INNOVATIVE BLOCKCHAIN TRACEABILITY TECHNOLOGY AND STAKEHOLDERS' ENGAGEMENT STRATEGY FOR BOOSTING SUSTAINABLE SEAFOOD VISIBILITY, SOCIAL ACCEPTANCE AND CONSUMPTION IN EUROPE

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Nature of the deliverable

R	Document, report (excluding the periodic and final reports)	☒
DEM	Demonstrator, pilot, prototype, plan designs	☐
DEC	Websites, patents filing, press & media actions, videos, etc.	☐
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Other	Software, technical diagram, algorithms, models, etc.	☐

Dissemination level

PU	Public — fully open (automatically posted online on the Project Results platforms)	☒
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Current seafood traceability tools and services have the potential to take advantage of novel blockchain technologies to obtain a wide range of data making sustainable seafood practices more visible to consumers. Sea2See project will fill in existing seafood traceability gaps through development and demonstration of an innovative end-to-end blockchain traceability model throughout the seafood value chain and professional and consumer applications to increase trust and social acceptance of sustainably fished and farmed seafood.

The project will provide technological solutions to answer the need for a valuable source of data collected throughout the whole seafood value chain, verified, and covering inputs from diverse stakeholders. For that purpose, a specific focus will be put on active commitment of stakeholders and real empowerment of consumers through the implementation of societal and sectoral strategies for co-creation, communication and awareness raising.

The project runs from July 2022 to June 2026. It involves 14 partners from 6 EU countries, and is coordinated by SMARTWATER PLANET SL, Spain.

More information about the project can be found at: http://www.sea2see.eu/

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EXECUTIVE SUMMARY

The power consumption of blockchain networks, particularly those using proof-of-work (PoW) consensus mechanisms like Bitcoin, is often singled out and rightly so. The energy consumption required for mining blocks in PoW blockchains is enormous, translating into significant ecological impacts and economic costs. Fortunately, there are alternatives to this power consumption, especially in the context of a private blockchain network, available by using other consensus algorithms.

This document describes the consensus algorithm used by the Tilkal blockchain engine, and why it is not a risk of dispendious energy consumption.

ACRONYMS AND ABBREVIATIONS

ACRONYM	DEFINITION
POW	Proof of work
POS	Proof of stake
VM	Virtual Machine

PROJECT PARTNERS

#	Partners full name	Short	Country	Website
1	SMARTWATER PLANET SL	SmartWater	ES	www.smartwaterplanet.com
2	TILKAL	Tilkal	FR	www.tilkal.com
3	PAGE UP	PAGE UP	FR	www.pageup.fr
4	SUBMON	SUBMON	ES	www.submon.org
5	CENTRO DE CIENCIAS DO MAR DO ALGARVE	CCMAR	PT	www.ccmar.ualg.pt
6	ASOCIACION NACIONAL DE FABRICANTES DE CONSERVAS DE PESCADOS Y MARISCOS-CENTRO TECNICO NACIONAL DE CONSERVACION DE PRODUCTOS DE LA PESCA	ANFACO	ES	www.anfaco.es

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1. WHY A BLOCKCHAIN?

A blockchain is a decentralized ledger (database) that allows to collect and exchange data between several partners.

The main purpose of using this technology inside a traceability platform is to bring transparency, traceability and auditability to your supply chain by tracing all data flows. This comes with two major advantages:

- Smoothen the deployment of an end-to end traceability network. It is a technology that is decentralized, in the same way a supply chain is decentralized.
- Have auditable data. This means knowing who said what and when. It allows to create a chain of responsibility shared with all the network participants

The Tilkal platform is based on a permissioned blockchain that uses MultiChain (MultiChain, 2024) technology. A permissioned blockchain is a decentralized ledger that requires permission to access and use. Only a specific group of participants who have been granted access by the network administrators can join and use the network. Tilkal's permissioned blockchain uses a PBFT algorithm (Practical Byzantine Fault Tolerant), a "round robin" type, where there is a random validation of each block. It does not require a significant amount of energy. In contrast, a public blockchain is a decentralized ledger that is open to anyone who wants to participate, typically used for cryptocurrencies, such as Bitcoin. They use a proof-of-work (PoW) consensus algorithm, which requires nodes to solve complex mathematical problems to validate transactions and add new blocks to the blockchain. This process is computationally intensive and requires a significant amount of energy, as nodes compete to be the first to solve the problem and earn a reward.

2. THE TILKAL BLOCKCHAIN ENGINE

At the time of the inception of the Tilkal project (2016), some blockchain engines were already available. The most popular were the Bitcoin engine of course, and some derivatives of Hyperledger engine. Ethereum and derived engines were not available, and no engine based on Proof of stake (PoS) or other *light* consensus were generally available.

But being based on Bitcoin does not mean that Proof of Work is the only alternative, and this has been proven by the MultiChain blockchain engine creators. Even at this time (2015), it was obvious for them that PoW was an obstacle to blockchain based application development that’s why unlike public blockchains like Bitcoin and Ethereum, which use proof-of-work (PoW) and proof-of-stake (PoS) consensus algorithms, MultiChain employs a different consensus mechanism tailored for permissioned (private) blockchain environments. The primary consensus algorithm used by MultiChain is called “round-robin mining” (MultiChain, 2024).

Using it as the Tilkal blockchain network foundation was based on its light consensus, and its ease of installation, making it possible to onboard traceability actors in an uncomplicated way.

Since then, MultiChain has become a popular open source blockchain platform designed for the creation and deployment of private blockchains.

2.1. ROUND-ROBIN MINING CONSENSUS

“Round-robin mining” is designed to operate in a controlled environment where all participants are known and trusted to a certain extent. Here's a breakdown of how it works:

- Permissioned Mining: MultiChain operates as a permissioned blockchain, meaning that only approved nodes can participate in the mining process. This approval is managed through a whitelist of permitted miners.

- Round-Robin Order: In round-robin mining, the right to create the next block is rotated among the approved miners in a predefined order. This means that each miner takes turns to produce a block, ensuring a fair and predictable distribution of mining rights.

- Block Creation Rules: To maintain the order and prevent any single miner from dominating the chain, each miner must wait for their turn to mine a new block. If a miner tries to create a block out of turn, the block will be rejected by the network.

- Block Validity: Blocks created by miners are validated by the rest of the network nodes to ensure they follow the blockchain's protocol rules and that the miner was indeed the next in line to produce a block.

- No Competitive Mining: Unlike PoW, where miners compete to solve complex puzzles, round-robin mining eliminates the need for competition. This drastically reduces the energy consumption associated with mining, as there is no need for extensive computational work.

The Round-Robin Mining in MultiChain comes with some advantages:

- Energy Efficiency: Since miners do not compete against each other to solve puzzles, energy consumption is minimal compared to PoW blockchains.

- Predictable Block Production: The block production process is orderly and predictable, which can enhance the stability and reliability of the blockchain.

- Lower Costs: Without the need for expensive mining hardware and significant electricity expenditure, the operational costs for maintaining the blockchain are reduced.

- Enhanced Security in Permissioned Environments: In a permissioned blockchain, the participants are typically known and vetted, reducing the risk of malicious activities. The round-robin consensus further ensures that block production is fairly distributed among trusted parties.

2.2.A PERMISSIONED BLOCKCHAIN

While round-robin mining works well for private and permissioned blockchain networks like those supported by MultiChain, it is not suitable for public, permissionless blockchains. This is because the trust model and security assumptions differ significantly between private and public blockchain environments. In a permissionless context, where participants are anonymous and potentially malicious, consensus mechanisms like PoW or PoS, which are designed to handle such adversarial conditions, are more appropriate.

In summary, MultiChain's round-robin mining consensus algorithm provides a secure, efficient, and fair method of block production in permissioned blockchain networks, making it well-suited for enterprise applications and private blockchain deployments like a traceability platform involving actors of a supply chain.

3. THE NETWORK

The consensus algorithm complexity or simplicity is only one cause of the energy consumption of a blockchain network. To be a network, a system must be composed of several connected participants. In the context of a blockchain network, these participants are called “node”.

The ecological impact of the Tilkal blockchain network is then directly dependent on the energy consumption of the nodes.

Blockchains that do not use Proof of Work consensus mechanisms generally have a much lower carbon impact. This is primarily due to their reduced energy consumption, lower hardware requirements, and potential use of renewable energy sources in data centers. These factors collectively contribute to a more sustainable blockchain ecosystem.

The carbon impact of a blockchain network based on the MultiChain engine depends on several factors, including the consensus mechanism used, the network's hardware requirements, and the efficiency of the data centers or servers hosting the nodes.

3.1. KEY FACTORS INFLUENCING CARBON IMPACT

Here is a list of factors influencing the carbon impact of a blockchain network:

1. **Consensus Mechanism**:
    a. Proof of Work (PoW): High energy consumption due to the need for extensive computational power to solve cryptographic puzzles.
    b. Proof of Stake (PoS) or Other Mechanisms: Lower energy consumption since they do not require intensive computation. MultiChain uses a configurable consensus mechanism which can be more energy efficient. This is the consensus used by the Tilkal network.
2. **Number of Nodes**:

The number of nodes in the network impacts the overall energy consumption. Private blockchains typically have fewer nodes than public ones.

3. **Hardware Efficiency**:

The type of hardware running the nodes (e.g., energy-efficient servers vs. standard desktops) and the efficiency of the underlying infrastructure. This is largely linked to hosting services energy efficiency, as we will see below.

4. **Energy Source**:

The carbon intensity of the electricity used by the servers, which depends on whether the energy comes from renewable sources or fossil fuels. Again, this will depend on the hosting services energy source choices, or on-premise locations.

4. THE NODES

To evaluate the carbon impact of the Tilkal blockchain network, we will focus on two different kinds of nodes:

- Servers hosted in the cloud, provided by well-known hosting services like OVH, AWS, Azure, Google Cloud Platform.
- Severs hosted on premise, usually using some small to mini-PC.

In both cases we must keep in mind that a Tilkal blockchain node must be a Linux server, with low technical requirements, since the consensus used is based on round robin mining and not PoW. Usually this means a “2 cpu / 4 GB of ram / 20 GB” of disk space instance.

4.1. NODES HOSTED IN THE CLOUD

The carbon impact of a typical Linux virtual machine (VM) instance provided by a classical hosting service can vary widely based on several factors, including the energy efficiency of the data center, the source of the electricity used, and the utilization efficiency of the VM itself. Here's a breakdown of these factors:

Key factors influencing carbon impact:

1. **Energy Source:**
    1. **Renewable vs. Non-renewable:** Data centers powered by renewable energy (e.g., solar, wind, hydro) have a much lower carbon footprint compared to those relying on fossil fuels (e.g., coal, natural gas).
2. **Data Center Efficiency:**
    1. **PUE (Power Usage Effectiveness):** PUE (Wikipedia, 2024) is a measure of how efficiently a data center uses energy; it is the ratio of total building energy to the energy used by the IT equipment. The closer the PUE is to 1.0, the more efficient the data center. Modern, energy-efficient data centers typically have a PUE between 1.1 and 1.4.
3. **VM Resource Utilization:**
    1. **CPU Utilization:** Higher utilization of the VM's resources (CPU, memory) means more efficient use of energy per computational task.
    2. **Idle vs. Active:** An idle VM still consumes power, but not as much as an actively processing one.
4. **Hardware Efficiency:**
    1. **Modern Hardware:** Newer, more energy-efficient servers contribute to a lower carbon footprint.
    2. **Virtualization Overhead:** Efficient virtualization technologies reduce the overhead and improve the energy efficiency of VMs.

4.2. NODES HOSTED ON PREMISE

The carbon impact of a small on-premise computer, such as a typical desktop or small server, can be calculated similarly to a virtual machine (VM) instance in a data center, but with some differences due to the specific hardware and operational conditions.

Key factors influencing carbon impact:

1. **Power consumption:**
    1. **Typical desktop computer:** Power consumption can range from 50 to 200 watts, depending on the hardware configuration and usage.
    2. **Small Server:** Power consumption might be slightly higher, ranging from 100 to 300 watts, depending on whether it's a simple file server, application server, or a more robust small business server.
2. **Usage patterns:**
    1. **Operational hours:** The number of hours the computer is powered on per day.
    2. **Idle vs. Active:** The power consumption during idle time versus when the computer is under load.
3. **Energy source:**
    1. **Electricity mix:** The carbon intensity of the electricity used, which depends on the energy sources (renewable, coal, natural gas, etc.) in the region.

4.3. ESTIMATING TYPICAL CARBON IMPACT

To estimate the carbon impact, we need to consider the average power consumption of the nodes, the efficiency of the data centers or servers, and the carbon intensity of the electricity used.

While exact figures can vary, here is a rough estimation approach:

Energy consumption of a typical server:

A typical VM might consume between 10 to 50 watts of power, depending on its configuration and workload. A Tilkal blockchain will have a low to very low activity, except during data handling where medium activity can be needed for very short periods. Let's use a value slightly less than the average (15 watts).

Annual energy use:

If a VM consumes 15 watts on average, its annual energy consumption would be:

15 (watts) x 24 (hours/day) x 365 (days/year) = 131,400 watt-hours or 131.4 kWh/year

Carbon emission factor:

The carbon emission factor depends on the energy source. For example:

Coal: ~0.91 kg CO_2 per kWh

Natural Gas: ~0.45 kg CO_2 per kWh

Renewables: ~0 kg CO_2 per kWh

Carbon footprint calculation:

For a data center using a mix of energy sources, let's assume an average emission factor of 0.5 kg CO_2 per kWh, this is a very pessimistic value in regard of well-known hosting services, like we will see below:

131.4 (kWh/year) x 0.5 (kg CO_2/kWh) = 65.7 kg CO_2/year

To sum up:

- **Average VM Power Consumption**: 15 watts
- **Annual Energy Consumption**: 131.4 kWh
- **Average Carbon Emission Factor**: 0.5 kg CO_2 per kWh
- **Annual Carbon Footprint per VM**: 65.7 kg CO_2

4.4. MITIGATING CARBON IMPACT

1. **Use Renewable Energy:** Choose hosting services that power their data centers with renewable energy.
2. **Efficient Resource Management:** Optimize VM usage to ensure high resource utilization and avoid idle time.
3. **Modern Hardware:** Use VMs hosted on modern, energy-efficient servers. Opt for energy-efficient CPUs, GPUs, and power supplies for on-premise server.
4. **Reduce Operational Hours:** Power off or put the computer in a low-power state when not in use, blockchain blocks will synchronize when the server is awakened.
5. **Geographic Considerations:** Host VMs in regions with a cleaner energy grid. You can for example leverage the nuclear power grid in France regions.

4.5. HOSTING SERVICES CONSIDERATIONS

Many (serious) cloud services publish information about their energy efficiency. This makes it possible to have a better idea of which one provides the least power consumption.

1. **Azure Data Center Efficiency:**
    1. **Power Usage Effectiveness (PUE):** Azure data centers have a PUE that is typically around 1.2 to 1.3, indicating efficient use of energy (Microsoft, 2022).
    2. **Energy Source:** Microsoft is working toward using 100% renewable energy by 2025. As of now, a significant portion of the energy comes from renewable sources.
    3. **Carbon Intensity of Electricity:**

        1. **Average Carbon Emission Factor:** Depending on the location, the carbon intensity can vary. For regions with a high renewable energy mix, the factor can be much lower.
2. **AWS Data Center Efficiency:**
    1. **Power Usage Effectiveness (PUE):** AWS data centers are known for their efficiency, with PUE values often around 1.2 to 1.3 (AWS, 2015).
    2. **Energy Source:** AWS is committed to increasing its use of renewable energy and has already reached significant milestones in various regions.
    3. **Carbon Intensity of Electricity:**
        1. **Average Carbon Emission Factor:** This varies by region. AWS operates in many regions worldwide, and the carbon intensity can be significantly lower in regions with higher renewable energy usage.
3. **GCP Data Center Efficiency:**
    1. **Power Usage Effectiveness (PUE):** Google's data centers are among the most efficient in the world, with PUE values often around 1.1 to 1.2 (Google, 2024).
    2. **Energy Source:** Google has been purchasing enough renewable energy to match its global consumption since 2017 and is working toward operating entirely on carbon-free energy by 2030.
    3. **Carbon Intensity of Electricity:**
        1. **Average Carbon Emission Factor:** This can vary by region, but Google's use of renewable energy significantly reduces the carbon footprint of its operations.
4. **OVH Data Center Efficiency:**
    1. **Power Usage Effectiveness (PUE):** OVH data centers have PUE values that are generally efficient, often around 1.2 to 1.3 (OVH, 2023).
    2. **Energy Source:** OVH uses a significant proportion of renewable energy, especially in its European data centers.
    3. **Carbon Intensity of Electricity:**
        1. **Average Carbon Emission Factor:** This varies by region but is generally lower in regions with a high mix of renewable energy. OVH's European data centers benefit from the EU's focus on reducing carbon emissions.

4.6.SUMMARY

Here is a summary of typical carbon impact of a Tilkal blockchain node, be it provided by a hosting service or on-premise:

Table 1: Typical carbon impact

Service	Instance type	Average power consumption (watts/hour)	Emission factor (kg CO_2 per kWh) / (PUE)	Carbon impact (kg CO_2/year)
Azure	B1 or similar	15	0.2 / 1.2-1.3	26
AWS	T2.micro or similar	15	0.2 / 1.2-1.3	26
GCP	E2-micro or similar	15	0.1 / 1.1-1.2	13
OVH	B2-7 or similar	15	0.15 / 1.2-1.3	19
On-premise	Intel n100 mini-pc or similar	8 (6W TDP) (Intel, 2024)	0.5	35

CONCLUSION

The Tilkal traceability platform's use of a permissioned blockchain, powered by MultiChain's round-robin mining consensus, offers a sustainable and efficient solution for modern supply chains. This approach provides transparency, traceability, and auditability while aligning with the decentralized nature of supply chains.

KEY ADVANTAGES

Efficiency: MultiChain’s round-robin mining eliminates the need for competitive mining, ensuring minimal energy consumption. Each participant takes turns in block creation, which reduces the computational power required and makes the process predictable and orderly.
Lower Carbon Impact: Unlike traditional public blockchains that use Proof of Work (PoW) and consume substantial energy, Tilkal's blockchain uses a light consensus mechanism that is energy efficient. The network nodes operate on modest hardware requirements and consume minimal power.

Scalability: The ease of installation and low technical demands of MultiChain make it ideal for deploying an end-to-end traceability network across various stakeholders. This promotes seamless integration without incurring significant energy costs.

Sustainability: The choice of hosting services can further mitigate carbon impact. Data centers from providers such as AWS, Azure, Google Cloud Platform, and OVH leverage renewable energy and efficient infrastructure, resulting in a lower carbon footprint for the Tilkal nodes.

ESTIMATING CARBON IMPACT

In section 4.3 we have made a conservative estimation of the power consumption for a Tilkal node. Even when considering a pessimistic evaluation of a standard virtual machine or a small on-premise server, the carbon footprint per VM could be estimated at 65.7 kg CO_2 per year (around 15 watts per hour on average. with an annual energy use of approximately 131.4 kWh and assuming a mixed energy source of 0.5).

This is considerably lower compared to traditional blockchain setups using proof-of-work (PoW) or proof-of-stake (PoS) consensus algorithms, like Bitcoin or Ethereum. In the case of these "public blockchains" we must also consider the devices used to solve cryptographic puzzles, usually some graphic power units (GPU). This means adding between 150 to 300 watts per hour, increasing the typical carbon footprint tenfold.

When we consider the efforts made by major hosting services, the carbon footprint is getting even lower for permissioned blockchain networks (between 13 and 35 kg CO_2 per year as showed in Table 1), reducing the risk of carbon impact of the Sea2See blockchain based traceability even more.

TO SUM UP:

Tilkal's blockchain-based traceability platform integrates seamlessly into supply chain operations without excessive energy consumption. By leveraging a permissioned blockchain and efficient consensus mechanisms, Tilkal ensures that sustainability is at the core of its operations, providing a responsible and eco-friendly solution for modern supply chain traceability.

This approach not only supports the ethical and environmental standards of modern businesses but also showcases a commitment to reducing the ecological impact of blockchain technology in practical applications.

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