to load data directly increases the risk of poor-quality data: a system is only as good as its weakest point.

Business logic layer
This solution had business rules developed in line with the specific use case (biofuel markets using the EU RED Voluntary Scheme), but a scalable solution would include the development of a configurable business logic layer.

Data at point of entry
Blockchain technology ensures that once data is captured on a blockchain its veracity is irrefutable, but it cannot control whether the data being entered is true or not. This blockchain solution showed how photos, signatures, and geolocation can be used to minimise this risk. To fully eliminate the risk of incorrect data entry, however, a cost versus benefit assessment needs to be undertaken, considering that technology such as artificial intelligence (AI) and specialist internet of things (IoT) devices would be required.

RED compliance
A full solution should fulfil the specifications of stakeholders and demonstrate compliance with the EU RED requirements for sustainability of all types of biofuel feedstocks and biofuels. As these requirements and data points are set out in the voluntary scheme system documents in fine detail, the full solution should facilitate recording of all mandatory data points within the data architecture and interfaces.

The system should aim to replace the internationally traded, paper-based chain of custody documents (i.e., RSB Product Transfer Documentation and ISCC EU Proof of Sustainability (POS)) and should be finally benchmarked against the requirements of the voluntary schemes for RED compliance by the voluntary scheme administrators or the independent certification bodies responsible for their implementation.

If approved as a suitable method for chain of custody compliance by the commission approving voluntary schemes, the database should also be accepted by Member State Regulators for the purposes of reporting into the Member State RED biofuel markets. Member State Regulators should be included in the consensus building process — to further embed trust and understanding of the system among all stakeholders.

Governance

The roles assigned to stakeholders in the existing verification system provide a trusted and robust framework for the governance of a biofuel supply chain database. Legal agreements already established between supply chain companies and their auditors, certification bodies, and voluntary schemes provide the necessary protections between those participants to allow disclosure of sensitive commercial data to specific trusted, legally permitted auditors and their supporting supervisory functions.

Surveillance audits by voluntary schemes and/or member state regulators can be supported along these existing hierarchies or by creation of an additional agreement with database users. Disclosure of aggregated, anonymised reports to member state regulators will be useful for supporting their investigations into fraud and providing detailed statistics on the sustainability impact of the biofuels market.

Stakeholders may also consider whether regular public disclosure of anonymised and aggregated supply chain data or case studies could be useful for public understanding of the sustainable biofuel industry, supporting consumer choices, investment and policy support — and if so, how. For example, the scope of the database could be extended further downstream, to track sustainable biofuel consignments to the point of consumption at a petrol forecourt, allowing a mobile app extension of the blockchain database to inform drivers about the sustainability impact of their fuel purchases.

To align with demand in other markets, a blockchain database could also be extended to provide a ‘book and claim’ system for sustainable biofuels to be diverted to other non-road transport fuel markets such as those in the aviation or maritime sector.

Certified sustainable waste-based biofuel consignments within the blockchain database (downstream from the biofuel production plant) could be assigned to a sustainable aviation fuel (SAF) customer account on a book and claim basis, whereby the block changes ownership and becomes unavailable for reporting into the EU RED road transport fuel market, allowing aviation customers to directly incentivise the production of waste-based biofuels, along the entire chain of custody from point of origin — claiming the greenhouse gas savings without any risk of double accounting of that consignment into any other biofuel mandates.

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Sustainable Business Model

Bioledger is considering a number of investment options for utilising the lessons gained from the pilot project to provide a new blockchain database for the biofuels market that could include RSB in its governance structure.

These are the possible funding scenarios:

- If the European Commission adopt a Bioledger blockchain database to deliver the EU-wide RED II database, a budget will need to be assigned from the Commission or a consortium of private and public stakeholders for development, operation and improvement of the system to the specification of the system owner (EC or public/private consortium).
- Bioledger operates as a voluntary market database, governed by commercial stakeholders and financed via fees on traded volumes.

The significant support from industry during this project has indicated that — due to the ongoing risk of fraud — there is sufficient commercial demand to justify the creation of a voluntary, industry-owned blockchain database.

7. Annex A – Technical report

This technical report provides more details on each component of the blockchain biofuel database prototype, as well as of its architecture.

7.1. Key components of the blockchain biofuels database

The key components are: Permission Issuer, Application Layer, Blockchain Code, Nodes, Analytics, and Ledger.

7.1.1. Permission Issuer

The permission Issuer is the developer of the database and by writing the code and system logic is responsible for managing the identities, authentication, and authorisations of all users of the database. It can allocate unique capabilities — written into the code by the blockchain developer — to read or write different data sets within the ledger, tailoring them according to the responsibilities and trust attributed to the different Users by the stakeholders in this project.

Companies should be able to perform transactions according to their voluntary scheme's accreditation for those transactions.

Individual Auditors must be approved by Certification Bodies and Voluntary Schemes to issue Certificates and can only view data associated with their client's supply chain data if their client approves such access

Having access to a global mass balance of all trades and analytics, for reviewing consignments sold into specific markets, will facilitate effective regulation and fraud prevention for biofuel regulators. However, Member State and EU regulators may have clearly delineated jurisdictions which could also be reflected in their access permissions for the ledger.

Users identified that it would also increase security if they could control who reads and writes different elements of data within their own company account — including granting temporary read-only access for named auditors or regulators.

To define these roles and permissions in code, the developer adopts a central management role for the distributed ledger. It is important that the Permission Issuer is a trusted, independent entity and that the roles are discussed and agreed upon by all stakeholders and users — as they cannot be changed later. Consensus was possible early on in the design, thanks to the EU RED data requirements being consistently defined by the voluntary scheme documents.

Stakeholders identified a demand for additional due diligence on new Users in the system, such as independent know your customer (KYC) checks, signing terms of use, or financial deposits. While these additional controls could be integrated into the blockchain code requirements for new database users — increasing trust and value in the consignments traded in the blockchain database — we did not reach consensus to adopt or define specifications for these features.

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7.1.2. Application Layer

The application layer deals with all incoming and outgoing traffic. Because the user will not directly connect to a blockchain to log information, we need an agent between the user and the blockchain — where the application layer sits — for the user to enter the details that they want placed on the blockchain as well as to read the information in the blockchain.

This project used a simple webserver for this purpose in our application. The webpage was coded in standard HTML, transaction data from users was transferred to the blockchain using application programming interfaces (APIs), and a second database was used to store nonessential data to reduce the development time and cost.

Project stakeholders identified sustainability claims on consignments as being generated at the point of first collection — by a driver collecting UCO at a restaurant. This means that a mobile interface would be critical for generating robust supporting evidence of the claim for the remainder of the supply chain to utilise.

In the UCO-to-biodiesel use case, operators in the supply chain may need or want to write transactional data into the blockchain from mobile devices, internal reporting applications such as enterprise resource planning (ERP), or external databases. Due to the variety of potential applications that are used in the market, the pilot project partners did not dictate integration with any common external applications — so that the prototype was developed as a stand-alone web interface.

In the future, integrating additional data from external data sources could support the veracity of supply chain data recorded in the blockchain, including physical quantity data from weighbridges or meters, certification data from voluntary scheme databases, as well as report databases in which Member States record the final claims made to consumers. Companies also use a multitude of internal IT systems for reporting physical stocks and biofuel sustainability claims which could interface with the blockchain database without being a component of it. It is worth noting, however, that with increased integration comes increased risk of error. A solution is only as secure as its weakest component and any integration would need to be carefully balanced with any risk to data integrity.

One of the target outputs of this project was to understand the user roles and business processes in order to enable the design of standardised interfaces across supply chain companies. The common data reporting requirements dictated by the EU RED and clearly defined User roles fed into the design of the application interface, and through the engagement of stakeholders during the design phase a final set of very comprehensive features was identified. However, due to the limitation of time and budget, only the critical features could be implemented for the mobile interface (for the first collection driver) and the web interface (for the Traders and Administrators).

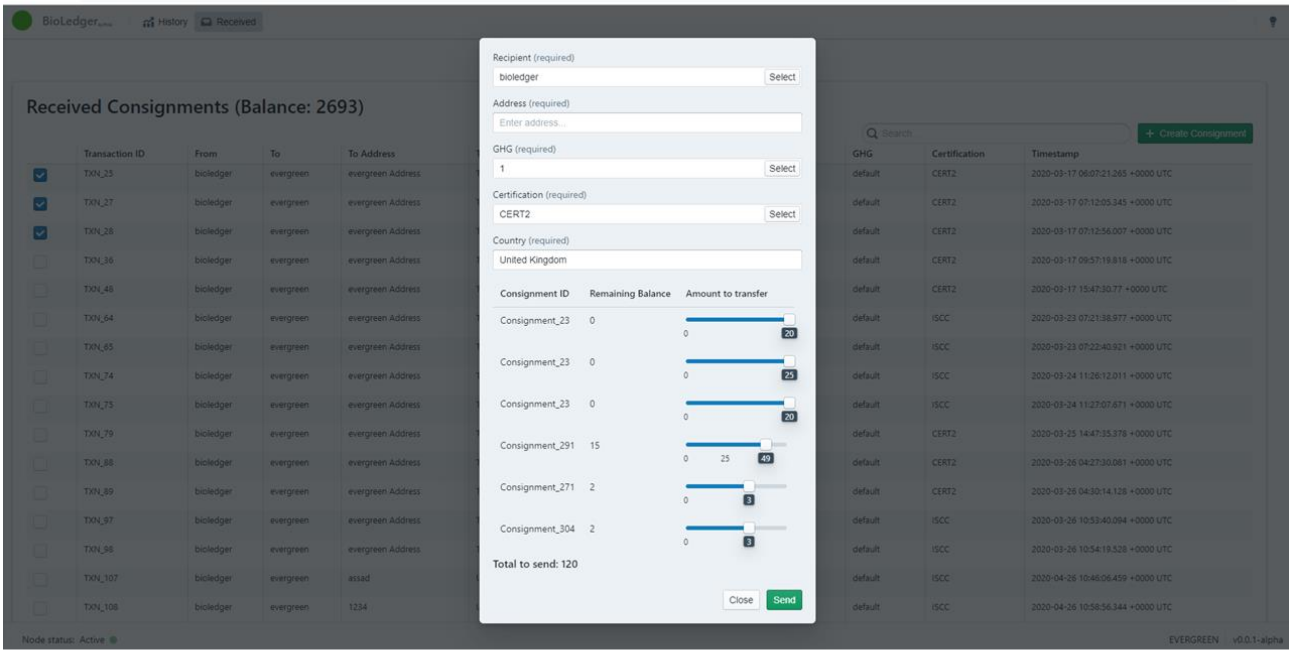

Figure 18: Bioledger web application screenshot. The web interface allows the User to view stock, aggregate, split, and transfer consignments.

Users who need to read or write data to the database from a mobile device could access the web app from a web browser on their smart phone or via a specially-built mobile app.

Access via a mobile app rather than a web browser is preferred, as collector stakeholders advised that some collections are performed in rural areas or in basements in shopping centres without adequate internet or GPS signal, and that while a regular browser application would cease function in such circumstances, a dedicated app could display a flag showing the driver's offline status while recording the critical collection data offline — including photos or signatures — and upload them upon signal reconnection.

It was identified by stakeholders that Google's Android platform is more common than Apple's iOS platform among drivers who would be accessing this system remotely — explained by the low cost (starting around EUR 40), and huge variety of Android devices.

While a number of very comprehensive design features were defined for the app interfaces by the stakeholders, it must be noted that not all were implemented in the prototype.

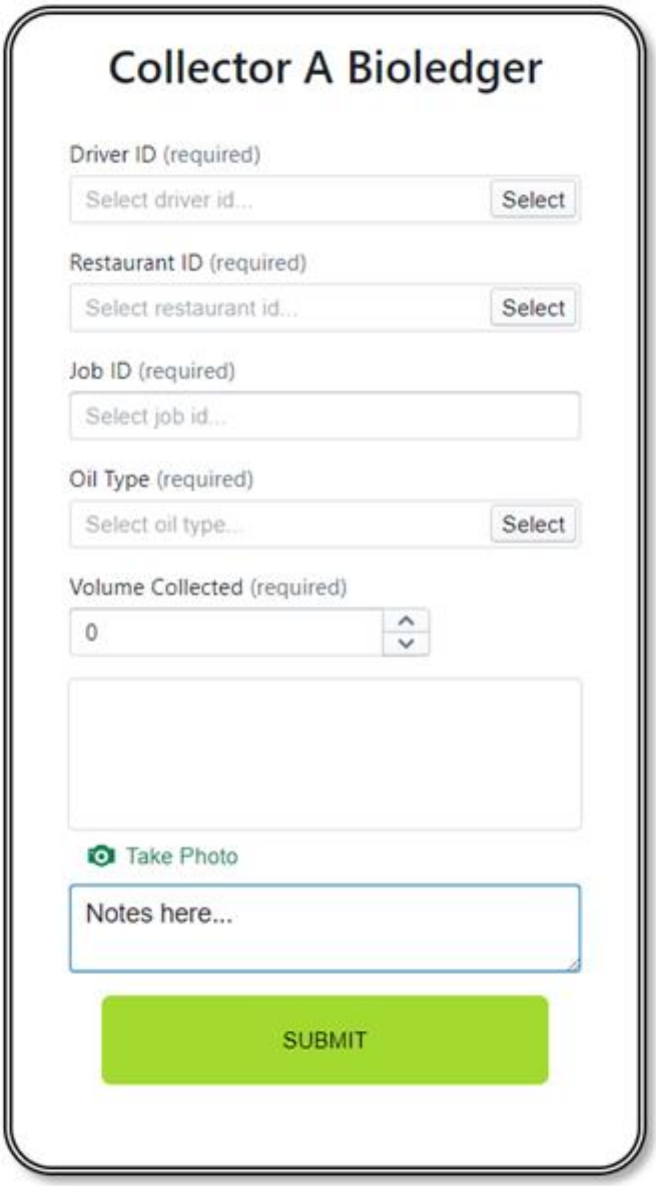

Figure 19: First Collector Driver interface in the Bioledger mobile application

7.1.3. Blockchain Code ('Chaincode')

'Chaincode' is the term for programs that run on top of the blockchain to implement the logic dictating how users interact with the ledger via the applications. When a transaction is proposed, it triggers chaincode that decides whether the transaction is permitted and which resulting state change should be applied to the ledger, thereby creating the blocks that form the ledger.

In the project application prototype, the chaincode checks that a user has the available consignments available to sell before allowing them to be transferred to another User account. The outcome of the chaincode logic being applied is that the ledger is changed to show that the consignment no longer belongs to the seller and now belongs to the buyer. This transaction is recorded in the history of the ledger as a new block that can never be deleted or changed.

7.1.4. Nodes

Nodes are the computers on a network that maintain a shared ledger of transactions. Each node involved in a transaction, whether as a direct participant or verifier, will have access to the ledger across multiple machines. This allows for decentralisation and for control to be shared across the network, instilling trust into the transaction ecosystem. All transactions which are appended to the blockchain are first verified by all members. This verification happens instantly and without oversight as the logic of the blockchain code is exercised. The nodes in the network can review the outcomes of all transactions and whether transactions have been attempted but rejected.

The application was developed using three nodes (a 'cluster') on the Oracle Blockchain Platform Cloud Service. To ensure access to all three nodes for full verification that the data was replicated correctly, and that the application could write and retrieve the information from the cluster of nodes, Bioledger hosted all three nodes. For a full solution, the nodes would be hosted by separate key holders who are trusted impartial adjudicators such as Bioledger, RSB, the European Commission, and a Certification Body.

7.1.5. Analytics

There are two key elements to be tested in proving the hypothesis that blockchain technology can mitigate the risk of fraud in sustainable biofuel supply chains: that of embedding automated compliance logic into transactions, and that of providing supply chain transparency to regulators.

Since the outcome of the consensus logic is that all transactions are recorded in each copy of the distributed ledger database, it is important to define which peers in the stakeholder group hold a copy of the distributed ledger — since they may have access to view all transactions if permitted by the rest of the network.

The transparent and peer-reviewed nature of the distributed blockchain database enables everyone to verify a new transaction's ownership and prohibits transactions from being hidden from regulators or peers.

Digitisation of supply chain data will already improve the ability of regulators to understand the supply chain and identify risks and implausible trades — assisted by analytical tools and potentially even artificial intelligence. Access to a single true statement of all consignments in the market at any point in time, including a historical log of all transactions, will give regulators the ability to know exactly what has happened in the market.

To demonstrate this potential, Bioledger designed some 'global mass balance analytics' for stakeholders. It will be important to control this privileged access, in order to protect commercial information as well as present it in a meaningful way.

Figure 20: Example of Bioledger analytics dashboard, summarising the trade flows of sustainable biofuel

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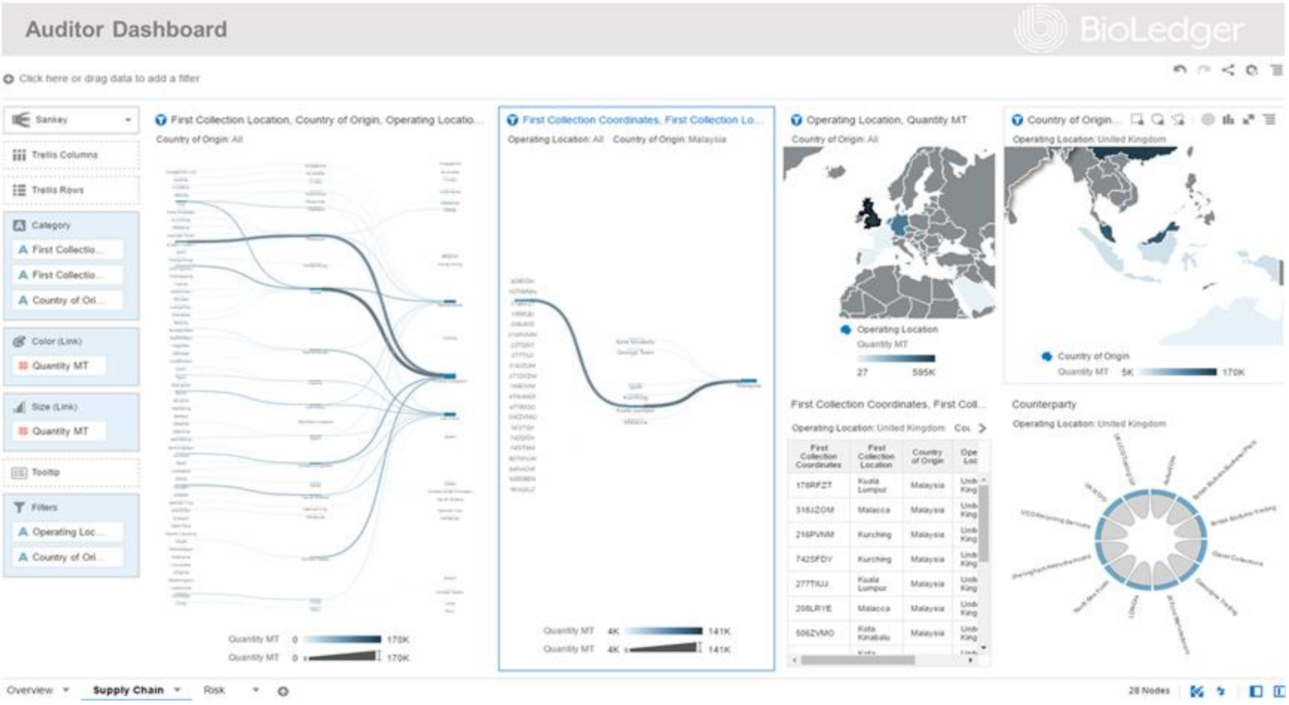
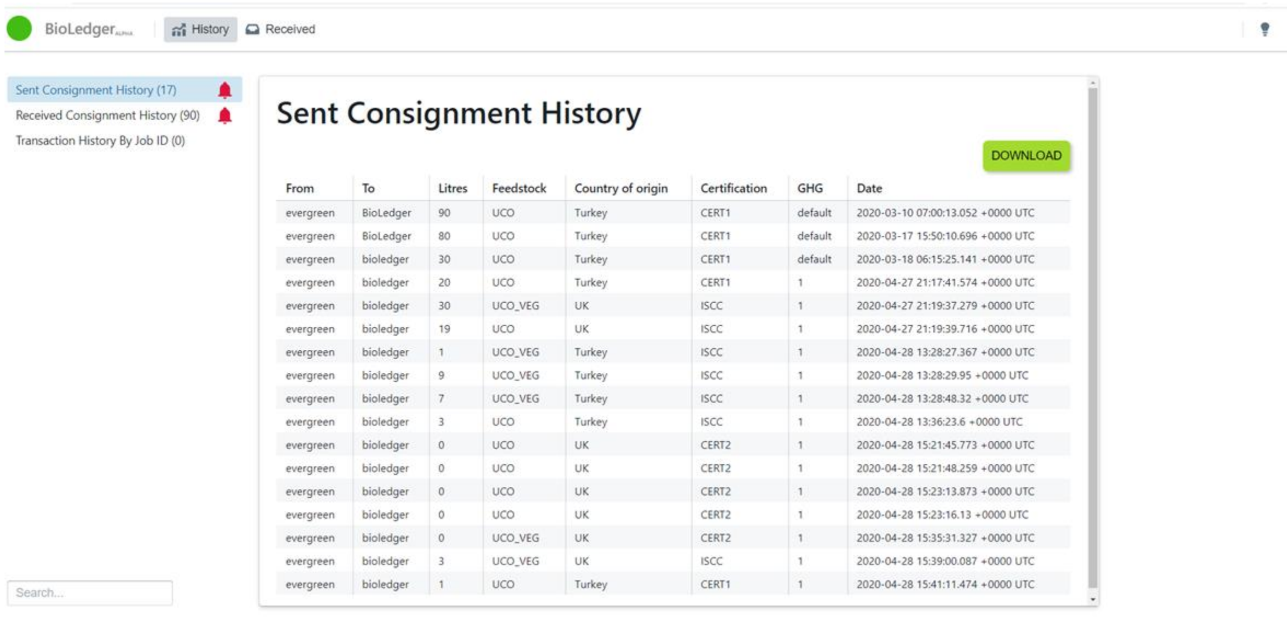


Figure 21: Example of Bioledger analytics dashboard, showing supply chain traceability to investigate fraud

Since a blockchain database will always present the current true state of ownership of consignments within the database, it may also be important for biofuel users to record a snapshot at specific moments — such as at midnight every day or at midnight on the last day of a three-month mass balance period — enabling auditors to view the process of compliance throughout a mass balance period or reporting year. Storing these snapshots would require an additional database.



From	To	Litres	Feedstock	Country of origin	Certification	GHG	Date
evergreen	BioLedger	90	UCO	Turkey	CERT1	default	2020-03-10 07:00:13.052 +0000 UTC
evergreen	BioLedger	80	UCO	Turkey	CERT1	default	2020-03-17 15:50:10.696 +0000 UTC
evergreen	bioledger	30	UCO	Turkey	CERT1	default	2020-03-18 06:15:25.141 +0000 UTC
evergreen	bioledger	20	UCO	Turkey	CERT1	1	2020-04-27 21:17:41.574 +0000 UTC
evergreen	bioledger	30	UCO_VEG	UK	ISCC	1	2020-04-27 21:19:37.279 +0000 UTC
evergreen	bioledger	19	UCO	UK	ISCC	1	2020-04-27 21:19:39.716 +0000 UTC
evergreen	bioledger	1	UCO_VEG	Turkey	ISCC	1	2020-04-28 13:28:27.367 +0000 UTC
evergreen	bioledger	9	UCO_VEG	Turkey	ISCC	1	2020-04-28 13:28:29.95 +0000 UTC
evergreen	bioledger	7	UCO_VEG	Turkey	ISCC	1	2020-04-28 13:28:48.32 +0000 UTC
evergreen	bioledger	3	UCO	Turkey	ISCC	1	2020-04-28 13:36:23.6 +0000 UTC
evergreen	bioledger	0	UCO	UK	CERT2	1	2020-04-28 15:21:45.773 +0000 UTC
evergreen	bioledger	0	UCO	UK	CERT2	1	2020-04-28 15:21:48.259 +0000 UTC
evergreen	bioledger	0	UCO	UK	CERT2	1	2020-04-28 15:23:13.873 +0000 UTC
evergreen	bioledger	0	UCO	UK	CERT2	1	2020-04-28 15:23:16.13 +0000 UTC
evergreen	bioledger	0	UCO_VEG	UK	CERT2	1	2020-04-28 15:35:31.327 +0000 UTC
evergreen	bioledger	3	UCO_VEG	UK	ISCC	1	2020-04-28 15:39:00.087 +0000 UTC
evergreen	bioledger	1	UCO	Turkey	CERT1	1	2020-04-28 15:41:11.474 +0000 UTC

Figure 22: Example of transaction history presented in the Bioledger prototype

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7.1.6. Ledger

The ledger is much like a traditional database, in that it records data, but differs in that it is an immutable record that can only append, meaning that data transactions can be recorded but never edited or deleted. The data are also recorded simultaneously and identically across multiple distributed versions, and the ledger is also encrypted so that access to read or write into the ledger is controlled by the Permission Issuer — providing additional levels of protection over confidential information. These features make it a record of the truth that is inherently more secure and less vulnerable to corruption.

Transactions that demonstrate compliance with the consensus logic will be recorded simultaneously in all copies of the distributed ledger hosted by permitted peers in the network. To enable functioning of the distributed ledger there must be at least two peers who host a copy of the ledger. Stakeholders will need to identify the entities who can be trusted with full content of the distributed ledger and require access to it.

This prototype was configured with Bioledger and RSB assigned as the nodes of the network. Commercial supply chain users may not necessarily hold a copy of the distributed ledger, to mitigate the risk of commercial entities viewing other users' confidential data. Ledger reading will need to be configured to present Users with the data on consignments they own the titles of, so that they can review their current stock and perform sales to other Users via the web-based application layers.

Data stored in the distributed ledgers must be transcribed, ordered, and stored in servers so that it can be recalled accurately at any time. The use of cloud-based storage will allow the ledger to be scalable to host hundreds of millions of recorded transactions per year in the EU biofuels market.

7.2. Blockchain Prototype Architecture

This solution compliments traditional legacy OSS/BSS systems by enabling blockchain supply chain management capabilities via traditional web 2.0 interfaces. The architecture provides all the key functions that form the basis of a blockchain biofuel supply chain solution.

Multiple distributed ledger technologies (DLTs) can potentially be supported by this solution, however, Hyperledger Fabric's enterprise-grade quality positions it as the primary supported platform.

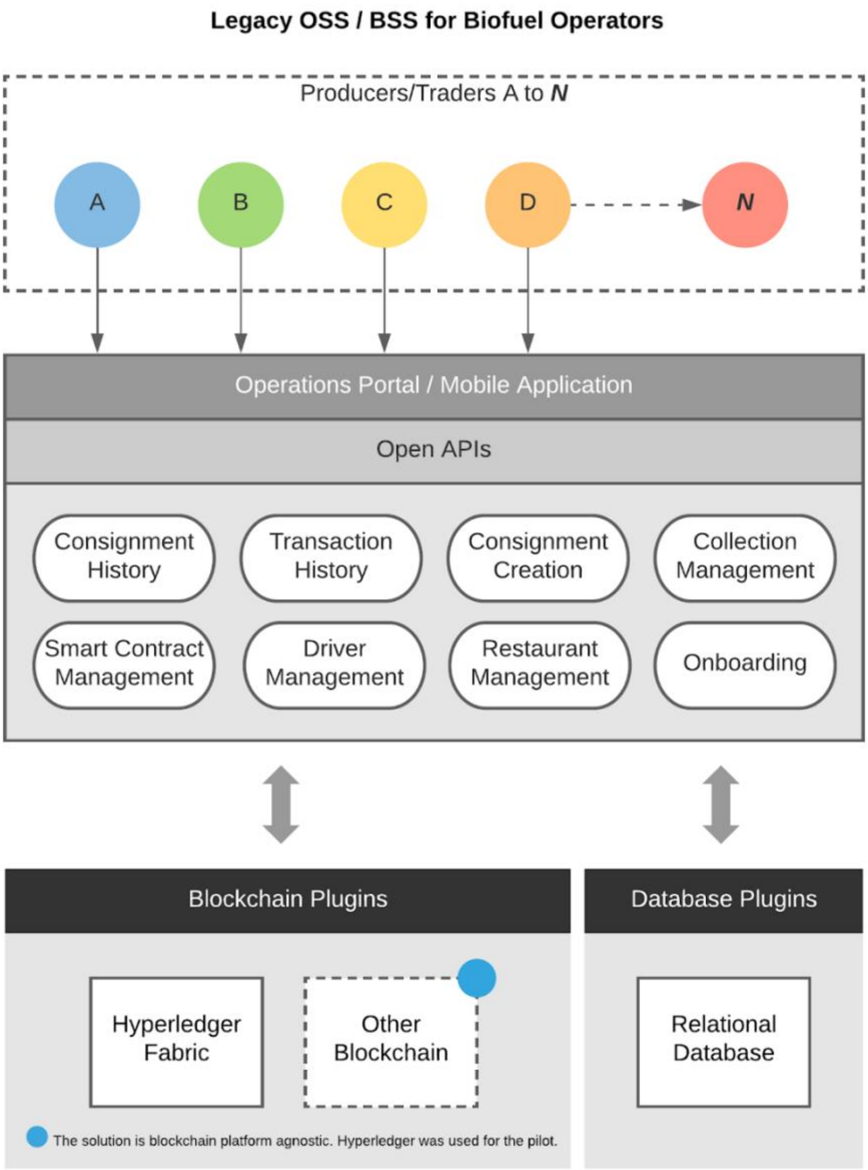

Figure 23: Business Architecture of the blockchain solution

7.2.1. Operations Portal

The operations portal is the key interface for traders, suppliers, and auditors in the consortium — providing self-service capabilities. Some of its key features are:

- Consignment history viewing.
- Detailed transaction history viewing.

- Consignment creation.
- Collection management.
- Onboarding of new members (permission issuer).

7.2.2. Mobile Application

Collection management is facilitated primarily by a mobile app that is provided to the collection personnel. Some of its key features are:

- Collection management.
- Tracking of location data.
- Collection timestamps.

7.2.3. Open APIs

The solution comes with a library of Representational State Transfer (REST) Application Programming Interfaces (APIs) that act as a middle layer to enable the integration of existing legacy systems. Some of its key APIs are:

- ‘Create consignment’.
- ‘Get transaction history’.
- ‘Create/get wallet’.
- ‘Get job’.
- ‘Send consignment’.
- ‘Timestamp collection’.

7.2.4. Relational Database

This solution also supports the integration of a traditional relational database for storing any metadata necessary to support the process. Best practice dictates that only a cryptographic reference to off-chain data should be held on the distributed ledger, due to the permanent nature of a blockchain. A traditional database is used for this purpose, holding information such as location addresses and collection drivers’ personal data.

7.2.5. Blockchain Network

The parties governing the Hyperledger Fabric network will be able to define the network, add/remove participants, provide roles and privileges, create/modify/delete channels, and so on.

The Hyperledger Fabric network will include multiple organisations, each representing a collaborating entity involved in the biofuel supply chain process. Paired entities will be able to communicate directly with each other via a secure separate channel, ensuring that the data from their mutual customers is available only to them and not any other entity.

For example, let's say Restaurant A and Biofuel Trader B communicate with each other via Channel 1 while Restaurant C and Biofuel Trader D communicate with each other via Channel 2. Neither Restaurant A nor Biofuel Trader B can retrieve or tamper with any data pertaining to Restaurant C or Biofuel Trader D, and vice versa.

There must be at least one ledger per channel to record each transaction. These ledgers will be in sync across all the general peers of all organisations on a single channel, ensuring that the data is distributed across multiple ledgers, to maintain integrity.

There will be at least one smart contract per channel to write to the corresponding ledger. The smart contract, also known as 'chaincode' in Hyperledger Fabric, will include custom logic to perform the required operations for supply chain transactions.

7.2.6. Blockchain Node Ownership

The pilot for this solution hosted the three nodes that provided the distributed ledger. Note that to truly leverage the benefits of a distributed architecture for a production solution it is recommended that the consortium members each host their own blockchain nodes.

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