Imperial College London
Department of Civil and Environmental Engineering

CIVE60001 Civil Engineering Design 3
Development of Carbon Footprint Blockchain Platform Integrated with a Green Finance System for Water Infrastructure

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Executive Summary

The UK water industry is ambitious and has aimed to reach Net-Zero by 2030, which is 20 years earlier than other industries. However, 2030 is just around the corner and the pace to cut emissions is not on schedule. There is a distinct technology gap where the companies can bridge reality to ideology, and hence this project is positioned as a start-up company which can provide the framework and strategies to realise the water industry's goals. "Whater" is a blockchain-based business that can incorporate green finance ideas by introducing an industry-wide carbon trading model as well as technologies that can create a circular economy for materials.

Thorough research of the UK water industry indicates that it faces infrastructure, regulation, and leakage problems, among others, and can benefit from the blockchain in carbon emission tracking, sustainability, and compliance strategies.

As demonstrated, this can primarily be achieved through the Ethereum platform and layer 2 extension, Arbitrum. The coding of smart contracts in Solidity which can set caps for the Whater Tokens, allowing users to stake them, trade them and access a tiered reward system that can incentivise greater sustainability. A robust token economy which will allow water companies to trade tokens to either meet missed targets or benefit if they have successfully cut down on emissions will be implemented.

Whater also looks beyond just the water industry as these technologies can be applied to the construction, fashion, transport, and energy industries moving beyond 2030. Hence, insights into how the existing blockchain platform can shape other sectors as well as AI technologies which can help individuals and companies alike have been discussed.

App technology has been explored to demonstrate the proof-of-concept and how the users will be able to work towards the net zero goals. Ultimately, Whater will shape human behaviour to make a real-world change.

Acknowledgements

We would like to express our gratitude to Dr Po-Heng Lee for the support, encouragement and expertise he has given throughout the project. We are grateful for the opportunity he gave us to apply our civil engineering knowledge to something novel, allowing us to realize our potential.

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1 Introduction

The financial technology sector (FinTech) has undergone rapid development in recent years. According to McKinsey, seven key technologies will drive fintech development and shape the competitive landscape of finance over the next decade: Blockchain, Artificial Intelligence (AI), Cloud Computing, IoT, Open Source, SaaS and Serverless, No-Code and Low-Code (Fong, 2021).

Meanwhile, the UK water industry has pledged a ground-breaking commitment to achieving net zero emissions by 2030. It hopes to achieve this via methods including reducing energy consumption, adopting sustainable practices and investing in technologies that promote environmental responsibility. However, the industry is not on pace to achieve these targets and so there is a need for a clearer carbon zero pathway.

Meanwhile, the UK water industry has pledged a ground-breaking commitment to achieve net zero emissions by 2030, 20 years ahead of the deadline set by the government. The method includes reducing energy consumption, adopting sustainable practices and investing in technologies that promote environmental responsibility.

Whater proposes that Blockchain and Artificial Intelligence systems can effectively be applied to the water industry to create a green finance ecosystem. This will accelerate the path to net zero, improve transparency and efficiency while generating jobs and opportunities for the community.

The Whater plan consists of two-stages (pre-2030 and post-2030) to help water companies reach sustainability targets and continue improving beyond 2030 to improve efficiency in the water industry and scale to other countries and industries.

Phase 1 (pre-2030): The focus of this phase is primarily on developing a blockchain finance system to encourage water companies to reduce emissions over time, focusing on their wastewater operations as they are deemed to be the biggest emitters. The way this is achieved is through the revolutionary WHTR token that is pegged to the price of carbon offsetting. Companies will need to purchase tokens to emit CO_2. If they emit less than their cap, they could sell unused tokens or invest them elsewhere. The dissemination of WHTR tokens will reduce over time with reduction in emissions in the industry.

Phase 2 (post-2030): After net-zero is projected to be met in 2030, the next phase involves scaling Whater's blockchain technology to other industries and countries. Moreover, there will be an element of proliferation of Whater into domestic households through integration with smart-meters. Customers with smart-meters will be able to receive tokens as rewards for using water below average levels. Moreover, AI language models will be integrated in app form to provide personalised messages and suggestions for residents based on smart-meter data.

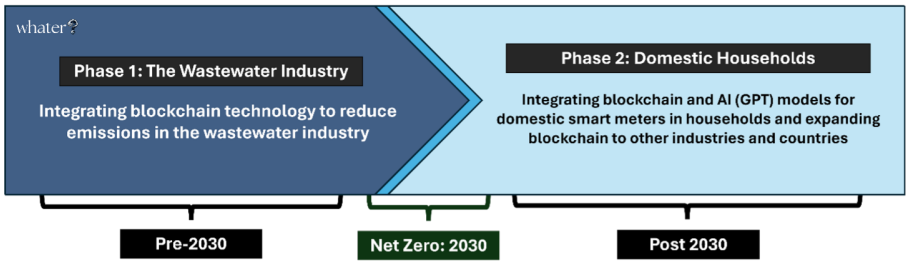


Figure 1.1: Diagram of Whater's two stage plan.

Whater's team consists of eleven dedicated students from Imperial College London, each bringing a blend of expertise in blockchain technology, artificial intelligence, and sustainable water management. Together, the Whater team is passionate about creating impactful solutions that address environmental challenges and promote sustainability.



2 Introduction to Blockchain Technology

2.1 Description of Blockchain

A blockchain is an immutable digital distributed ledger that uses a chain of blocks as a component of its protocol. It documents transactions in a secure and transparent way, since information is stored across a network of computers, instead of a centralised database, which makes it more difficult to alter or hack (Dock, 2024). It is an irreversible chain of transactions and has 3rd generational accountability.

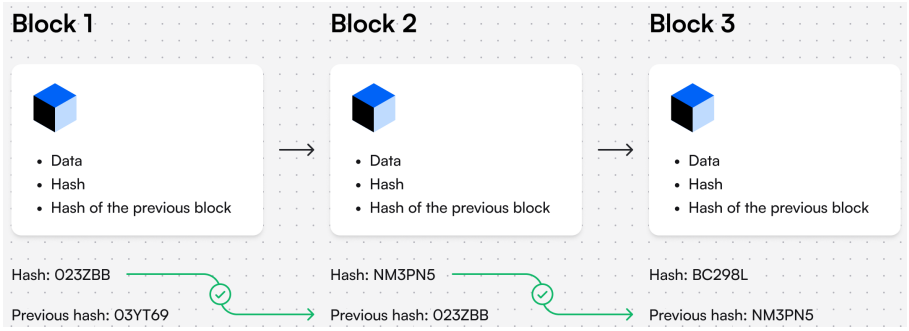


Figure 2.1: Blocks in a blockchain (Dock, 2024).

Since it is decentralised, central authorities do not have control over it, and it functions on a network of computers that interact peer-to-peer. As seen in Figure 2.1, each block has a hash, which serves as a distinct digital fingerprint identifying a particular data element and links it to the preceding block, creating a virtually tamper-proof blockchain. This block connectivity makes it difficult to alter previous transaction data without detection by the network, and hence blockchains are very secure.

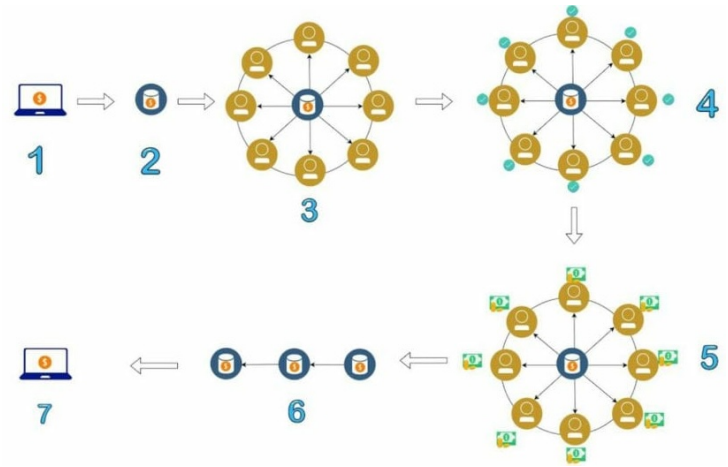


Figure 2.2: Diagram showing how blockchains work (CoinCodeCap, 2024).

Figure 2.2 schematically shows how a blockchain functions (CoinCodeCap, 2024). Firstly, the transaction is initialised and then placed in a block. The transaction block is sent to all nodes in the network before it is validated by miners using Proof of Work. The miners that crack the puzzle in 'Proof of Work' receive the reward, and finally the block is placed on the blockchain.

The key elements of a blockchain include distributed ledger technology, immutable records and smart contracts. Distributed ledger technology means that all users have access to the distributed ledger and its immutable transaction records. Transactions are recorded once, which reduces duplication. Immutable records mean that once a transaction is recorded on the shared ledger, participants cannot alter it. If there is an error in the transaction record, it can only be corrected by adding a new transaction to reverse the error, with both the original and corrective transactions being visible (IBM, 2021).

2.2 Types of Blockchains

There are 4 different types of blockchains as seen in Figure 2.3. These can be grouped into permissionless and permissioned.

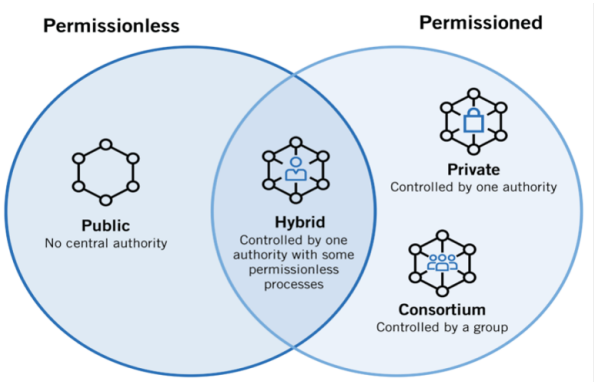


Figure 2.3: Types of blockchains (Damre et al., 2022).

2.2.1 Public Blockchain

A public blockchain is open to anyone and can be reached by anyone on the network, hence it is permissionless. No single entity has control over the entire blockchain. Its key features include transparency, security and decentralisation; hence they are a good choice for organisations wanting data security, privacy and scalability (Dock, 2024). Examples include Bitcoin, Ethereum and Litecoin.

Table 2.1: Advantages and Disadvantages of a Public blockchain.

Advantages	Disadvantages
Security: Cryptographic algorithms verify transactions and run on a decentralised network, making the public blockchain secure. Accessibility: They are accessible to anyone with an internet connection which creates trust among the user community. Innovation: It provides a platform for developers to create services and applications, motivating the contribution towards its advancement. Transparency: Transactions on the network are open for verification by anyone, all participants share the same information.	Privacy: Anyone can track the transaction history on the network which is bad for applications requiring privacy and confidentiality. Scalability: Each transaction needs to be verified by a network of nodes, creating a transactional speed problem. When more nodes join the network it becomes slower. Energy Consumption: Requires significant amount of energy, resulting in high costs and negative environmental impacts. Governance: They can be hard to govern as they are run by a network of computers with no single point of control, decision-making and coordination issues arise.

2.2.2 Private Blockchain

Private blockchains are controlled by a single organisation. To gain access, individuals must receive an invitation and verify their identity. The network operators use smart contracts or other automated methods to authenticate and verify the participant's details (Dock, 2024). Since there are less users in the network, efficiency, privacy, control, and immutability are a priority as they can process more transactions faster. Examples include Hyperledger and Corda.

Table 2.2: Advantages and Disadvantages of a Private blockchain.

Advantages	Disadvantages
Fast: Since there are fewer users than on a public blockchain, the network sets up consensus faster which result in faster transactions. Scalability: Only several nodes are allowed to validate transactions, allowing scalability. Enhanced Privacy: Participation by invitation helps to secure sensitive data from threats and unauthorised access. It also allows for better control over who manipulated data on the blockchain.	Security: With fewer nodes it is more vulnerable to security risks. If a hacker gains access, they can alter data or obstruct transactions. Lack of Transparency: There is no transparency as privacy is prioritised, making it harder to verify authenticity of information on the blockchain. Centralisation: Private blockchains tend to be centralised and controlled by a single organisation, conflicting blockchain's principle of decentralisation.

2.2.3 Hybrid Blockchain

A hybrid blockchain is the amalgamation of a private and public blockchain, where information is accessed via smart contracts. It has the capability of constructing a private, permissioned based system alongside a public, permissionless one. This creates a network that is not restricted by one blockchain's limitations and allows a single owner or central authority to control who has access to certain data and what is made public. When a user joins a hybrid blockchain, they have full access to the network. The user's identity is protected from other users unless they engage in a transaction. Then, their identity is revealed to the other party. This is often used in real estate.

Table 2.3: Advantages and Disadvantages of a Hybrid blockchain.

Advantages	Disadvantages
Closed environment: There is no need to make anything public. Flexibility: Rules can be amended according to needs. Resistant to 51% attacks: Prevents hackers to gain majority control over the network. Scalability: Better scalability than the public network, provides privacy while remaining connected to a public network.	Not very transparent Difficult to upgrade: There is no incentive for users to participate or contribute to the network.

2.2.4 Consortium Blockchain

A Consortium Blockchain, also known as Federated Blockchain, is a type of hybrid blockchain. It is a partially decentralised network and is permissioned, meaning only organisation members with access can be on the network. It is a blend of both public and private blockchains but in a different way compared to hybrid blockchains. Here the term public refers to entities, not customers. It preserves a decentralised nature despite its inaccessibility to the public as decision-making power lies in the hands of multiple entities, unlike hybrid blockchain. It is usually used in logistics, finance and banking, healthcare and insurance (Christine Campbell, 2023).

Table 2.4: Advantages and Disadvantages of a Consortium blockchain.

Advantages	Disadvantages
No monopoly: Presence of multiple owners from multiple organisations, power is not centralised. Low cost: Low fees regardless of the number of users (unlike public blockchain where more users lead to higher transaction fees). Scalability: Validation process is faster since consensus can be reached within a smaller number of nodes. Easier to scale since transaction speed is high.	Difficult To Launch: Tedious and delicate process. Lack of cooperation: More than one entity involved, higher chances of disputes to reach an agreement. Slow upgrading: Long process to upgrade the blockchain system, regulations and permissions take time.

2.3 Smart Contracts

Smart contracts are digital contracts stored on a blockchain that are automatically executed when predetermined conditions are met between two parties. Their main contribution is making the blockchain applications programmable, bringing blockchain applications beyond just

currency transfers, which relates to this project. They can also automate a workflow, triggering the next action when predetermined conditions are met. These actions might include releasing funds to the appropriate parties, registering a vehicle, sending notifications or issuing a ticket. The blockchain is then updated when the transaction is completed. That means the transactions cannot be changed, and only parties who have been granted permission can see the results.

There are 3 different types of smart contracts. Smart Legal Contracts are legally enforceable and require the parties to satisfy their contractual obligations. Decentralised Autonomous Organisations (DOA) can be defined as communities that exist on the blockchain. These communities can be defined by a set of agreed upon rules, which are coded via smart contracts. Application Logic Contracts (ALC) allow devices to function securely and autonomously. These contracts contain an application-based code, which typically remains in sync with other blockchain contracts (BasuMallick, 2023) .

Solidity is a programming language designed for developing smart contracts that run on Ethereum. It is a contract-oriented language, which means that smart contracts are responsible for storing all the programming logic that transacts with the blockchain. Ethereum provides a platform for the development of smart contracts and decentralised apps. As explained in Figure 2.4, the Solidity code is converted into EVM bytecode format for deployment on the network, making it executable. When the smart contract is deployed on the Ethereum network, it runs by all the nodes in the ecosystem. If a contract has an infinite loop, it will cause all nodes to execute this infinite loop. This could be the result of a denial-of-service attack (DDoS) and this feature would protect the Ethereum network (Ekici, 2020). There are other Ethereum based smart contract languages such as Vyper (which is based off python instead of JavaScript) but given the prevalence of Solidity and the stacks available for it, Solidity provides the best framework for Whater.

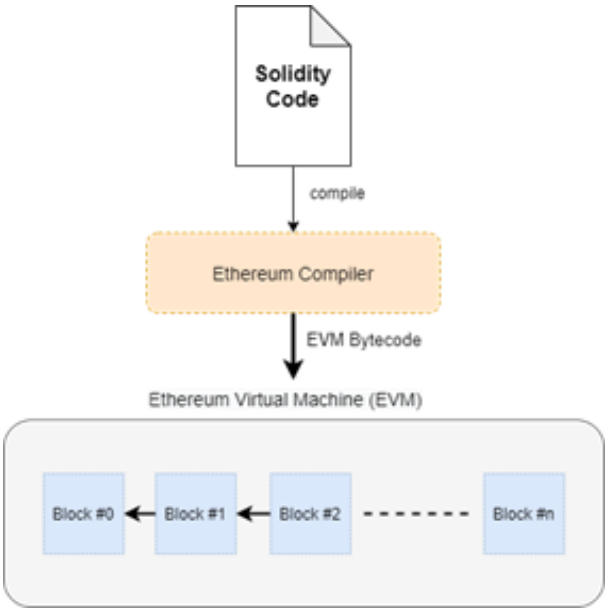


Figure 2.4: 'A Smart Contract's compile and deploy process' (Ekici, 2020).

3 Carbon Trading Market & Green Finance

The UK water industry has pledged to achieve net zero greenhouse gas (GHG) emissions by 2030 as part of its Public Interest Commitment, 20 years ahead of the Central Government's target enshrined in law. Water and wastewater companies currently account for their GHG emissions using the industry's Carbon Accounting Tool (CAW, UK Water Industry Research), which uses global methodologies to estimate direct (Scope 1) and indirect (2 and 3) emissions.

Since the Paris Agreement in 2015, certain types of companies are required to buy carbon allowances for each unit of carbon they emit. Globally, there are four substantial carbon allowance markets: the European Union, the United Kingdom and the California and Regional Greenhouse Gas Initiative (RGGI) in the United States (Flammer, 2021). Article 10 of the Agreement envisions collaboration enhanced by technological development.

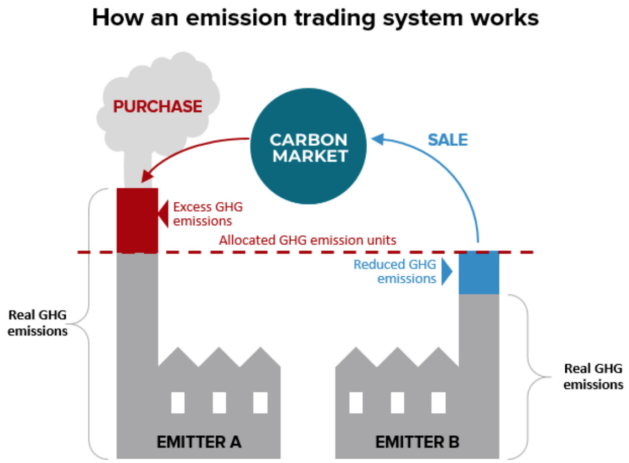


Figure 3.1: 'Cap and Trade' model used in carbon trading (Suri, 2023).

There are two elements in carbon trading markets: carbon credits and carbon offsets. A carbon market allows investors and corporations to trade both carbon credits and carbon offsets simultaneously. This mitigates the environmental crisis, while also creating new market opportunities. Credits and offsets form two slightly different markets, although the basic unit traded is the same – the equivalent of one ton of carbon emissions, also known as CO_2e. Governments set a limit on the total emissions allowed, which is then divided among parties depending on their revenue and scale. Carbon credits are these carbon allowances, and act essentially as a tax. A carbon offset is when companies compensate their carbon emissions by investing in carbon offsetting projects that reduce the equivalent emissions somewhere else. They are voluntary, beyond regulatory requirements. Figure 3.1 shows the model used.

3.1 Carbon Credits

The government sets caps on the emissions that are then split between the companies, accordingly to their scale for instance. The cap for a company represents its carbon emission allowance, representing a permission slip to generate a certain amount of CO_2. At the end of the year the company will need to have a certain amount of carbon credits tokens, equivalent to the carbon emission allowance. These carbon credits represent the quantity of CO_2 the company is short off to achieve net zero (Suri, 2023).

3.2 Carbon Offsets

Carbon offsets are a kind of carbon credits that a company can obtain by voluntarily engaging in projects aiming to reduce the amount of GHG emissions. A company might have an interest investing in regenerative finance project to obtain carbon offsets tokens, for instance if the price of buying a carbon credit to another company is higher than the price of an investment in a green finance project equivalent to one carbon offset (Suri, 2023).

3.3 Green Bonds

Green bonds are loans used to finance environmentally friendly projects, supporting sustainable development (Bhutta et al., 2022). They are essential to raise funds to sponsor projects that have minimal carbon effects (Gyamerah & Asare, 2024). To meet SDGs (Sustainable Development Goals), the use of FinTech can be implemented in industry, helping businesses accomplish "carbon neutrality"(Rahman et al., 2024).

More people are choosing eco-friendly products to adopt a more sustainable lifestyle, a trend highlighted in recent media coverage. Nielsen Media Research reveals that two-thirds of consumers worldwide are prepared to spend more on sustainable goods. This preference for sustainability is especially strong among millennials, with 73% showing a greater inclination towards eco-conscious purchases (Rahman et al., 2024). It has also been found that customers are likely to pay a premium for products from companies they perceive as sustainable. Hence, the implementation of green bonds can attract more customers, generating more revenue.

3.4 Green Finance

A green finance system refers to a set of policies, regulations and financial instruments designed to facilitate capital allocation towards environmentally sustainable economic activities, projects, and initiatives. Its goal is to support the transition to a low-carbon, resource-efficient and environmentally sustainable economy by mobilising investments into clean technology, renewable energy, and sustainable infrastructure. It promotes environmental risk management by incorporating sustainability factors into lending and investment decisions while fostering innovative green financial products such as green bonds and carbon credits. Companies are increasingly recognising the need to minimise their environmental impact, manage climate risks and align with the global sustainability goals. The green finance market has grown from $5.2bn in 2012 to $540.6bn in 2021. The issuance of UK green bonds also rose from $1.1bn to $35.4bn during the same period (Green finance: A quantitative assessment of market trends, 2022).

Green financing means increasing financial flow levels from the public, private and not-for-profit sectors to sustainable development priorities (Green Financing, 2018). The definitions and examples of the different types of funds are discussed in Table 3.1 below.

Whater uses blockchain technology to provide transparent and tamper-proof data on GHG emissions from wastewater treatment, enhancing sustainability reporting and making companies more attractive to green investors. This accurate emissions data helps identify areas for improvement, incentivising green investments in infrastructure upgrades and the adoption of sustainable technologies crucial to green finance.

Table 3.1: Types of funds in Green Finance.

	Private Funds	**Public Funds**
Definition	It refers to the capital and financial resources provided by non-governmental entities such as businesses, individuals, and private financial institutions.	It refers to financial resources provided by governments, international organisations, and public institutions. These funds are typically sourced from tax revenues, development aid, or multilateral financing mechanisms.
Examples	Green Bonds.	Green investment banks established by government.
	Private green investment funds.	Government subsidies and tax incentives.
	Private equity and venture capital.	Climate finance funds established by multilateral organisations.
	Corporate sustainability funds.	

3.5 Regenerative Finance (ReFi)

Regenerative Finance (ReFi), on the other hand, is an alternative financial system that promotes and restores environmental, social, and financial stability along with monetary gains. It uses money as a tool to solve systemic problems by changing the underlying story that sits beneath Whater's current economic model, which values the accumulation of money and wealth that often comes at the expense of people and planet (Wade, 2023). Whater's accurate tracking of GHG emissions helps wastewater treatment plants mitigate their environmental footprint, supporting ecosystem restoration and improving air quality.

The technology fosters a circular economy (a component of ReFi) by identifying inefficiencies and promoting recycling and reuse. It also benefits communities by creating cleaner environments, enhancing quality of life, and stimulating local economies through job creation and skill development. Whater's approach contributes to the long-term resilience of natural and human systems, aligning with the regenerative finance goal of creating lasting positive impacts on the environment and society.

3.6 Carbon Markets

A blockchain carbon market is a blockchain where the currency is carbon credits, represented by tokens that can be minted, traded and burned. Creating Whater's own carbon trading market can represent challenges that will need to be solved as a high technical demand in terms of programming, complex verification processes due to the high number of entities (this issue could be tackled with smart contracts), and a slow build up at the beginning of the project since the power of the market rely on the number of users. There are two types of carbon markets: compliance and voluntary.

3.6.1 Compliance Market

Compliance carbon markets are created in response to legally binding caps on emissions set by governments or international agreements, such as the 1997 Kyoto Protocol and the 2015 Paris Agreement. These agreements and governments set a cap on the total amount of GHGs that can be emitted by all participating entities. This cap on GHGs is then split into emissions allowances given to each entity, represented by carbon credits, distributed accordingly to the scale of the entities. The EU Emissions Trading System (EU ETS) is based on the carbon currency EUAs, and is by far the largest carbon market worldwide, accounting for 87% of the total market.

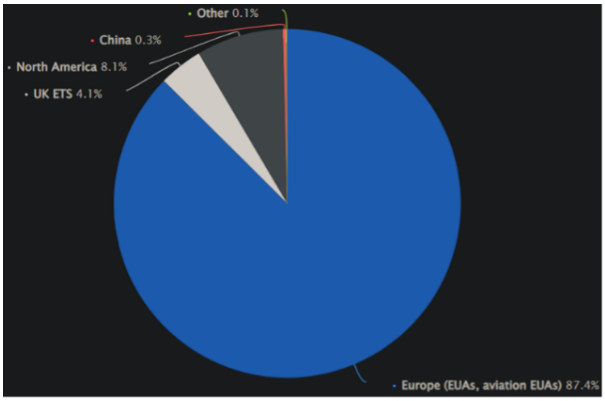


Figure 3.2: Carbon market size worldwide (Tiseo, 2024).

The EU ETS is based on the emissions of power stations, manufacturing plants and aircraft operators in 28 countries. In total, around 45% of total EU greenhouse gas emissions are regulated by the EU ETS (European Commission, n.d.).

Since 2005, the EU ETS has helped bring down emissions of these sector in Europe by 37%. (European Commission, n.d.). The cap is expressed in emission allowances, where one allowance gives the right to emit one tonne of CO2eq. For each year, companies must surrender enough allowances to fully account for their emissions, otherwise heavy fines are imposed. Each year the cap will be decreased to reach Net Zero goal.

3.6.2 Voluntary Market

Voluntary carbon markets exist outside of government on international agreements regulations, alongside compliance markets. This type of market allows companies to offset their emissions by purchasing carbon on a voluntary basis with no intended use for compliance purposes. The choice of a company to engage in the voluntary carbon market is often driven by corporate social responsibility, branding, or stakeholder pressure. Carbon credits in voluntary markets are typically generated from projects that reduce, avoid, or remove GHGs from the atmosphere, for instance projects of reforestation, methane capture or development of renewable energies. Various independent organisations certify and verify the emission reductions of offset projects. Standards include the Verified Carbon Standard (VCS), Gold Standard, Climate Action Reserve (CAR), and American Carbon Registry (ACR). Certification standards ensure the credibility, additionality, and permanence of the emission reductions. The additionality the idea of the reductions would not have happened without the project, to avoid entities minting tokens while developing a project that they would still have developed in any case. Some corporate companies may participate in voluntary carbon markets to offset their emissions, mostly for reputation motives. Platforms such as Gold Standard, Verra, and marketplaces like ClimateTrade facilitate the buying and selling of voluntary carbon credits.

3.6.3 Differences of Compliance & Voluntary Markets

Regulation: Compliance markets are regulated by law, while voluntary markets are not.

Participants: Compliance markets involve entities required by law to participate (generally the most polluting company) whereas voluntary markets include a diverse range of participants acting by choice.

Types of Projects: Voluntary markets often support a broader range of project types, for instance smaller projects, compared to compliance markets.

Market Size and Value: Compliance markets are typically larger in terms of traded volume and monetary value due to regulatory enforcement.

Table 3.2: Pros and cons of tackling compliance and voluntary markets.

	Pros	**Cons**
Compliance	Regulatory Mandates: Companies in compliance markets are legally required to reduce emissions, ensuring a consistent demand for carbon credits.	High Barriers to Entry: Navigating regulatory requirements and gaining necessary certifications can be complex and resource-intensive.
	Established Frameworks: These markets have clear rules and standards, which can provide a stable environment for business operations.	Intense Competition: Established players dominate the market, making it challenging for new entrants.
	Larger Volume: Compliance markets generally have larger trading volumes due to the mandatory nature of participation.	Regulatory Dependence: Changes in government policies or regulations can significantly impact the market dynamics.
Voluntary	Flexibility: Fewer regulatory constraints allow for more innovative and diverse project types.	Market Fragmentation: The voluntary market is more fragmented, with varying standards and less oversight.
	Broad Range of Participants: Companies, organizations, and individuals can participate, expanding your potential customer base.	Potentially Lower Volume: Demand can be more variable compared to the compliance market.
	Growing Demand: Increasing corporate social responsibility (CSR) initiatives and consumer demand for sustainable practices drive growth in this market.	Credibility Issues: Ensuring the credibility and additionality of projects can be challenging and requires robust verification.

With all these information in mind, the compliance market should be the most relevant for the Whater startup considering the larger trading volumes and that governments would make it mandatory to take part in the carbon market. Whater would be a tool that companies would use to obey the legislation.

4 Bottlenecks

Carbon trading markets, material circularity and green finance all come with bottlenecks, identified below. These may delay the achievement of net-zero targets.

4.1 Carbon Trading Markets

- Lack of standardisation, integrity, and transparency: Often a lack of information on how carbon credits are generated and traded. They should be carefully audited to make sure there is clear accountability.
- Regulatory Inconsistencies: Differences in regulations and standards in different countries complicates international cooperation and scaling of carbon credit markets.
- Price Volatility: Prices of carbon credit can be volatile, influenced by policy change and market demand.
- Revenue Gap: There is a revenue gap in carbon trading for water companies.

4.2 Material Circularity

- Design for Circularity: Some products and infrastructure components are not designed for reuse or recycling, complicating material recovery and circularity.
- Supply Chain Transparency: Insufficient traceability throughout the supply chains, making it difficult to ascertain the origin of materials and ensure they are sourced sustainably and ethically.
- Economic Viability: Recycling and reusing could be more expensive than using virgin materials, especially without subsidies or financial incentives.

4.3 Green Finance

- Access to Capital: Green projects sometimes struggle to secure funding due to perceived higher risks and uncertain returns compared to traditional investments.
- Lack of standardised impact metrics: There is no universal standard to measure the environmental impact of green projects, which can deter investors who are unable to clearly assess the benefits or outcomes of their investments.
- Regulatory barriers: Financial regulations can unintentionally limit the types of investments that can be labelled as 'green', restricting the flow of funds into sustainable projects.

5 Water Industry Research

5.1 Overview of the UK's Largest Water Utility

Thames Water's mission statement states "Our purpose is to deliver life's essential service, so our customers, communities and the environment can thrive." Thames Water was formed in 1973 as part of the reorganisation of the UK water industry, which brought together several smaller water companies. The company was then privatized in 1989 during the Thatcher government's privatization of the water industry in England and Wales.

Thames Water serves approximately 15 million people for water supply and 14 million for wastewater services. It covers the Greater London area and surrounding counties (including parts of Oxfordshire, Buckinghamshire, Surrey, Wiltshire and Gloucestershire) (Thames water, 2023).

They are committed to achieve net zero carbon emissions by 2030 and currently need to cut about 280 $kTCO_2$. To do so, they are focusing on using renewable energy like wind, solar, and biogas from sewage sludge to generate about 500 GWh every year. They are also considering carbon offsetting as part of their Net Zero strategy, with a focus on carbon capture. Additionally, there are a lot of efforts to measure and reduce carbon footprint. Figure 5.1 shows the GHG emissions reductions.

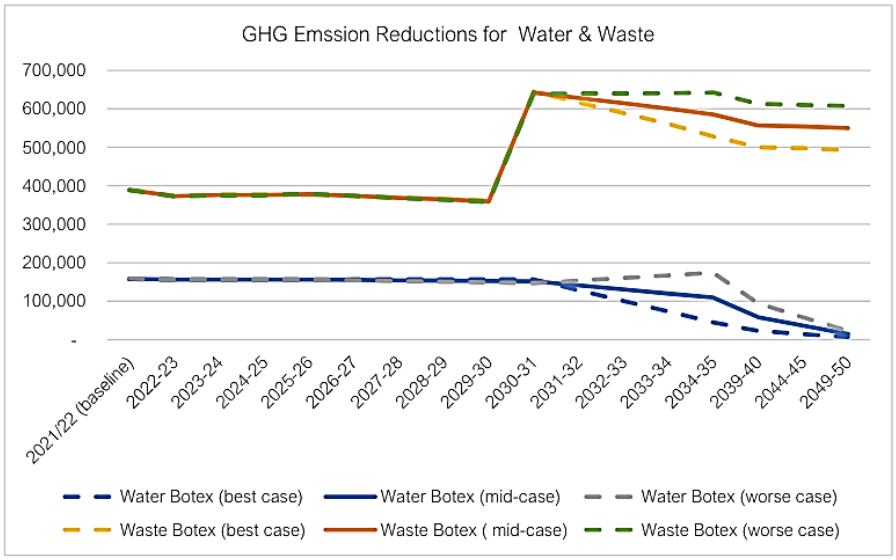


Figure 5.1: GHG Emission Reductions for Water & Waste (Thames Water, 2023).

5.1.1 Problems with the Company

The main problems that the company is currently encountering are listed below:

1. Ageing infrastructure

   Ageing assets need more maintenance to provide core services.

2. Water leakage

   TWUL had to spend £19.8 billion through 2030 to fix leaks, increase sewage treatment and improve resilience to climate change, while they missed their 2022/23 target for leakage. Currently, almost 24% of water is lost through leakage (Thames Water, 2023) .

3. Water quality

   Current infrastructure sometimes struggles to cope with the volume of sewer during heavy rainfall, causing pollution incidents (Thames Water, 2023).

4. Environmental Regulations

   Information disclosure identified a number of locations that have potentially breached their permits, and TWUL also remains under investigation by the EA for its compliance with these environmental permits.

5. Population growth and urbanisation

   Robust and accurate population tracking is necessary to ensure demand can be met and the water supply is reliable in the future, whilst accommodating wastewater network and wastewater treatment works.

6. Climate change

   It was found that extreme flooding in London and the intensity of the storm were above the design capacity of the systems, which failed to meet the customers' expectations (Thames Water, 2023).

7. Customer expectations and engagement

   Thames Water is proposing to raise the bills by 56% by 2030. However, this is challenging considering the living crisis that UK customers are facing and their low trust in Thames' utilities (Shankleman & Perez, 2024).

8. Investment and financing

   From the year end data in 2022, Thames Water has the highest debt to equity ratio among any UK water companies, accounting to 80.6%. Investors refused to inject money into Thames' Water which makes it into a higher debt of £1.4 billion after it falls to meet an interest payment.

9. Technological innovations

   To address the extreme weather conditions, smart metering is implemented by Thames water. However, it suffers from a shortage of microprocessors in the global supply chain, affecting the meters availability.

There are also a set of problems that are faced by Thames' Water regarding its approach to reduce greenhouse gas emissions (Thames Water, 2023).

- Carbon Accounting Tools: The existing tools are not suitable for meeting the requirements for the Thames' expectations in 2022/23 and further updates are required to meet future requirements.
- Scope 3 Carbon Reporting: There is a lack of consistent industry approach to wider Scope 3 carbon reporting and measurement beyond items included within the Carbon Accounting Workbook.
- Wastewater Treatment Process: It is necessary to develop an industry understanding of wastewater treatment process emissions and the technologies available to control them. This suggests a technology gap in monitoring and controlling emissions from the wastewater process.

- Reporting methodology and indicators: The current methodology and indicators used for reporting capital and operational carbon are not enough to support Thames' Water actual performance and efficiency in reducing carbon throughout the development and delivery of a project.

5.1.2 Advantages of Blockchain Technology for Thames Water

Carbon Footprint Tracking

Accurate tracking: Carbon footprint blockchain platform can securely record and track data on carbon emissions from many sources. This ensures that data is accurate and cannot be tampered with. This allows Thames water to have a clear idea of where emissions within their systems are coming from. Reduction strategies: Blockchain can store and verify the effectiveness of strategies used to reduce their emissions. It also helps in comparing data over time to see which strategies work best.

Sustainability

Compliance and Reporting: Blockchain can provide a transparent and irreversible records of emissions data, making it easier to meet legal standards. This also facilitates in proving and showcase they are meeting regulatory requirements and sustainability targets. This also increases customer engagement as they can see that Thames Water is genuinely trying to reduce its carbon footprint.

Efficiency and Accountability

Smart contracts: autonomous contracts that are written in code and terms are encoded. For example, a smart contract may automatically pay a provider upon the delivery of water of above-standard quality, no longer needing humans to make manual checks and fill out paperwork. This saves time and effort.

Supply Chain: Blockchain can maintain track of the different steps in the supply chain, from the purchase of materials and procurement to service delivery. All parts of the supply chain are thus ensured efficiency through this transparency.

Green Infrastructure

Natural Water Management: blockchain technology can monitor the success of green infrastructure projects, such as how much stormwater is collected. This data assists in optimising these projects for better environmental effects.

Biodiversity: can capture data on biodiversity enhancements, such as increases in plant and animal species in places with new green infrastructure. This aids in measuring and reporting environmental benefits.

Regulatory Compliance and Reporting

Improved Reporting: enables clear, verifiable reporting that regulators and stakeholders can rely on, proving Thames Water's adherence to environmental standards.

5.2 Issues throughout the Wider Water Industry

5.2.1 Analysis of the Carbon Emissions of Water Companies

Thames Water

The following pie chart (Figure 5.2) illustrates the emissions breakdown for the year 2021/22, showing a total of 546 kilotons of CO_2 equivalent ($ktCO_2e$). The emissions are categorized according to the Greenhouse Gas (GHG) Protocol, which includes Scope 1, Scope 2, and Scope 3 emissions.

Scope 1 emissions, which are direct emissions from owned or controlled sources, include significant contributions from process and fugitive emissions amounting to 188,824.438 $ktCO_2e$, representing 34% of the total emissions.

Scope 2 emissions, which account for indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the reporting company, are primarily represented by purchased electricity (location-based), contributing 169,139.219 $ktCO_2e$ or 30% of the total emissions.

Scope 3 emissions, which cover all other indirect emissions that occur in a company's value chain, include several categories. Outsourced activities contribute 28,521.798 $ktCO_2e$, accounting for 5% of the total emissions. Disposal of waste adds 40,953.312 $ktCO_2e$ (7%). Purchased fuels for E&P and T&D contribute 13,679.704 $ktCO_2e$ (3%), and the use of chemicals adds 9,691.509 $ktCO_2e$ (2%). Business travel is minimal, contributing only 975.836 $ktCO_2e$ (Thames Water, 2021)

The presence of negative emissions from exported biomethane and renewables offers a slight reduction to the overall emissions, highlighting areas for potential enhancement in emission reduction strategies across all scopes.

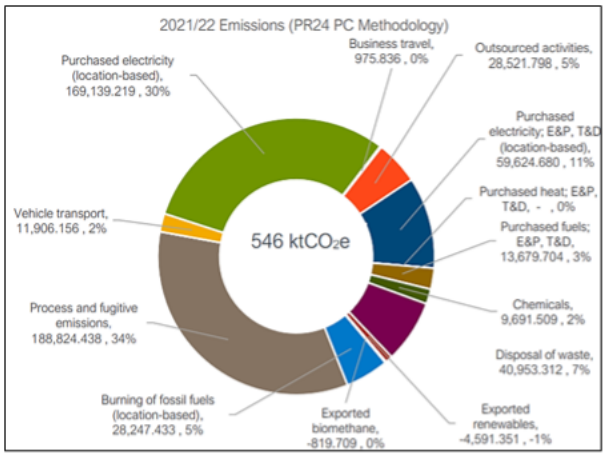


Figure 5.2: Breakdown of emissions in $ktCO_2e$ (Thames Water, 2021).

Wessex Water

Wessex Water's gross and net emissions can be seen in Figure 5.3 below. The main reason for the decline in annual emissions is because renewables have made up an increasing proportion of the energy supply. This can be seen by the contraction in Scope 2 emissions.

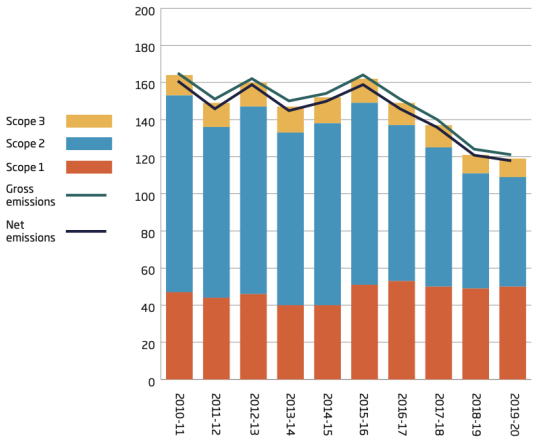


Figure 5.3: Recent greenhouse gas emissions, kilotonnes CO2 equivalent ($ktCO_2e$) (Wessex Water, 2021).

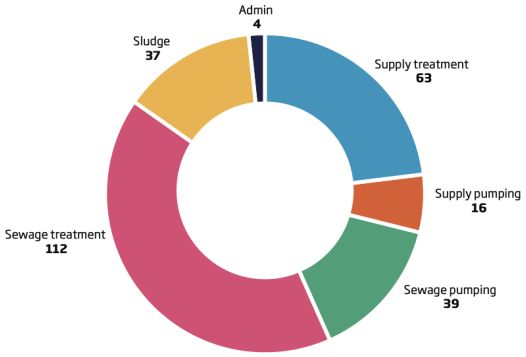


Figure 5.4: Electricity use for different activities in 2019-20 (Wessex Water, 2021).

Since the Scope 2 emissions make up such a large proportion, it is worthwhile to try and understand the operational activities that are the most energy intensive. The electricity usage for different activities in 2019-20 is shown in Figure 5.4 (in gigawatt hours GWh).

From this, clearly, the processing of wastewater (sewage treatment & sewage pumping) is very energy intensive and therefore is responsible for a large proportion of the scope 2 (electricity generation) emissions. Thus, when thinking about emissions associated with wastewater, it is important to recognise these indirect emissions in addition to the direct ones in the form of nitrous oxides and methane. Wessex Water notes that there is a relatively high degree of certainty for the emissions related to energy and transport. Whereas, emissions of methane and nitrous oxide are much less certain, as there are no direct measurement methods. In fact, there is speculation that historically these emissions have been underestimated.

5.2.2 Going Beyond Operational Carbon Emissions

There are two categories of embodied carbon. The first category stems from building materials and other aspects of the construction procedure, often referred to as capital carbon. The other emissions are associated with consumables, i.e. chemicals, IT equipment and clothing. Wessex Water are currently unaware of the extent of their embodied carbon footprint but some of their counterparts have found that capital carbon tends to be equivalent to about 33%-50% of annual scope 1 emissions (Wessex Water, 2021).

5.3 Quantitative Comparison of Emissions

To try and appreciate which aspect of a water company typically contributes the most towards overall greenhouse gas emissions, it is useful to compare the three scopes (as outlined in the GHG Protocol) for some of the largest UK utilities. Whilst Table 5.1 above can give us a good indication, it is important to recognise that there is variation in how these emissions are reported and therefore it is difficult to directly compare them with a reasonable degree of certainty. The more general findings from this research are that all three scopes have the potential to contribute significantly to the overall emissions of a water company. Although the Scope 3 emissions listed below may appear small, this is because these are not the true total emissions originating from the value chain. For example, in 2023, United Utilities reported 338 ktCO2e, with 81 kt coming from procedures directly linked to wastewater and sludge and most

of the rest coming from purchased goods and services (United Utilities, 2023). This is not only interesting, but also emphasises how a blockchain platform dedicated to material circularity could help such companies apply pressure to members of the supply chain that are perhaps not serious about their emissions.

Table 5.1: Scope 1, 2 & 3 total gross (location based) emissions of some of the largest water utilities in the UK. Total GHG missions in 2023 ($ktCO_2e$).

Company	Scope 1	Scope 2	Scope 3	Total
Thames Water	220.3	173.6	150.1	544.0
Wessex Water	49.8	59.4	9.9	119.1
Anglian Water	97.6	315.6	42.2	455.4
Southern Water	60.7	58.7	14.1	133.5
Severn Trent Water	182.4	156.6	n.d.	339.0
Welsh Water	56.8	103.6	16.4	176.8
United Utilities	94.5	126.8	81.9	303.2
Yorkshire Water	90.5	105.3**	8.8	204.6
Northumbrian Water	77.9	71.1	6.6	155.6

It may not be apparent, but in some cases above, Scope 2 emissions in reality are net zero because the company purchased certified zero carbon renewable electricity.

Additionally, the emissions created by Anglian Water are abnormally large compared to the size of the company which could be due to large amounts of wastewater that their customers generate. "Anglian Water pleaded guilty to allowing millions of litres of untreated sewage to overflow from a water recycling centre in Essex. It was fined £2.65m, the largest penalty imposed for environmental offences in the east of England region" (Laville, 2023).

5.4 Forecasted Decline of Net Emissions to 2030

Table 5.2 below contains both the reported and forecasted net operational emissions associated with wastewater treatment (i.e. these values consider the reduced emissions from electricity generated from renewable energy). The forecasted values have been calculated by finding the average change in emissions for the reported years and then using this to extrapolate up to 2030. As mentioned in the part dedicated to Wessex Water, we are seeing a very rough 5% to 10% decrease in net emissions due to the Scope 2 emissions becoming less carbon intensive. By 2030 the water companies are forecasted to still be far from their target to achieve net zero emissions. Therefore, offsets to the equivalent of the values shown in Table 5.2 will need to be purchased, thus providing scope for carbon trading using tokenisation via Whater's blockchain network.

Table 5.2: Forecasted total net (market based) wastewater emissions from 2018 to 2030 in $ktCO_2e$.

Year	Thames Water	Wessex Water	Anglian Water	Southern Water	Severn Trent Water	Welsh Water	United Utilities	Yorkshire Water	Northumbrian Water
2018/19	230	120	322	56.5	378.4	70.9	209	170.8	195
2019/20	251.5	118	293	54	362	67.7	196.1	166.6	160
2020/2021	224.6	112.1	216	51.5	345.6	64.5	211.6	160.4	135
2021/2022	229.3	106.2	208.6	49	329.2	61.3	200.4	160.1	128.3
2022/2023	284.2	100.3	200	46.5	312.8	58.1	206.3	159.4	121.5
2023/2024	270.6	94.4	186.4	44	296.4	54.9	196	158.8	114.8
2024/2025	257	88.5	184.3	41.5	280	51.7	185.7	157.4	108
2025/2026	243.4	82.6	171.5	39	263.6	48.5	175.4	156	101.3
2026/2027	229.8	76.7	164	36.5	247.2	45.3	165.1	155.2	94.5
2027/2028	216.2	70.8	159.8	34	230.8	42.1	154.8	154.5	87.8
2028/2029	202.6	64.9	154.3	31.5	214.4	38.9	144.5	153.7	81
2029/2030	189	59	149.3	29	198	35.7	134.2	152.9	74.3

5.5 Identified Bottlenecks

Currently there are two main areas where technological and innovative advancements are required. As mentioned briefly above, there is considerable uncertainty about the true level of methane and nitrous oxide emitted from wastewater treatment processes. Unfortunately, these cannot be measured directly because they typically diffuse into the air from tanks, filters and anaerobic digesters that are not fully sealed. UK water companies estimate these emissions via a standard method, using emission factors dating back to fifteen years ago. There have been suggestions that more accurate estimates of nitrous oxide emissions could be up to four to eight times higher than how they are currently reported (Wessex Water, 2021).

The other notable uncertainty involves the emissions associated with construction materials, products and services that they consume via their supply chain. Currently, the calculations involved carry many assumptions and estimates, many of which can be attributed to uncertainty surrounding each materials history and origins. This area is particularly well suited to and could benefit significantly from a blockchain-based traceability network.

Additionally, there is a revenue gap in carbon trading for water companies. Two thirds of the largest companies worldwide rely heavily on carbon offsets to reach net zero emissions (Gabbatiss, 2023). Carbon offsets are expensive, comprising big investments from the companies. Hence, water industry firms are challenged when it comes to revenue in the carbon trading schemes, a problem Whater aims to solve.

5.6 Wastewater Treatment: N_2O & CH_4

5.6.1 Nitrous Oxide

During nitrogen removal in conventional activated sludge processes, nitrous oxide can be emitted. With a global warming potential of 298 CO_2-equivalents, it is an important greenhouse gas that affects the sustainability of wastewater treatment. The photochemical reactions that take place also produce oxygen molecules that combine in the atmosphere to produce ozone, another greenhouse gas that contributes to global warming. In wastewater treatment plants,

N2O production can occur through various pathways including hydroxylamine oxidation, nitrifier denitrification, and heterotrophic denitrification. The extent to which each pathway contributes to N_2O emissions is influenced by the different microbial species present, such as ammonia-oxidising bacteria (AOB), ammonia-oxidising archaea (AOA), nitrite-oxidising bacteria (NOB), and anammox bacteria, as well as the specific process conditions (Kemmou & Amanatidou, 2023). Many factors affect the amount of N_2O emitted from a plant, which blockchain technology can help track and optimise, therefore reducing these emissions. The main ones are presented below:

DO (dissolved oxygen) concentrations: Low DO concentrations during nitrification result in high N_2O emissions.

Rapidly changing process conditions: Numerous studies have shown that sudden changes in process conditions, such as high ammonia concentrations and oxygen limitations, often lead to increased nitrous oxide emissions.

Ammonia shock loads cause incomplete nitrification, which reduces nitrogen removal efficiency, leads to nitrite accumulation, and subsequently increases N2O production. This implies that bacterial metabolism requires some time to adjust itself to the rapid shifts in the process conditions.

Temperature and PH: Denitrification rate increases with increasing temperature. Increasing temperature decreases the solubility of N2O. With a temperature increase from 25 °C to 35 °C, a reduction in the solubility of nitrous oxide in water of 23% was observed (Kemmou & Amanatidou, 2023).

The above factors are only a few among the ones that govern the process that releases N_2O from wastewater treatment plants. There is a need for an automated control scheme to monitor the quantity of each those factors and reduce N_2O emissions.

5.6.2 Biomethane production from anaerobic digestion

Biogas arises as a result of anaerobic digestion from WWTP of sewage sludge and comprises approx. 65% methane and 35% carbon dioxide. This can be converted to generate high purity biomethane that can be directly injected into natural gas distribution systems, also known as gas grid (Hassaan, 2022), therefore providing additional power/energy source, and decarbonising the domestic and industrial heat sector by offsetting the reliance on NG imports (Michailos et al., 2020). For the conversion to be achieved, an additional step of "upgrading" of the biogas (increase its calorific value) must be introduced before it can enter the gas grid and power nearby homes. Biomethane will have a great impact in reaching the carbon neutrality goal by 2030 and it also promotes the concept of circular economy. In summary:

- Upgrading biogas to biomethane captures a significant amount of CO2 which can be permanently removed from the atmosphere.
- European governments have been creating policies and monetary support schemes to incentivise biomethane market growth such as feed-in tariffs or investment supports (Silva et al., 2024).
- Biomethane can also be used to offset the energy intensive process required by wastewater treatment plants. In the USA, it is estimated that WWT demand is 20-30 kWh per person annually. Biomethane produced from these same plants can help cut it down to 15-18 kWh per person (Nguyen, 2021).

A challenge is that WWTP may not have a power generator license, therefore they are not allowed to inject biomethane into the grid for electricity production. An alternative could be to use this source of energy for domestic consumption, transport fuel or energy storage instead. Apart from tracking the amount of biomethane produced and convert it into carbon credits/tokens, blockchain can help monitor the concentrations of fundamental factors in the upgrading of biogas for biomethane production such as hydrogen sulfide content, water vapour content and presence of siloxanes (Nguyen, 2021).

5.6.3 Innovative ways to improve accuracy of emissions measurements

Methane: Two solutions to improve measurements of emissions

Methane (CH_4) has a global warming potential 84–86 times greater than CO_2 over 20 years, contributing to 16% of current atmospheric warming. Accurate measurement, especially in the wastewater sector (5–8% of global anthropogenic methane emissions), is therefore crucial. Traditional methods often underestimate emissions due to outdated IPCC factors so improved data collection and control strategies are essential.

Table 5.3: Solutions to methane measurement (John, 2000; Torsten et al., 2017).

Solution	**Description**	**Application**
Direct Measurement	Using Gas Chromatography with Flame Ionisation Detection (GC-FID) to directly measure methane.	Precise, localized measurements at specific points, e.g. anaerobic digesters.
Continuous Emissions Monitoring Systems (CEMS)	CEMS installed on treatment equipment/process flow to continuously monitor emissions.	Facilities needing continuous monitoring for compliance, high output, or emission reduction goals.

For comprehensive and accurate measurement, wastewater facilities should integrate multiple methods. Continuous CEMS monitoring can be enhanced with periodic GC-FID analyses for detailed accuracy. Blockchain technology could further ensure data reliability and transparency.

Nitrous oxide: A solution to improve measurement of emissions

Nitrous oxide (N_2O) emissions result from nitrification and denitrification in wastewater treatment. Incomplete denitrification forms N_2O, which escapes into the atmosphere variably across treatment points, making direct measurement difficult. Estimating techniques using emission factors (EFs) may not always be accurate (Haas & Andrews, 2022).

Solution Component 1: Advanced continuous monitoring sensor technologies can significantly improve real-time N_2O measurement accuracy. These durable sensors detect emission patterns and anomalies instantly. Integrated with control systems, they enable automatic emission reduction adjustments. Blockchain technology enhances data integrity and transparency, with smart contracts ensuring accurate verification and providing incentives for emission reductions.

Solution Component 2: Machine learning (ML) models combined with big data, offer sophisticated analysis of sensor data. They predict N_2O emission trends, detect anomalies, and suggest optimal operational parameters to minimise emissions, improving accuracy over time. Data integration from multiple sources provides a comprehensive understanding of emission factors. Blockchain technology secures this data, maintaining its integrity and facilitating a tokenised incentive system for emission reductions.

6 Case Studies & Outreach

Whater is a company based on blockchain technology that aims to make an effort on environmental sustainability. This section explores the transformative potential of blockchain technology in managing carbon footprints across various sectors through detailed case studies such as Regen Network, the Water Credit Initiative, CircularChain, and EmpowerChain. By integrating insights from industry experts and rigorous outreach, the Whater team demonstrated how blockchain not only enhances transparency and efficiency but also plays a crucial role in promoting sustainable environmental practices and a circular economy. This introduction sets the stage for a deeper examination of blockchain's applications and its impactful benefits in ecological and carbon management efforts.

6.1 Regen Network

Regen network is a blockchain technology company aiming to track, verify, and reward positive changes to the ecological systems (Regen Network, 2019).

There is essentially two parts to the business model. The first being to gather and verify ecological data from satellites, sensors, or ground observations. This provides proof of land health which is subsequently uploaded into a data marketplace. Then, the verified data is used to issue digital ecological credits, which are cryptographic tokens that represent a quantifiable ecological benefit, such as carbon sequestration or habitat restoration. These credits are then sold on a credit exchange, where governments, institutions, and businesses purchase them to meet sustainability goals or regulatory requirements.

They've targeted the scheme towards small scale farms which nowadays can particularly benefit from funding or additional revenue streams. To ensure they can participate, they focus on satellite powered remote sensing verification to keep costs low.

A rough outline of the process is as follows. Firstly, farmers log onto the website and declare their ecosystem services. Depending on the selections, Regen Network issues cryptographic digital credits. These are stored on the credit registry and sold through the credit exchange to people that are trying to achieve their climate goals (Regen Network, 2020). All data is logged and verified onto a native blockchain which leverages the Cosmos SDK. Finally, corporations log in and set their preferences to then be matched to the portfolio of credits from farmers around the world.

Regen Network enables small-scale farmers to monetise their conservation efforts by directly linking ecological impact with financial rewards through tokenized carbon credits, thus demonstrating how blockchain can facilitate environmental stewardship and carbon credit markets, encouraging sustainable practices through financial incentives.

6.2 Water Credit Initiative

One of the major barriers to safe water and sanitation is affordable financing. WaterCredit helps bring small loans to those who need access to affordable financing and expert resources. Millions of families spend more than 20% of their total income just trying to find water when these people can get a water or sanitation solution in their home for a fraction of their annual water costs. As research indicates, people living in poverty would much rather finance long-term solutions versus struggle day-to-day to find that next litre of water (water.org, 2024).

A region where people need access to water and sanitation and that is ready for a microfinance solution is firstly identified. Partners from selected institutions provide affordable financing for water and sanitation by establishing water and sanitation loans in their portfolio of offerings. People in need use these small, affordable loans to put a tap or toilet in their homes and access local resources to do the work. Every repaid loan can be lent to another family in need of safe water or sanitation which brings about material circularity (water.org, 2024).

The benefits of the Water Credit Initiative are concluded in two aspects (water.org, 2024): enhancing access to clean water and sanitation and Sustainability of funding. This case illustrates blockchain's potential in enhancing the effectiveness of green microfinance initiatives and supporting sustainable development goals.

6.3 CircularChain

CircularChain, developed by SUEZ Group, is a blockchain technology supporting the circular economy, specifically in wastewater treatment. This decentralised and immutable technology ensures secure information storage and transfer, certifying all transactions. CircularChain enhances transparency and trust in the health and environmental quality of secondary raw materials, promoting material reuse and recycling. It records every step in wastewater treatment, ensuring full transparency from production to final use, such as spreading on soil or converting waste to energy (SUEZ, 2021).

A notable application in France shows that using treatment sludge on agricultural soil reduces the production of synthetic nitrogen and mining of phosphorus, lowering the carbon footprint and combating organic matter depletion. CircularChain Passport facilitates the transition from a "Take Make Dispose" model to sustainable operations, allowing companies to efficiently utilise secondary raw materials with confidence in tamper-proof traceability. The technology strengthens trust among stakeholders in material reuse through enhanced transparency (SUEZ, 2021).

CircularChain promotes material reuse and recycling with enhanced trust and accountability, reducing the carbon footprint associated with new material production. Thus, blockchain helps to promote a circular economy, enhancing supply chain transparency, and supporting carbon reduction in industrial processes.

6.4 EmpowerChain

The EmpowerChain network is an innovative, tailored blockchain network designed to support the circular economy and promote equal opportunities for stakeholders in the global decentralised waste management ecosystem (EmpowerChain, n.d.). It consists of a series of interconnected applications and tools that incentivise and facilitate collaboration between stakeholders (waste collectors, manufacturers, and impact investors). The first is tracking systems, which serve as proof of existence and ensures the traceability of waste using blockchain's inherent immutability and cryptographic techniques such as "hashing" (essentially an identifier of fixed length). Plastic credits (PCRDs) are the chosen token so to speak and act as incentives for collection organisations, sorting facilities, and recyclers to efficiently collect and process waste materials responsibly. PCRDs can be traded, used as proof of offset, or applied in gamification strategies to promote better waste management practices and drive circular economy efforts. These can be sold to individuals or businesses interested in offsetting their plastic footprint. Conveniently, they have also developed an all-in-one deposit application for managing collection rewards, other assets and NFTs related to EmpowerChain, where collection incentives can be received in exchange for collected plastic.

EmpowerChain enhances the traceability and efficiency of waste management processes, leading to better recycling rates and reduced environmental impact. Thus, blockchain could be used to transform waste management through improved data integrity and incentivization, contributing to lower carbon emissions.

6.5 Outreach

An outreach to several experts in the water industry was conducted with the aim of collecting insights that are otherwise more complicated to extract merely from the use of public online resources. The team actively attempted to connect with industry experts such as Thames Water, Southern Water, and Wessex Water, with a very positive outcome. Following an introduction to Whater project's aim and the rationale behind blockchain technology (since it is a new concept and something that many are unfamiliar with), most of the people the Whater team connected with recommended critical areas within the water industry that are contributing the most to emissions of greenhouse gases and that should be further explored. Their response corresponded with the Whater team initial findings that identified the wastewater sector to be one with the highest emissions overall. Southern Water's in-house innovation 'Bluewave' team has expressed great interest in Whater's project saying that it incorporates "innovative thinking while providing a solution for one of the largest emission contributors to the environment"

Reaching out to staff within Imperial also proved to be an effective additional source of information that gave confidence in the direction Whater was taking and validated its theories. Whater plans to follow up on this and have already scheduled several meetings with industry experts and PhDs. While proprietary Carbon Accounting Tools and blockchain-based project materials are inaccessible at the moment, meetings with a Thames Water Research Engineer and a Principal Civil Engineer at Southern Water have been conducted, with important questions for discussion.

Equipped with a greater understanding of the origin of water companies' greenhouse gas emissions, Whater believes there are two main areas that could benefit from blockchain technology. The first being to incentivize the reduction of emissions attributed to wastewater treatment by cataloguing these emissions on a public blockchain. This should hopefully encourage additional research to be undertaken into better monitoring of nitrous oxides and ensure the efficiency of the treatment processes is maximised. The second is to endorse and provide a blockchain platform and supply chain system to better quantify capital carbon and enhance material circularity. This will not only allow these companies to get a better indication of their true total GHG emissions but generally promote recycling and responsible sourcing of materials throughout the entire supply chain.

7 Sustainability

7.1 Carbon Accounting

Carbon accounting is a process of quantifying an organisation's greenhouse gas (GHG) emissions, also known as its corporate carbon footprint. This includes emissions resulting from the organisation's direct operations and activities, like heating, as well as indirect emissions, like emissions generated by a company's suppliers (CarbonChain, n.d). The standard unit used is CO2e (carbon dioxide equivalent). By considering the global warming potential of other greenhouse gases (i.e., methane and nitrous oxide) relative to that of CO2, their impact can be quantified too using the same standardised unit. All carbon accounting exercises will typically involve:

The standard unit used is CO_2e (carbon dioxide equivalent). By considering the global warming potential of other greenhouse gases (i.e., methane and nitrous oxide) relative to that of CO2, their impact can be quantified too using the same standardised unit.

All carbon accounting exercises will typically involve:

- Defining the organisational boundary. This involves determining a reporting period and establishing exactly what should be included (for example, whether subsidiaries or joint ventures should contribute).
- Establishing reporting boundary. Normally this would involve categorising all emissions under one of the three scopes.
- Collecting and quality-checking data.
- Calculating the carbon. Assuming the data gathered in the previous step is deemed to be of high enough quality, the overall emissions of an organisation can be calculated.

In addition to the obvious benefits in relation to tracking performance and setting targets, carbon accounting can help inform companies on how many offsets may need to be purchased to compensate for residual emissions. It also forms the basis for trading carbon credits in the carbon market as commonly one carbon credit can be equated to one tonne of CO2e emissions. However, there are several challenges in carbon accounting. Inaccurate calculations can happen easily given many of the inherent assumptions of carbon accounting. Therefore, the results of carbon accounts should be used carefully to prevent greenwashing and misinforming carbon reduction plans. Carbon accounting is also only as good as its follow-up; so, to benefit from undertaking one, organisations should act upon the results and work to reduce emissions across their operations and supply chains.

7.2 GHG Scopes and Protocol

The Greenhouse Gas (GHG) Protocol is a comprehensive global standardised framework that measures and manages greenhouse gas (GHG) emissions from private and public sector operations, value chains, as well as mitigation actions (World Resources Institute, 2024). There are three scopes as seen in Figure 7.1 and explained further below in terms of Thames Water's emissions:

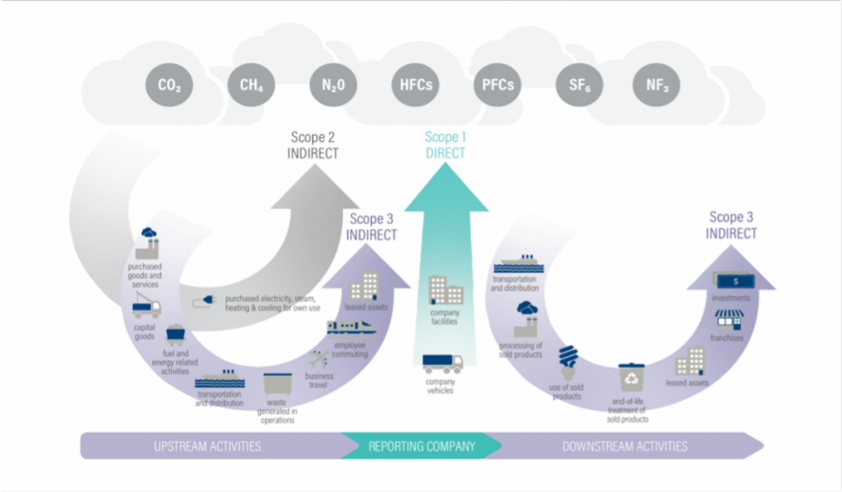


Figure 7.1: Types and examples of the 3 scopes (World Resources Institute, 2024).

Scope 1 involves the direct emissions from sources owned and controlled by Thames Water. These include:

- Fossil fuels: Plans to reduce emissions from the burning of fossil fuels using known technologies with a high technology readiness level (TRL) (Thames Water, 2023).
- Process Emissions: Emissions from wastewater treatment processes such as methane (CH4) emissions from anaerobic digestion of sewage sludge.

Scope 2 uses methods of reporting indirect GHG emissions from the generation of purchased electricity, steam, heating, and cooling consumed (Sotos, 2015).

- Purchased Electricity: Emissions from the electricity used to operate water and wastewater treatment plants, pumping stations, and office buildings.
- Purchased Heat/Steam: Although less common, if Thames Water uses any purchased steam or heat, the associated emissions would also be included.
- Pump and blower efficiency.
- Location-based accounting methods: Reflects the average grid emission factors where Thames Water operates.
- Market-Based accounting methods: Highlights emissions based on specific energy purchasing decisions, such as green energy contracts.

These can be related to the Thames Water case analysed. It needs to monitor and manage the direct emissions to reduce its overall carbon footprint and comply with environmental regulations. Reduction of Scope 2 emissions can be achieved by improving energy efficiency and purchasing renewable energy. However, as the electricity grid decarbonises towards a government target of 2035, scope 2 emissions are naturally expected to decline (Thames Water, 2023).

7.3 Sustainable Development Goals

Sustainable Development Goal 6 (SDG 6) is part of the UN's 2030 Agenda, aiming to ensure water and sanitation for all. Its targets include universal access to safe drinking water, adequate sanitation, improved water quality, efficient water use, integrated water management, protection of water ecosystems, international cooperation, and community involvement (UN, 2018). Despite progress, significant challenges remain. One in three people lack safe drinking water, two in five lack basic hand-washing facilities, and over 673 million practice open defecation, highlighting the urgent need for continued efforts.



Figure 7.2: SDG 6.

7.4 PAS

These principles aim to drive down carbon emissions, reduce costs, and enhance value through a collaborative and integrated approach to infrastructure delivery (BSI, 2023).

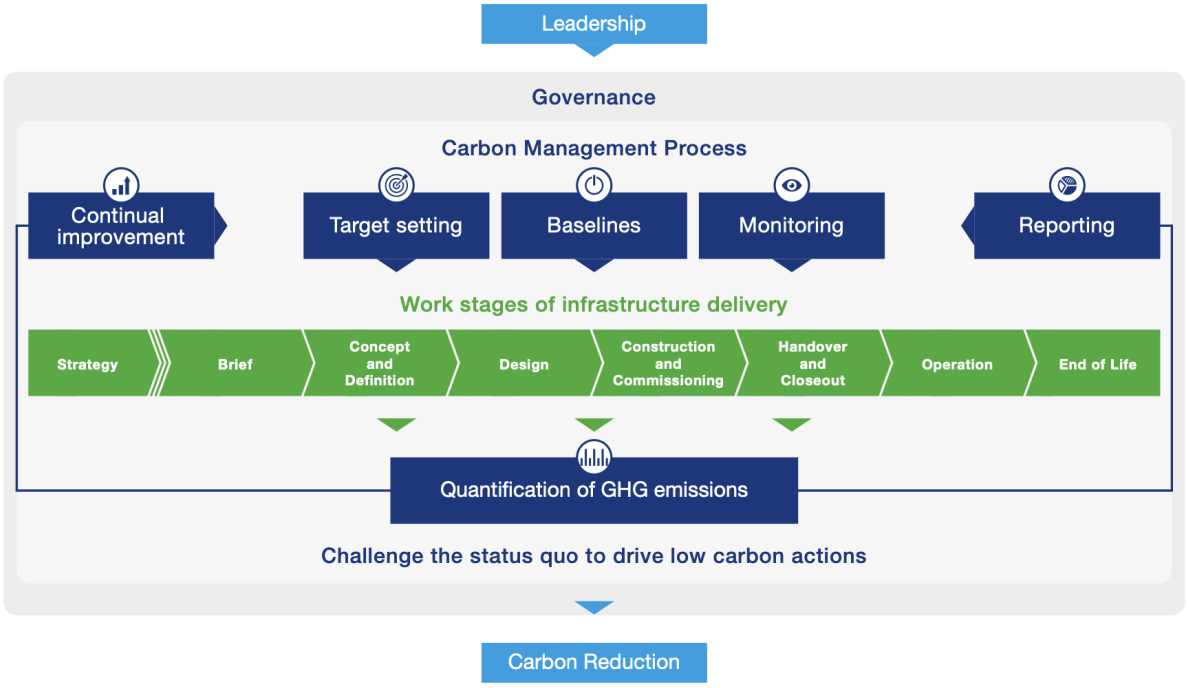


Figure 7.3: The framework of PAS 2080 in the Carbon Management Process (BSI, 2023).

PAS 2080 outlines the need for selecting a GHG emissions quantification methodology that minimises uncertainty. Practitioners have three general options:

1. Calculation-based Methods:

- Bottom-up/Life Cycle Assessment (LCA): Analyses specific processes and activities within defined boundaries.

- Top-down/Input-Output Analysis (IOA): Uses broad, often boundary-free, economic sector data to determine emission factors.

2. Measurement-based Methods: Measures physical GHG emissions directly, offering high reliability but only useful for real-time monitoring.

3. Combination of Both: Integrates calculation and measurement methods for more comprehensive assessments.

Calculation-based approaches are typically preferred due to their broader applicability and predictive capability. Practitioners should consider data quality and work stages when selecting the methodology and may need to use different methods at various stages to ensure comparability or adjust baselines as necessary (CLC, 2023).

8 Whater's Identity

Whater tackles the "what" in water by offering a carbon footprint blockchain platform integrated with a Green Finance System for the Wastewater industry until 2030, helping them reach net zero. After 2030, Whater will be expanding into other industries, offering a similar platform. Figure 8.1 shows Whater's logo with the additional sub-branches.



Figure 8.1: Whater's Identity.

8.1 Stakeholder Incentives

8.1.1 Company incentives

Joining Whater's carbon footprint blockchain scheme offers water companies numerous benefits, even those worried about high emissions. By committing to transparency and environmental responsibility, companies can enhance their reputation, comply with regulations, and avoid fines. Economically, the scheme provides token rewards for emission reductions, leading to financial benefits and substantial cost savings through improved efficiency. As mentioned, water companies struggle with a revenue gap in carbon trading. The investments and rewards offered through Whater's blockchain platform fill this gap, offering revenue potential. Participating companies can differentiate themselves in the market, attract environmentally conscious consumers and investors, and position themselves as industry leaders in sustainability. The blockchain system provides precise data for better decision-making and operational efficiencies. Engaging in this initiative can also boost investor confidence, attract investment, and improve employee morale by showcasing a commitment to sustainability. Additionally, the scheme fosters partnerships and access to expert advice, helping companies innovate and improve. By proactively addressing emissions, companies can prepare for stricter future regulations, contribute to climate resilience, and ensure long-term operational viability. Demonstrating a commitment to reducing environmental impact can also garner community support and enhance corporate social responsibility initiatives, turning the challenge of high emissions into a powerful opportunity for growth and leadership in sustainability.

8.1.2 Investors incentives

On the other hand, investors will have the chance to diversify their portfolio beyond traditional stock holdings, therefore mitigating risks and enhancing potential returns. Additionally, this diversification will allow them to reach their green investment quotas and meet their environmentally responsible investment goals.

Given that blockchain technology has not yet been implemented in the wastewater industry, there exists significant untapped potential for investors. Whater is uniquely positioned to capitalise on this opportunity, with the potential to become a market leader and drive innovation in this sector. This venture could potentially be viewed as a loss leader for the investors in order that they could establish a monopoly for big returns later.

8.1.3 Consumer incentives

Post 2030, when most wastewater treatment plants will have reached the net zero emissions target, Whater will be applied to other industries that aim to involve and benefit consumers as well. By expanding Whater's application to a household level, the smart meters plan will save consumers money on their water bills by detecting leakages and advice on usage. An interactive app will be developed from which tokens can be traded between consumers therefore creating profit possibilities. This is showcased in more detail in Section 15.

9 Carbon Trading Business Model

9.1 Flowchart of Business Model

Figure 9.1 shows the flowchart of the Carbon Trading Business Model. Wastewater facilities measure their greenhouse gas emissions and report these to the government which regulates the compliance carbon markets (Chevallier et al., 2009). The emissions of the company will either be less than or greater than the initial cap set by the compliance market. If the emissions exceed the cap, facilities must take action to comply with regulations. This involves purchasing more WHTR coins from other businesses or from Whater to offset their excess emissions.

If emissions are below the cap, facilities have surplus allowances that can be utilised or traded. One way they can make use of their surplus in WHTR coins is by holding onto it for future use. Another way they can make use of the surplus coins is to trade with other companies which need to meet their emissions. Staking their coins will also help maintain the blockchain system, so companies that stake can be rewarded for this. They can invest in utility or governance tokens, which might represent ownership or voting rights in the compliance market or related initiatives. They can use the surplus allowances to fund community services and support local projects or initiatives related to environmental sustainability.

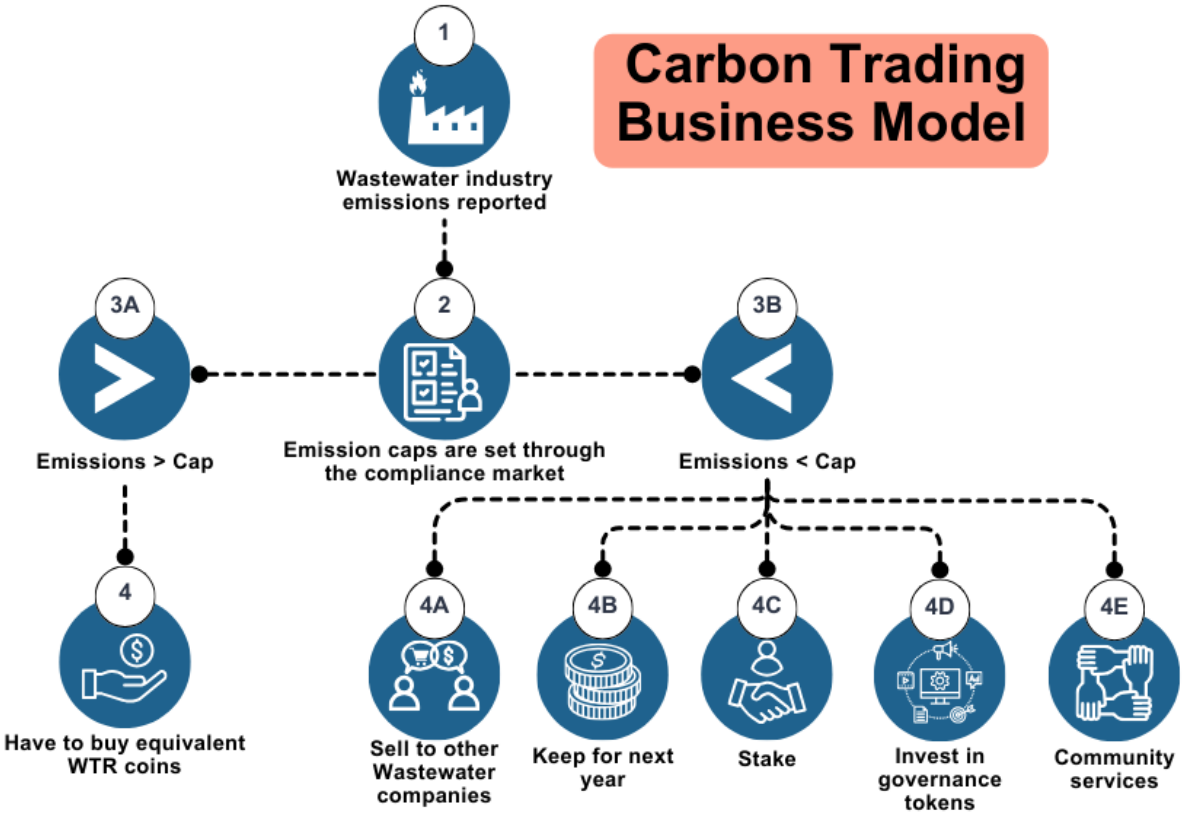


Figure 9.1: Carbon Trading Business Chart.

9.2 Token Reward System

Whater plans to implement a carbon credit system using blockchain technology, where each WHTR token represents a 1 tonne of carbon dioxide emissions for a business. Companies that effectively reduce their emissions will retain surplus tokens, which can then be traded on a blockchain marketplace. This trading mechanism allows businesses that have exceeded their

emissions reduction targets to monetise these efforts by selling their excess tokens to other businesses that need to increase their emission allowances. This system not only incentivises significant reductions in carbon emissions but also provides financial rewards for environmentally responsible behaviour.

Whater will implement a tiered system where the percentage of WHTR coins saved by a business will determine its tier level. Each ascending tier provides enhanced rewards, such as reduced transaction fees for trading tokens. Additionally, the system will prominently feature companies in the top tiers, recognising their successful carbon emission reductions and boosting their reputation and visibility. This visibility is particularly attractive for green investors, who are more inclined to invest in top-tier companies that demonstrate robust sustainability efforts, thus drawing more green bonds to these enterprises.

The following equation outlines a calculation the blockchain program will carry out which will help rank the success of businesses in a non-biased way.

$$\%\text{ of WTR coins saved} = \left(\frac{\text{Initial amount of coins} - \text{Current balance of coins}}{\text{Initial amount of coins}}\right) \times 100 \quad (1)$$

Table 9.1: Token Reward System.

Tier	**% of WHTR coins saved**	**Transaction Fee**	**Publicity**
Bronze	Up to 10%	Standard Rates (0.5% Fee)	Data shared to NGOs and Government as standard
Silver	10% to 20%	10% Discount (0.45% Fee)	Same publicity as Bronze
Gold	20% +	30% Discount (0.35% Fee)	Same publicity as Bronze, plus shared to the public and green investors

9.3 Ways to Carbon Offset

1. Optimising Data Centres and Computing Power: Whater can significantly enhance its environmental sustainability by optimising data centres and computing power. This involves transitioning to green data centres powered by renewable energy sources, which are designed for energy efficiency and minimal environmental impact. Upgrading to energy-efficient servers and computing hardware further reduces power consumption. These measures can collectively reduce energy consumption by 50% or more, leading to substantial CO_2 reductions.

2. Renewable Energy Certificates (RECs): RECs are part of market-based initiatives as a tool for supporting clean energy production to match the energy consumption of operations. This ensures that an equivalent amount of renewable energy is added to the grid. When RECs are sold, what's transferred is not the electricity produced by the attributes that make it clean energy but shows their holders own one megawatt-hour (MWh) of renewable energy. They can be sold for profit to those looking to offset their carbon emissions or speculators betting on the value of energy credits (AIB, n.d.).

   Directly invest in or partner with renewable energy projects such as solar or wind farms. Each REC represents 1 MWh of renewable energy generated and offsets approximately 1 metric ton of CO_2. RECs typically cost around £5-£15 per MWh (AIB, n.d.).

3. Carbon Offsetting Projects: Invest in certified carbon offset projects that either lower CO_2 emissions or sequester CO_2, meaning that they take CO_2 out of the atmosphere and store it. Projects include reforestation, methane capture, or clean energy initiatives. These projects are verified to ensure they reduce greenhouse gases. Participating in blockchain-based carbon credit trading platforms to ensure transparency and accountability in offsetting efforts.

4. Developing Sustainable Blockchain Solutions: Whater can enhance its sustainability efforts by developing and implementing energy-efficient blockchain algorithms that require less computational power. A key strategy involves transitioning to or supporting blockchain networks that utilise Proof-of-Stake (PoS) consensus mechanisms, which are significantly less energy-intensive compared to traditional Proof-of-Work (PoW) systems. Adopting PoS can lead to a substantial reduction in energy consumption, potentially decreasing it by up to 99% (Medium, 2023). While there are initial development costs associated with creating new algorithms and transitioning systems, these are offset by considerable long-term energy savings (Medium, 2023).

10 Tokenomic Flow

Tokenomics refers to the economic system that underpins the use, creation, distribution, and management of tokens within a blockchain ecosystem. Tokenisation involves converting physical assets like carbon credits into digital tokens on a blockchain network. This process would involve verifying the carbon credits to be tokenised and creating digital tokens representing a specific amount of offset carbon emissions. Smart contracts automate the verification and transfer of carbon credit tokens. Every transaction involving the tokens is recorded on a decentralised ledger, ensuring its transparency and safety. This section discusses the creation of the token of Whater's business model.

10.1 Cryptocurrency: Stablecoins vs Non-stablecoins

One of the main features of the cryptocurrency market is its unpredictability. Due to the volatility of cryptocurrencies, a safer digital asset, stablecoins, was created. Stablecoins are cryptocurrencies whose value is pegged to another currency, commodity, or financial instrument. They aim to offer a more stable option compared to the high volatility of major cryptocurrencies such as Bitcoin (BTC), making investments more practical for everyday transactions (Hayes, 2024). They also act as a bridge between cryptocurrency and fiat money, tying their value to assets like the US dollar or gold. There are different types of stablecoins such as algorithmic stablecoins and traditional stablecoins which include commodity-backed, cryptocurrency-backed and fiat-backed stablecoins.

Table 10.1: Types of stablecoins.

Types of stablecoins	**Purpose**
Algorithm-based stablecoins	Utilise smart contracts and algorithms for stability.
Currency or commodity-backed stablecoins	These are backed one-to-one by underlying assets.
Cryptocurrency-backed stablecoins	These use a mix of cryptocurrencies as collateral, often over-collateralised to manage volatility.
Fiat-backed stablecoins	These, such as Tether, and USDC are backed by fiat money and require transparency from issuers regarding their reserves.
Commodity-backed stablecoins	These use commodities like gold or silver as reserves.

Both the traditional and algorithmic stablecoins aim to achieve stability in asset value, however, they differ significantly in how they maintain this stability. On the other hand, algorithmic stablecoins utilise smart contracts and algorithms to manage supply. Algorithmic stablecoins use algorithms and smart contracts to dynamically adjust their supply in response to market demand, thereby mitigating price volatility. Unlike traditional stablecoins, they are not backed by physical assets or other cryptocurrencies (Kaur, 2024). There are four distinct models of algorithmic stablecoins, each operating differently but serving the same purpose of maintaining stability: rebase algorithm, seigniorage algorithm, fractional/ hybrid algorithm and over-collateralised algorithm.

1. Rebase Algorithm: This model uses price-elastic ERC-20 tokens to adjust the total circulating supply based on the token's price. When the token price exceeds the pegged price, the supply of tokens increases. Conversely, when the token price falls below the pegged price, the supply decreases.

2. Seigniorage Algorithm: The Seigniorage Algorithm uses multiple asset forms, such as stablecoins pegged at $1, seigniorage ownership tokens, and bond tokens (Kaur, 2024). When the stablecoin price exceeds $1 or the pegged price, seigniorage tokens are burned to create more stablecoins. On the other hand, when the price falls below $1, stablecoins are burned and converted into seigniorage tokens to stimulate demand. This process is managed by a mint-and-burn algorithm.

3. Fractional Algorithm/ Hybrid Algorithm: This algorithm combines collateral assets such as the USDC with algorithmic mechanisms to maintain stability. Unlike traditional asset-based reserves, this model employs a balancing mechanism that involves minting and burning tokens. When the stablecoin price rises above $1, the supply increases by depositing 92% USDC and 8% FXS. However, when the price falls below $1, users can buy FRAX and burn it to receive $1 worth of FXS, thereby decreasing the overall token supply (Naunt, 2023).

4. Over-collateralised Algorithm: This model depends on a large cryptocurrency reserve that exceeds the total value of the stablecoins in circulation. An example is DAI by MakerDAO and this mechanism includes several steps. The stablecoin is backed by collateral assets that surpass the value of the issued stablecoins. Users can mint stablecoins by depositing collateral assets into a smart contract, receiving stablecoins proportional to the collateral's value. Likewise, stablecoins can be burned to unlock and retrieve collateral assets, regulating the stablecoin supply. To maintain stability, the system ensures the collateralisation ratio remains above a certain threshold (Kaur, 2024). Table 10.2 below displays the advantages and disadvantages of the four models.

Table 10.2: Types of algorithms with their respective benefits and drawbacks.

Model	**Advantages**	**Disadvantages**
Rebase Algorithm	Automated token supply adjustment. Prevents dilution of ownership for existing token holders	Potential for price manipulation during periods of low liquidity. Complex understanding for users due to fluctuating token amounts.
Seigniorage Algorithm	Direct incentives for participants to stabilise prices. The multi-token system enhances stability and governance.	Vulnerability to speculative attacks and market manipulation. Dependency on secondary token utility and demand.
Fractional/ Hybrid Algorithm	Balance between collateralisation and algorithmic stability. Capital efficiency from partial collateralisation	Vulnerability to value fluctuations of collateral assets. Complexity in maintaining target collateral ratios.
Over-collateralised Algorithm	High level of security and stability due to excess collateral. Resistance to market volatility and insolvency risks.	Capital inefficiency from holding surplus collateral assets. Requires ongoing monitoring and management of collateral ratios.

Non-stablecoins are cryptocurrencies whose value is not pegged to any external asset or currency. Unlike stablecoins, it can experience significant price volatility which is subjected to market forces and other factors. One example is Ether (ETH) which is the nature cryptocurrency of Ethereum.

To choose which type of coins to adopt, the advantages and disadvantages of stablecoins and non-stablecoins are compared in Table 10.3 below.

Table 10.3: Advantages and disadvantages of stablecoins and non-stablecoins.

	Stablecoins	**Non-stablecoins**
Advantages	Price stability Reduced transaction costs Accessibility Builds trust with consumer	Potential for high returns Market liquidity Diversification
Disadvantages	Dependent on pegged assets Regulatory changes	High volatility Transaction costs and speed

10.2 WHTR Coin Creation

The price stability of WHTR coins is essential for customers' trust. It ensures predictability for carbon trading and business planning within each water company (DeMatteo, 2022), providing a reliable transaction medium for them and preventing unpredictable transaction costs that could make the blockchain platform less attractive to Whater's customers. It also fosters trust among water companies, as they need assurance that the token will retain its value. Overall, it reduces the risk of volatility and financial risk in carbon trading. Therefore, WHTR tokens are designed to be a traditional currency-backed stablecoin after consideration for the target customers in the wastewater industry.

WHTR coins are pegged to the carbon offsetting price, which is relatively stable, and each of them is equivalent to 1 ton of CO2e. The traditional stablecoins are chosen over the algorithmic stablecoins because the total supply of WHTR tokens cannot be varied throughout the year based on the market demand. The carbon offsetting price is averaged to be £10 which is the average price of 5 high-quality carbon offsetting projects that were selected and verified by Whater, while the stability is maintained by including more carbon offsetting projects across the world which diversifies Whater's portfolio. This provides an easier and more efficient way for Whater's customers to meet regulatory requirements and align with the carbon credit values set by the compliance market. The preference for trading stablecoins has also been proved by USDT, a type of stablecoin, which is the most used cryptocurrency in trading that exceeds the combined volume of Bitcoin and Ethereum (coinbase, 2022).

10.3 WHTR Token Flow

This section discusses the WHTR token flow on Whater's blockchain system. The flow chart of WHTR tokens is shown in Figure 10.1. The UK Emission Trading Scheme (UK ETS) adopts a cap-and-trade system. A cap is set on the total amount of GHG that can be emitted. This ensures that carbon dioxide emissions are limited and decreasing each year so that the net zero 2050 goal is met (Department for Energy Scrunity & Net Zero, 2024). Within this cap, water companies receive free allowances in the form of WHTR tokens which can be traded with other wastewater companies or staked for future trading. When companies are on a negative balance, they must trade with companies with extra credits. Suppose the companies cannot manage to trade enough WHTR tokens to offset their extra carbon emissions. In that case, it is mandatory to buy extra credits from Whater's blockchain to offset their extra carbon emissions. Companies must meet their carbon credit target set by the compliance market to adhere to legal requirements, enhance their reputation and promote global sustainability efforts to attract investors. Whater's extra carbon credits will be 10% more than the value of WHTR tokens and this percentage will go up by 10% each year to incentivise wastewater companies to reach net zero by 2030. These extra carbon credits will be invested by Whater in high-quality carbon offsetting projects as mentioned above, while the extra 10% will go towards Whater's revenue which is discussed in Section 12.2.

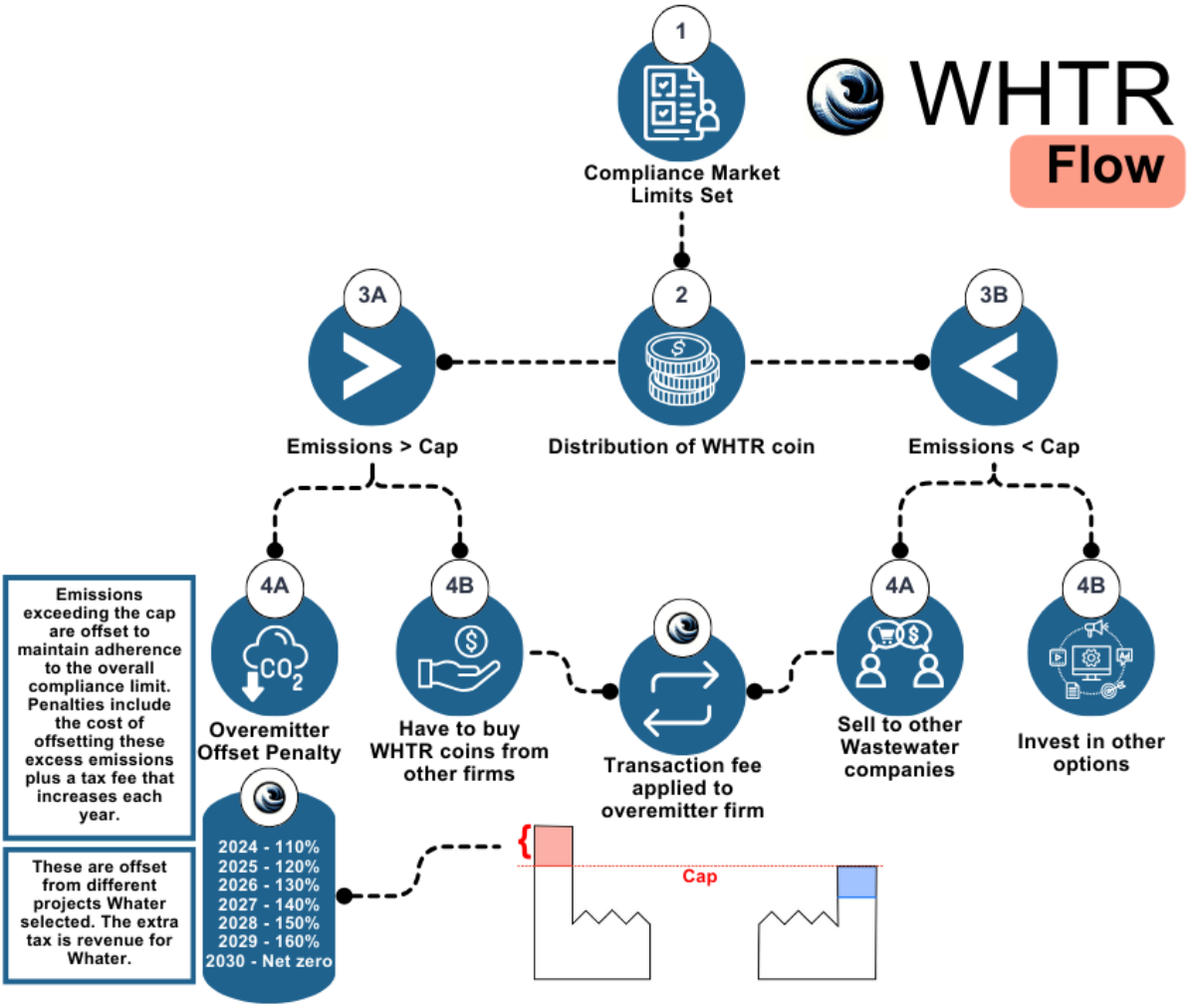


Figure 10.1: Tokenomic Flow of WHTR tokens.

10.4 WHTR Token Distribution

Whater tokens will have a total supply of 13,340,000 $WHTR tokens. This value has been calculated by having determined the carbon allocations of the companies and considering their long-term projections. The projections shown earlier in Table 5.2, indicate how fewer tokens can be released year on year. Other than these, tokens are also distributed to the Whater team, set aside as a governance reserve, waste ecosystem incentives, and burnable tokens are kept so that the value of the token can be maintained if necessary (EmpowerChain, 2024).

Table 10.4: Distribution of tokens.

Colour	**Owner**	**No. Token (million)**	**Percentage**
	Water companies (initial)	1.000	7.5%
	Water companies (long term)	5.000	37.5%
	Governance reserve	2.335	17.5%
	Waste ecosystem incentives	2.670	20%
	Whater team	1.000	7.5%
	Burnables	1.335	10%
Total		13.340	100%

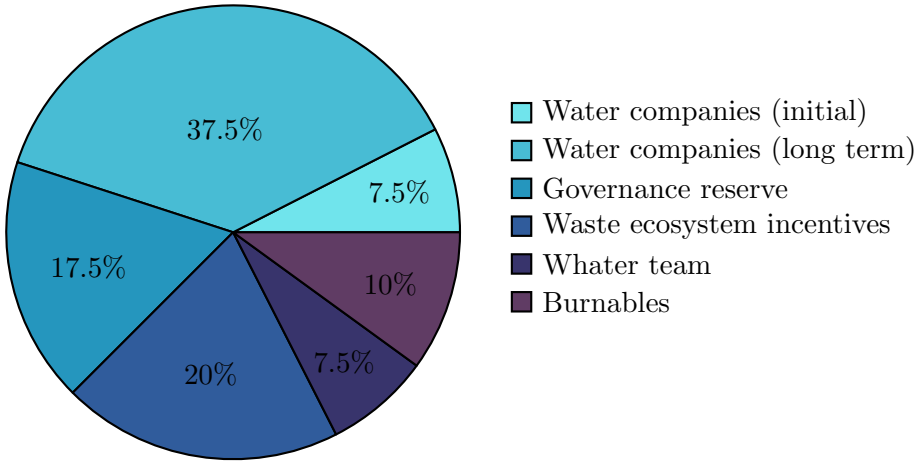


Figure 10.2: Pie chart of the distribution of tokens.

10.5 Black Swan Events - Decentralised Finance Insurance

In the case of a black swan event such as a global recession or catastrophic event, the carbon offsetting price could be volatile. Whater can mitigate this by implementing Decentralised Finance (DeFi) insurance in the blockchain platform to provide financial protection by leveraging smart contracts to handle the claims and payouts. DeFi insurance is a decentralised, transparent, and automated insurance unlike traditional insurance and provides stablecoin Depeg cover to prevent losses (OpenCover, 2022).

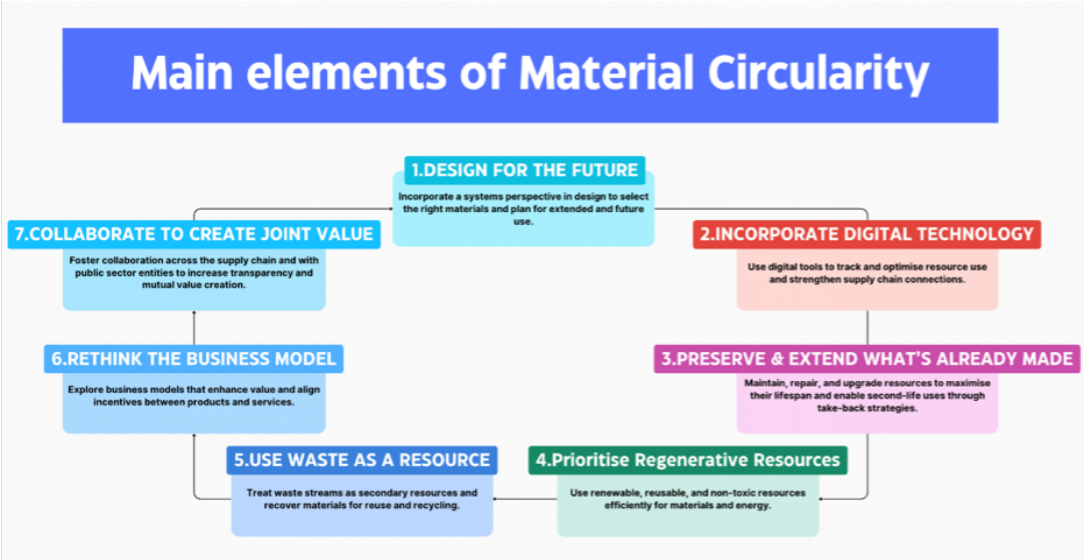
11 Material Circularity

Organisations must transform their approach to climate change to effectively reduce greenhouse gas emissions (GHGs) and meet the Paris Agreement targets. While enhancing efficiency and transitioning to renewable energy are crucial, they only address 55% of global emissions. Achieving net-zero involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials as long as possible (Farnham, 2021).

Monitoring the lifecycle of materials allows companies to identify emission hotspots and compare supplier products. From a financial perspective, this initiative allows businesses to save on maintenance and operational costs, implement targeted reduction strategies, and avoid regulatory penalties through better tracking and management of their supply chains/emissions. Decarbonisation enhances business value and provides evidence to demonstrate sustainability efforts to regulators, investors, and consumers.



(a) *The concept of material circularity (Heidi, 2022).*



(b) Main elements of material circularity set out by Circular Economy

Figure 11.1: Material circularity.

11.1 Bottlenecks

60% of the emissions responsible for climate change are embedded in the products we consume (Brende et al., 2022). This highlights the necessity to keep growing quantities of materials within productive cycles. Blockchain can be used to keep track of such cycles. Table 11.1 discusses the bottlenecks of material circularity and focuses on the aspects of technology, regulation, and finance, which are tackled.

Table 11.1: The bottlenecks of material circularity (Renfrew et al., 2023).

Category	**Bottleneck**	**Description**
Technology	Advanced Treatment Technologies	The lack of advanced and affordable technologies for the recovery of resources can be a major bottleneck. These technologies are capital-intensive and may not be fully developed for the complexities of different material streams.
	Integration with Existing Infrastructure	Retrofitting existing material recovery facilities with new technologies for resource recovery can be technically challenging and expensive, requiring significant modifications and system upgrades.
Regulatory	Unclear or Inadequate Regulations	The regulatory framework may not be developed to support the circular economy in material management.
	Permitting and Compliance Issues	Obtaining the necessary permits for new treatment facilities or expanded operations can be time-consuming and restrictive.
Finance	High Initial Investment Costs	Technologies for material recovery and recycling require significant capital investment, not feasible for all companies.
	Uncertain Return on Investment (ROI)	The financial returns from selling recovered resources may not always cover the costs of the technologies and processes needed to extract them, making it difficult to secure funding.

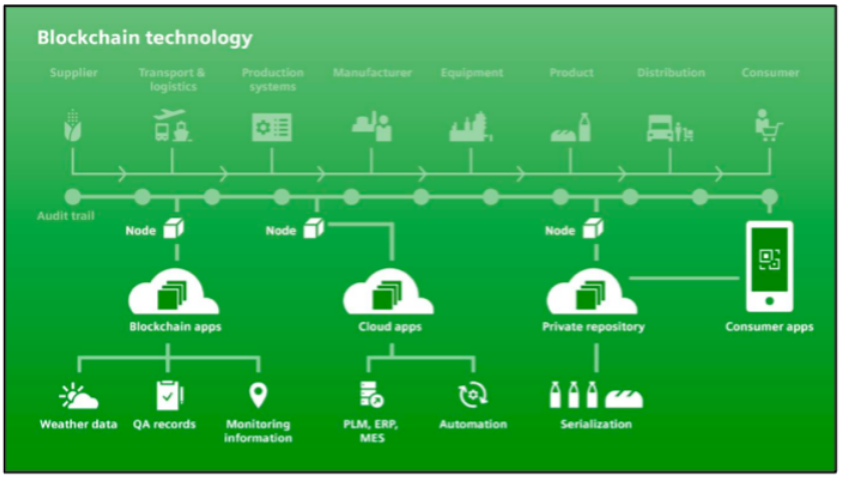


Figure 11.2: Solutions that improve data transparency, management and trust (Katsou, 2024).

The application of new technologies sometimes overlooks the environmental impact as they primarily target enhancing the efficiency of material circularity (Martí Rufí-Salís et al., 2022). Blockchain technology stands out as an important tool in addressing challenges related to material circularity within wastewater management, by augmenting transparency and efficiency. Whater is developing solutions that improve data transparency, management, and trust, preparing for new traceability requirements. The aim is to design blockchain-based traceability systems for circular value chains, as seen in Figure 11.2.

Blockchain's hallmark feature of providing immutable records can vastly improve traceability and install trust in the recycling processes. This simplifies compliance with regulatory standards and streamlines the permitting processes, crucial for ensuring environmental sustainability. From an economic standpoint, blockchain streamlines transactions and slashes operational costs, making investments in recycling technologies more attractive and feasible. In essence, blockchain technology offers multifaceted support for a robust circular economy.

11.2 Whater's Material Circularity Plan

Whater is a blockchain platform created to aid collaboration between stakeholders in the wastewater industry to create a more sustainable future by supporting the circular economy in the global decentralised waste management ecosystem. It contains a network of integrated applications and tools designed to encourage collaboration between stakeholders like waste collectors and manufacturers. Whater is aimed at eliminating waste and promoting the continuous use of resources, leading to a more efficient system.

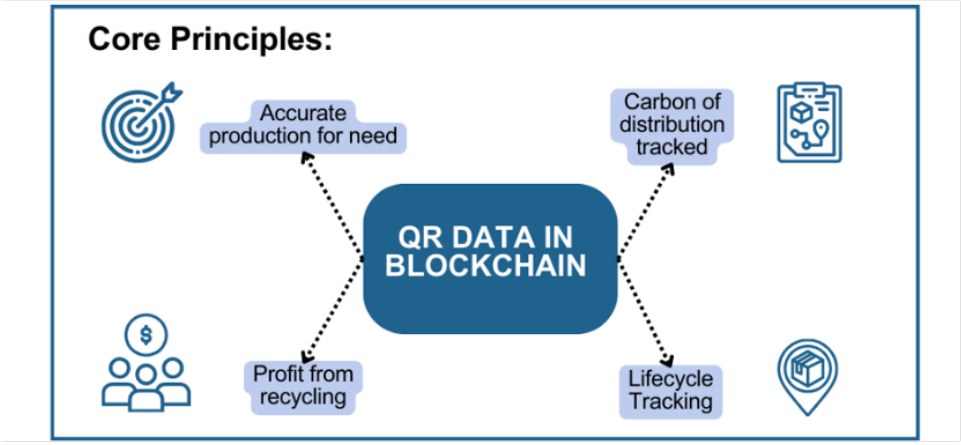


Figure 11.3: Four aspects of QR data tracking enabled by the blockchain.

The core principles of the data tracking aspect of the blockchain will allow Whater to:

1. Tracking and proof of existence – ensuring traceability from the point of production through waste, using blockchain's immutability and cryptographic techniques called 'hashing'.
2. Exchange incentive schemes: If a wastewater company has leftover material, they can sell it through the blockchain to other wastewater firms using WHTR coins.
3. Determine the correct material and production requirements to address problems in the system, which are identified by the blockchain in the first place.
4. The lifecycle of materials is tracked, and system health can be transparently monitored.

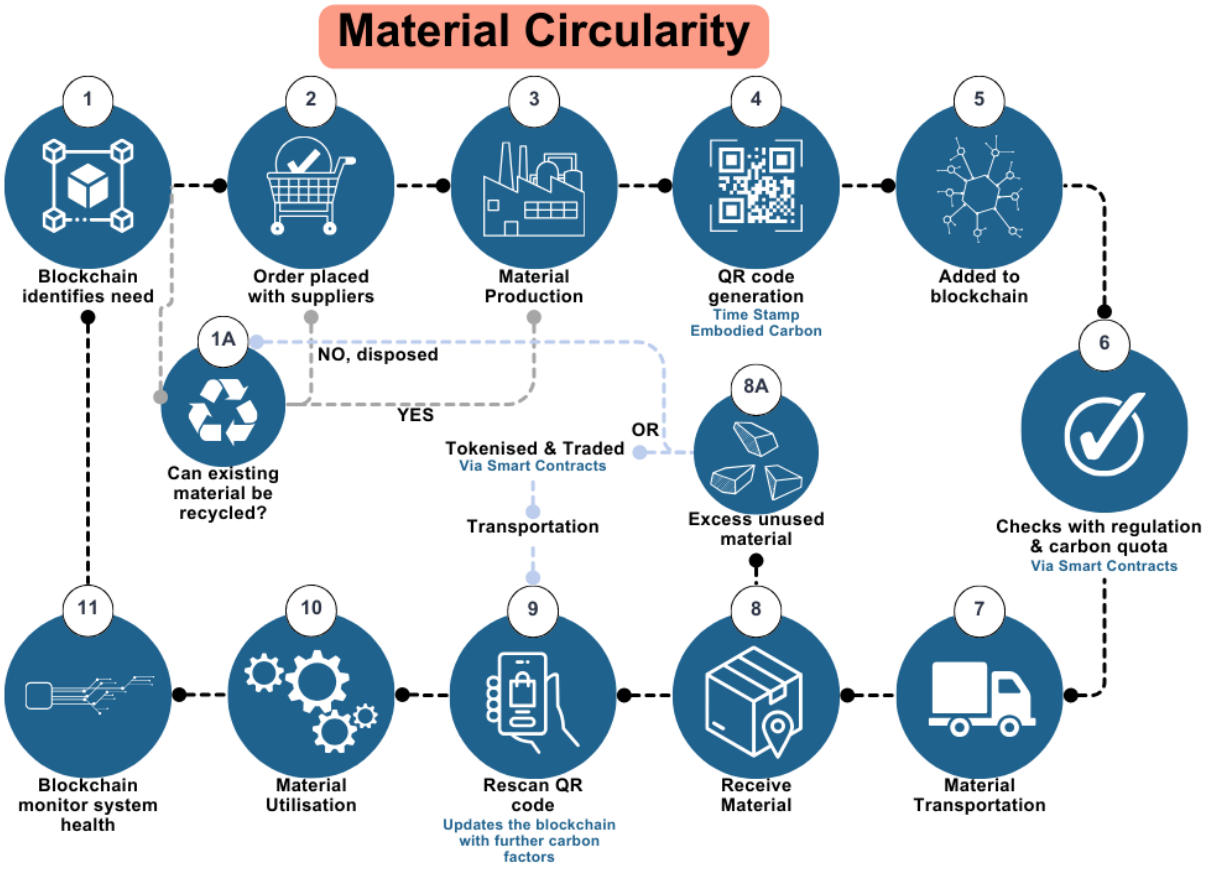


Figure 11.4: Material circularity business model incorporated within a blockchain.

Figure 11.4 shows the Material Circularity Framework. Below is the explanation of the procedure:

1. The process is initiated by a need identified by the blockchain which is tracking the existing system health.
2. Orders for the specific materials required to address the need can be placed with the suppliers.
3. Materials are produced (this has an associated carbon cost).
4. A QR code is generated for the material produced, this contains the data regarding the embodied carbon but also a time stamp and record of all the unique material identifiers and properties.
5. This identifier is added to the blockchain.
6. Once on the blockchain, smart contract checks can be made to ensure regulation standards are being met and the carbon quota is within tolerance.
7. Material is distributed, this has another associated carbon cost.
8. Material is received. If companies have excess materials which they do not end up using then there are two options. These could go back into recycling or disposal, depending on the material or they could sell it to another company that might need it. This would involve tokenisation and trading done via smart contracts. The materials can be bought using WHTR coins and transportation to the new firm would follow.

9. Rescan QR/update the blockchain with the new carbon factors up to this stage.
10. Materials are utilised.
11. Blockchain continues monitoring the health of the system and this feeds back into step 1.

Each block within the blockchain records the location, condition, and lifecycle stage of materials. Companies assign digital identifiers, such as QR codes or NFC tags, to materials at the source, registered on a blockchain ledger to ensure an immutable record. Data about the origin, energy consumption, waste production, and carbon emissions of raw materials are logged against the material's digital ID. The blockchain network tracks these materials through processing stages and locations throughout their lifecycle, while smart contracts authenticate the chain of custody. By including GHG emissions data in the blockchain, companies can easily monitor the CO2 contributions of each supply chain participant.

11.2.1 Energy

Energy could also be integrated within the material circularity model including both renewable and non-renewable energy sources. The QR codes would enclose information of both carbon emissions and the energy footprint associated with each material in the cycle. It would essentially disclose a material passport, which can be viewed by scanning the QR code. Visibility into the energy impact associated with the materials would be provided by the transparency of the blockchain (Ellen MacArthur Foundation, 2021).

The energy consumption would be tracked, starting from the production of materials to their utilisation and end of life, as well as the energy used by the water companies themselves. Moreover, wastewater companies aiming to achieve net zero emissions should adopt proactive approaches by looking into both the carbon emissions and the energy intensity of materials prior to procurement. They would hence be able to view information about each material through the QR code before purchasing. This places extra pressure on the suppliers to ensure that their materials are as low as possible in terms of carbon emissions and energy intensity, since if they are unsustainable their demand would decrease. Emphasising the need for materials with a lower energy footprint, or those manufactured using renewable energy source, is particularly important in fostering an energy-conscious behaviour. Transportation logistics are also crucial for optimising energy efficiency. Wastewater companies can enhance transportation efficiency by employing electric vehicles and meticulously planning routes to ensure they are both the shortest and the least congested to minimise emissions.

Recycling companies should also integrate energy considerations into their operations. Adopting energy-efficient methodologies for sorting and preparing waste materials for recycling is essential. These companies should prioritise the utilisation of renewable energy sources to power their processes. They can enhance transparency by updating QR codes on recycled materials to highlight the energy savings achieved compared to using virgin materials. This approach encourages sustainable practices across the supply chain, enabling informed decision-making and promoting sustainable practices.

11.2.2 Proof of Existence

The Proof of Existence is a module that uses blockchain technology to provide a secure and immutable method of verifying the existence and integrity of data at a specific point in time. This feature primarily utilises cryptographic hashing combined with blockchain's immutability, allowing users to prove that a particular piece of data not only existed but also remained unchanged since its time of entry onto the blockchain (EmpowerChain Docs, 2022).

The process involves:

1. Hashing: Converting data into a unique hash using a cryptographic hash function. This ensures that even minor changes in the data result in a completely different hash, thus verifying data integrity.
2. Timestamping: Associating the data hash with a specific time, recorded on the blockchain. This confirms not only the existence and integrity of the data but also the precise time at which it was recorded.

Figure 11.5 shows the procedure. Data is processed through a cryptographic hash function, transforming it into a fixed-size, unique hash value. This hash is then recorded on the blockchain along with a timestamp, verifying the data's existence at that moment. Because the blockchain is immutable, once the hash and its timestamp are recorded, they cannot be altered, ensuring the data's integrity permanently.

This functionality is crucial for several applications beyond just tracking data immutability, such as confirming ownership of intellectual property, proving the integrity of digital records, and ensuring that data has not been corrupted or tampered with over time. Thus, the Proof of Existence module is a powerful tool for maintaining transparency and trust in digital transactions and records management.

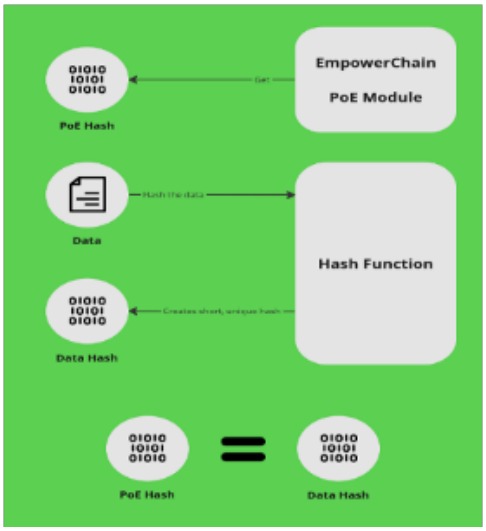


Figure 11.5: Proof of existence (EmpowerChain Docs, 2022).

11.3 How Embodied Carbon can be Measured in Materials

The embodied carbon footprint of wastewater treatment plants includes emissions from construction materials (like concrete, steel, and piping), equipment (such as pumps and motors), transportation (including material delivery and personnel transport), and waste management (construction debris and operational waste). Key factors influencing these emissions include the lifecycle stages of construction, maintenance, and disposal, along with accurate data collection and adherence to standards like the Greenhouse Gas Protocol. Strategies to reduce embodied carbon involve selecting low-carbon materials, optimising equipment, sourcing locally, improving logistics, and adopting sustainable waste disposal practices. Tools like the Transcend Design Generator and the Embodied Carbon in Construction Calculator can help in evaluating and implementing these strategies effectively, thereby enhancing sustainability in wastewater treatment (Transcend, 2018). To calculate the embodied carbon for a project, the product of the quantity and carbon factor for each material is used, as seen below (John, Orlando & Will, 2020):

$$\text{Embodied Carbon} = \sum_i \text{Quantity of Material}_i \times \text{Carbon Factor}_i \tag{2}$$

'Quantity of Material' is the amount of each material used, measured in kilograms, cubic meters, or square meters. Carbon Factor is the amount of CO_2e per unit of material. It quantifies the total GHG emitted during the lifecycle of the material, including extraction, production, and transportation. The unit is typically kgCO_2e /kg.

Table 11.2 below lists the main materials used in water infrastructure systems and how much CO_2 is produced from 1kg of each material, essentially their embodied carbon.

Table 11.2: Main materials used in water infrastructure.

Material	**Properties and Uses**	**kg CO_2-eq**
PVC (Polyvinyl Chloride)	A plastic material which is corrosion resistant, used in water supply pipes. It is also used in irrigation systems since it is lightweight (ecm, n.d.).	2
HDPE (High-Density Polyethylene)	A flexible and tough material used in water mains and service lines. Its resistance to corrosive substances makes it ideal for wastewater applications. Culvert pipes are used in drainage and stormwater management systems (Miller, 2019).	1.7 - 3.5
Ductile Iron	Used in pipes due to its long lifespan and ability to handle high pressures. Commonly used for main municipal water systems (Metal Exponents, 2023).	1.8 - 4.9
Concrete	Its high strength and longevity, as well as its resistance to weathering and corrosion, makes it appropriate for use in reservoirs, water treatment plants and storage tanks (Chen et al., 2023).	0.8 - 0.9
Steel	Steel is used in support structures for water treatment plants and pump stations, as well as hydroelectric power transmission as it handles high pressures. Also used extensively in storage tanks and reservoirs (Miller, 2019).	1.85 – 2.49
Copper	Copper is used in internal plumbing, in both cold and hot systems due to its excellent thermal conductivity (Copper Development Association Inc., n.d.).	3.8 – 5.5
Cast Iron	Its durability and strength make it appropriate for water mains and distribution pipes, as well as valves and fittings (NDT Group, n.d.).	1.8 – 4.9
FRP (Fiberglass Reinforced Plastic)	FRP is used in the fabrication of water storage tanks due to its corrosion resistance and the fact that it is lightweight, which means easy installation. Its structural strength makes it suitable for exposure to aggressive environments like pump stations and desalination plants (Tencom Ltd., n.d.).	2 – 6

11.4 App Creation and Development

In the proposed system, companies operating wastewater treatment plants will have access to an app designed to enhance material circularity within their operations. The application contains a unique QR code for each material used in the wastewater treatment plant as seen in Figure 11.6. This code then allows companies to track the emissions and the location of the various materials.

The utilisation of QR codes offers a streamlined and efficient method for material tracking and management. Each QR code is linked to a specific material, containing crucial information such as its composition, source, usage history, and associated carbon emissions. By scanning these QR codes using the application, companies can effortlessly access detailed insights into the origins and journey of each material throughout its lifecycle. As depicted in Figure 11.6, the application interface showcases a prototype design aimed at facilitating seamless material tracking and circularity. Through intuitive features and functionalities, users can visualise and manage the flow of materials within their operations, promoting transparency and accountability across the supply chain.

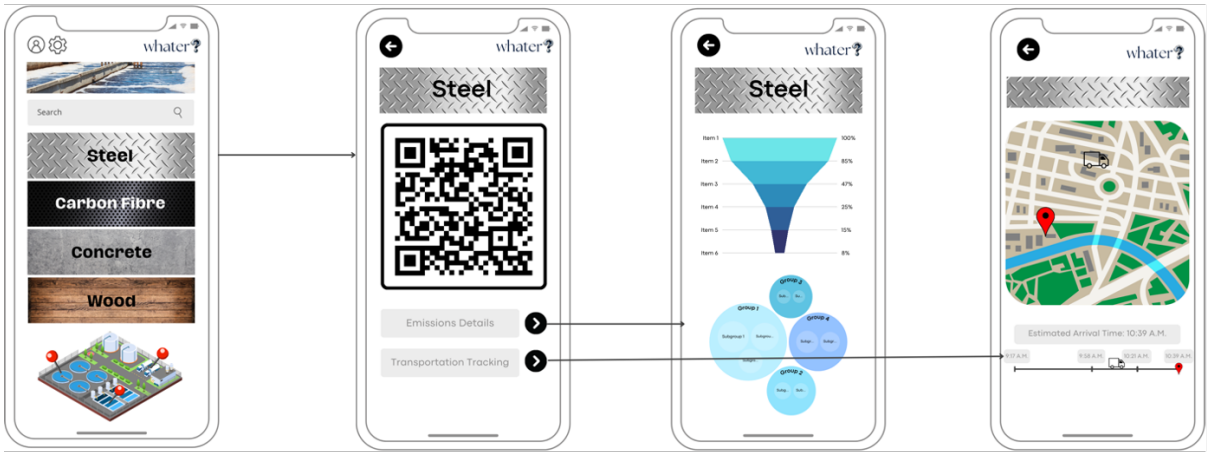


Figure 11.6: Prototype of app development for material circularity.

12 Finance

WHTR coin balance should not exceed the compliance market limit at the start of each financial year, beginning April 5th. As discussed in section 10, when a company exceeds emission limits and has a negative WHTR coin balance, the smart contract will require them to purchase enough WHTR coins to compensate. However, if a company's emissions fall below the compliance level, Whater will issue WHTR coins and these coins can be stored for the next year or sold to other companies at Whater's given rate. This allows companies with surplus emissions to obtain WHTR coins, leading to fewer emissions. Whater can later repurchase these surplus coins at a reduced price, making them available for sale to other companies who have gone over the emissions limit.

Whater intends to establish a dynamic cost point from 2024 to 2030. This involves providing an incentive to participate in research and development which will be consistent with the 2030 net-zero targets. To assess the revenue earned by startup transaction fees, Whater will determine each company's net carbon emissions as seen previously in Table 5.2 of Section 5. Whater will operate under the compliance market, meaning that companies are allocated a specific number of tokens based on the company's scale and their permissible emissions. This allocation serves as a cap, incentivising companies to reduce their emissions.

If a water provider exceeds its assigned token cap at the end of the year, it must compensate for its additional emissions. This is done by paying an extra 10% on top of the cost of mitigating excess emissions. For example, instead of paying the standard WHTR token price, they will have to pay an additional 10% per token. This 10% will increase to 20% in the second year and so on. Table 12.1 below shows the price multiplier for every year till 2030.

Table 12.1: Surcharge fee companies will be made to pay on top of the regular WHTR each year for their excess NET emissions from 2025-2030.

Year	Excess Emissions Fee
2024 - 2025	WHTR price x 1.10
2025 - 2026	WHTR price x 1.20
2026 - 2027	WHTR price x 1.30
2027 - 2028	WHTR price x 1.40
2028 - 2029	WHTR price x 1.50
2029 - 2030	WHTR price x 1.60

In essence, while the aim is to help water companies minimise their environmental footprint and stay within their allocated emissions limits, Whater's system provides a mechanism to address any unforeseen excess emissions fairly and sustainably by establishing an appropriate penalty. Companies will be charged more each year for their excess carbon emissions until 2030 to meet net-zero objectives.

The revenue generated will be allocated in two ways:

1. Fund carbon offsetting projects.
2. Obtained for Whater's expenses and operations.

Over time, this distribution will gradually shift, so that by 2030, all funds will be directed towards carbon offsetting. This strategy is designed to ensure companies gain returns on their investments by improving their business operations to cut emissions rather than depending

solely on offsets. According to various water company reports, including the Thames Water Net Zero Plan, offsetting should be a last resort. Therefore, Whater will emphasise improving production and treatment processes in the water processing chain. After 2030, the focus will shift entirely to offset any remaining emissions to uphold the net zero commitment. Whater plans to facilitate the release and purchase of WHTR coins on a quarterly basis, aligning with the fiscal quarters when companies typically review their financial reports. This schedule is beneficial as they will be able to incorporate WHTR transactions into their regular financial activities. From a blockchain trading point of view, quarterly trading is also more efficient as it provides adequate time for verification and processing of emissions data without

The conversion of CO_2 emissions to WHTR coins will be based on the company's energy sources. For instance, if a company derives 30% of its energy from renewable sources, this would be factored in, reducing the number of WHTR coins required to offset its emissions.

Emissions can be offset through the following methods:

1. Renewable Energy investment: Funds will be allocated to global renewable energy projects, including wind, solar, and wave energy initiatives.
2. Energy Efficient Measures: Investments can be made in energy-efficient technologies and practices, such as upgrading to more energy-efficient appliances.
3. Reforestation: Funds from the company's emissions can support the protection of existing forests and the planting of new trees which sequester CO_2.
4. Sustainable Agriculture: Promoting better agricultural practices to reduce CO_2, ultimately making the process more environmentally friendly.
5. Education: Resources can be used to educate people about CO_2 emissions and the importance of sustainable practices. This can incentivise companies themselves to reduce their own emissions and incorporate more energy-efficient practices.

12.1 Costs

Forecasted yearly expenses not only aids Whater in financial efficiency but also in estimating the time required to achieve profitability, thereby instilling confidence in investors. The pie chart in Figure 12.1 illustrates the company's expenditure, with Tables 12.2 and 12.3 providing detailed breakdowns of initial costs as well as annual costs. The primary cost lies in the development team, as Whater must compensate skilled professionals for blockchain development and security. Following, are research and development, and technology infrastructure expenses, reflecting Whater's need for ongoing innovation and robust infrastructure to support its blockchain operations.

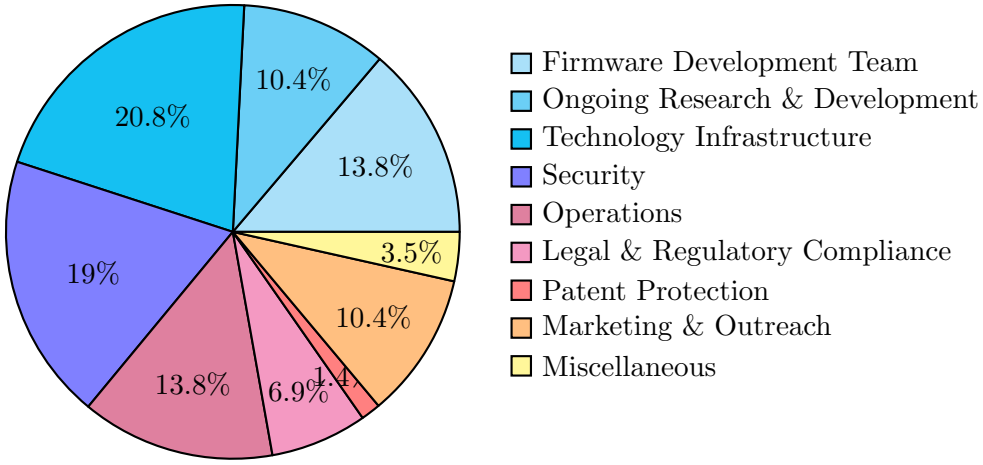


Figure 12.1: Pie chart representing the annual expenditure of the business.

Table 12.2: Breakdown of Whater's Initial Costs.

Expenditure	**Segment**	**Cost [GDP]**
Firmware Development Team	Initial development	700,000
Research and Development	Initial Research Initiatives	300,000
Technology Infrastructure	Servers and Data Centres	100,000 + 50,000
	IoT Integration	500,000
Security	Cybersecurity Setup	200,000
Operations	Operational Costs	150,000
Legal and Regulatory Compliance	Compliance Setup	100,000
Patent Protection	Filing	50,000
Marketing and Outreach	Campaigns	200,000
Miscellaneous	Contingency Fund	100,000
TOTAL		**2,450,000**

Table 12.3: Breakdown of Whater's Annual Costs.

Expenditure	**Segment**	**Cost [GDP]**
Firmware Development Team	Ongoing Maintenance and Updates	200,000
Research and Development	Ongoing R&D	150,000
Technology Infrastructure	Maintenance	150,000
	Expansion and Upgrades	150,000
Security	Security Enhancements	200,000
	Data Integrity and Backup	75,000
Operations	Operational Costs	200,000
Legal and Regulatory Compliance	Compliance Costs	100,000
Patent Protection	Annual Renewals and New Filings	20,000
Marketing and Outreach	Campaigns	150,000
Miscellaneous	Ongoing Miscellaneous Expenses	50,000
TOTAL		**1,445,000**

12.2 Revenue

Using Table 5.2 from earlier, total emissions were estimated to be 1354.1 $kTCO_2e$ in 2024. Based on this, the compliance market will set a limit for all water companies until 2030, with a plan to reach net zero. It has been assumed that the compliance market has set emission caps which decrease linearly from 1000 $ktCO_2e$ in 2024/2025 to 0 in 2029/2030 to reach net zero by the start of 2030. Using the estimated forecasted data until 2030, the total over-emitted emissions can be calculated, which would result in the company having a negative WHTR coin balance. Those with a negative WHTR coin balance can buy coins from other companies. The "best-case scenario" refers to a scenario where companies do not trade with each other and, hence are forced to pay the full penalty fee for their over-emissions. This will generate the most revenue for Whater. However, this is very unlikely, so it can be estimated that 80% of the over-emitted coins are traded within the blockchain between water companies, whilst 20% is purchased from Whater, who will be charging a penalty with every coin sold to the client company. This assumption falls under the realistic revenue in the table below.

Table 12.4: Revenue generated from over-emitters.

Year	Total emissions ($ktCO_2e$)	Compliance Limit ($ktCO_2e$)	Over limit ($ktCO_2e$)	Penalty Multiplier	WHTR Coin Price	Penalty	Carbon offsets	Revenue (Best case scenario)	Revenue	Revenue with subscriptions
2024/2025	1354.1	1000	354.1	1.1	10	£ 3,895,100	£ 3,541,000	£ 354,100	£ 70,820	£ 1,150,820
2025/2026	1281.3	800	481.3	1.2	10	£ 5,775,600	£ 4,813,000	£ 962,600	£ 192,520	£ 1,272,520
2026/2027	1214.3	600	614.3	1.3	10	£ 7,985,900	£ 6,143,000	£ 1,842,900	£ 368,580	£ 1,448,580
2027/2028	1150.8	400	750.8	1.4	10	£ 10,511,200	£ 7,508,000	£ 3,003,200	£ 600,640	£ 1,680,640
2028/2029	1085.8	200	885.8	1.5	10	£ 13,287,000	£ 8,858,000	£ 4,429,000	£ 885,800	£ 1,965,800
2029/2030	1021.4	0	1021.4	1.6	10	£ 16,342,400	£ 10,214,000	£ 6,128,400	£ 1,225,680	£ 2,305,680

The penalty multiplier has been discussed in Section 10.3, where part of the revenue will be generated. Furthermore, all 9 water companies will be required to pay a monthly subscription fee of £10,000 which will be used to run the blockchain and provide them with this transparent trading platform, where they can work together to reach net zero. This will form the bulk of the revenue generated by Whater – which is £1,080,000 in annual subscription fees from all 9 companies on the blockchain. According to the costs and revenue generated per year, Whater expects to break even during the second quarter of the 3rd fiscal year and become profitable after 2027/2028.

Figure 12.2 shows how Whater aims at breaking even, generating enough revenue to be able to cover annual operation costs by 2027/2028. Whater has considered that its revenue will not be sufficient to run the infrastructure and payroll for the development teams in the first few years, so will mainly rely on funding during this period of negative cash flow. However, as Whater's technology improves the UK's water industry's goals towards net zero, Whater is expected to receive more funding and generate more revenue through its success.

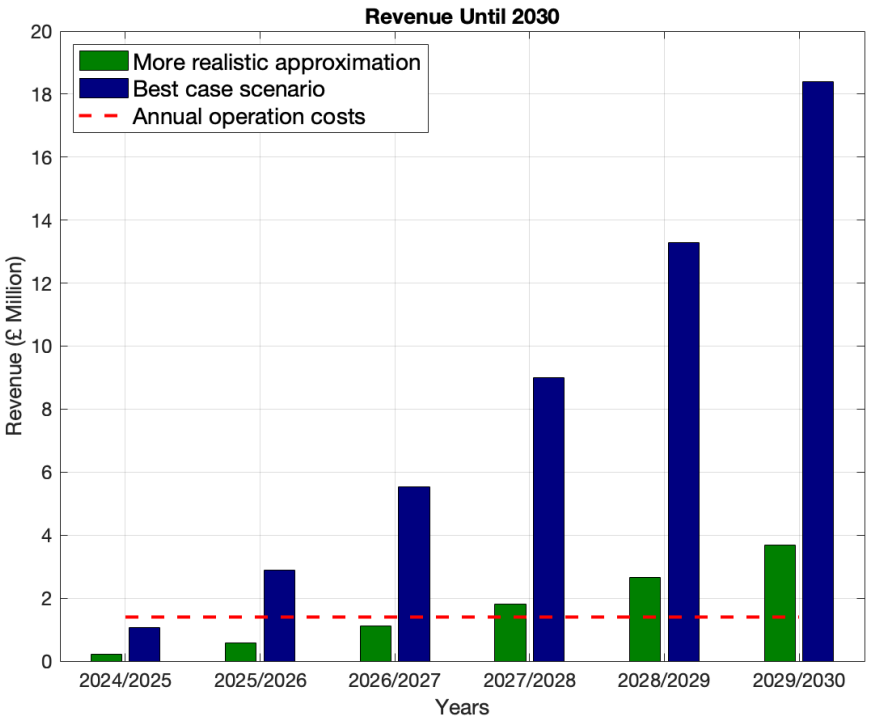


Figure 12.2: Bar chart showing revenues compared to operational costs.

Transaction fees will be charged to companies who purchase WHTR coins from other companies. The basic rate is 1%, where 50% of transaction fees goes towards maintaining blockchain costs, and the other 50% goes to offsetting the carbon emitted by the Whater blockchain.

Table 12.5: Transaction fees using a flat rate of 1%.

Year	Transaction Fees
2024/2025	£ 28,328.00
2025/2026	£ 38,504.00
2026/2027	£ 49,144.00
2027/2028	£ 60,064.00
2028/2029	£ 70,864.00
2029/2030	£ 81,712.00

Using similar assumptions of 80% of excess emissions traded and 20% of excess purchased from Whater, the table above shows an estimated amount of money generated from transaction fees. To simplify the calculations, transaction fees were calculated at the bronze tier, with a standard fee of 1%.

12.3 Funding

All stakeholders previously identified have been covered comprehensively in the Risk Assessment. Their roles and importance have been well-documented and are understood. Below is a table listing various stakeholders and when Whater expects them to fund the project before the Net Zero target.

Table 12.6: Estimated funding amounts from different stakeholders.

Stakeholders	**Funding (£100,000)**					
	2024-2025	**2026**	**2027**	**2028**	**2029**	**2030 (Net Zero Target)**
Governments	5	2				
Banks	1	1	2	3		
Corporate					5	
NGOs	2	1		3		
Academic			2	1	1	
United organisations		1	2	3	3	
Crowdfunding			2	1		
Private investor			3	5	5	10

According to the costs and revenue generated per year, Whater expects to break even during the second quarter of the 3rd fiscal year and become profitable after 2027/2028. The first year of Whater's costs will include both initial and annual costs. The revenue generated for the calculations includes both revenue from Whater's "best case scenario" due to the multiplier fee we have implemented and also the transaction fees when buying WHTR tokens.

Table 12.7: Costs, revenue, and overall cash flow for each year.

Year	**Cost (£)**	**Funding (£)**	**Revenue (£)**	**Net Cash flow (£)**
2024/2025	3,895,000	800,000	1,179,148	-1,915,852
2025/2026	1,445,000	500,000	1,311,024	-1,578,156
2026/2027	1,445,000	700,000	1,497,724	-863,936
2027/2028	1,445,000	1,800,000	1,740,704	1,182,624
2028/2029	1,445,000	1,000,000	2,036,664	2,714,224
2029/2030	1,445,000	1,600,000	2,387,392	5,185,752

13 Technical Blockchain Considerations

13.1 Incentives of Blockchain Type Chosen

Whater's system is going to be based on a public blockchain, specifically on the Ethereum platform, and coded using Solidity since the government and the companies need to have trust in the blockchain system. A public blockchain is more secure than a private blockchain because it is decentralised, ensuring its immutability and reliability. A private blockchain tends to be centralised and is controlled by a single organisation. The public blockchain is made tamper-proof by its transparency, where all the data is spread among participants, combined with smart contracts verifying and running the transactions, open for verification by anyone. Moreover, a private blockchain is more vulnerable to security risks because of its fewer nodes. A hacker can therefore access the system more easily. In addition, companies engaging in mitigating carbon emissions using Whater's blockchain could largely benefit from the blockchain being public as the transparency of a public blockchain provides a more inclined environment to develop trust among the users. The reputation of companies could be improved if they are on track towards Net Zero 2030 due to the fact that the public would have access to the blockchain's data. Conversely, for the private blockchain privacy is prioritised over transparency, making it harder to verify authenticity of information on the blockchain, creating a sense of distrust and therefore preventing potential improvement of the company's reputation.

13.2 Web 3.0

Web 3.0 is an infrastructure based on blockchain technology, using a decentralised network. It runs on permissionless blockchains and has decentralised applications (DApps) (Singh, 2022).

Web 3.0 is the next generation of the internet which puts the internet back into the power of the users rather than centralised organisations. This is undoubtedly a powerful tool, but it is important to realise its potential problems in order for the appropriate solutions to be implemented.

Challenges across computing, bandwidth, and storage areas such as limited processing power in the Ethereum network can lead to slow performance and high latency due to each node processing every transaction. This results in expensive computational costs, deterring the development of complex decentralised applications (dApps). Bandwidth issues include network congestion, which causes slow transactions and increased fees, particularly evident during events like the Ethereum-based CryptoKitties surge. The high costs of data transfers limit the ability to move large data volumes affordably. Despite solutions like Layer 2 and sharding, scalability remains a significant hurdle. Storage challenges revolve around ensuring the availability of data stored on increasingly large blockchains, where costs are high as data must be replicated across many nodes (Ethereum, 2024).

13.3 Layer 2

Layer 2 is a secondary blockchain that increases scalability by sharing the burden of transactions processing on the parent chain (Layer 1), meaning that it handles part of its capabilities. Built on top of Ethereum, Layer 2 solves the most common challenge in this field: the blockchain trilemma. Ethereum, like other blockchain architectures, inevitably prioritise decentralisation, security and scalability. Ethereum focuses on the first two since speed is not a priority. The drawback however, is that only 15-30 TPS are possible to be executed (compared to VISA's

1700 TPS). Layer 2 tackles this issue and offers faster, cheaper transactions. There are two types of Layer 2, Rollups and Sidechains that are outlined below.

Rollups: Rollups bundle (or 'roll up') hundreds of transactions into a single transaction on Layer 1. This distributes the Layer 1 transaction fees across everyone in the rollup, making it cheaper for each user. The transaction data in the rollup is submitted to Layer 1, but the execution is done separately by the rollup. By submitting transaction data onto Layer 1, rollups inherit the security of Ethereum. There are two types of rollups, optimistic and zero-knowledge (Ethereum, n.d.). In simple terms, this means the blockchain needs to do less work and store less data for transactions that take place on a Layer 2, leading to a lower total cost per transaction.

Optimistic rollups, a specific type of rollups, are termed "optimistic" because they presume that off-chain transactions are valid without immediately requiring proof of their validity when transaction batches are posted on-chain. Instead of verifying transactions immediately, optimistic rollups use a fraud-proving mechanism to identify incorrect transactions. After a rollup batch is submitted to Ethereum, there is a challenge period during which anyone can dispute the results by providing a fraud proof. If the fraud proof is validated, the rollup protocol will reprocess the transactions and adjust the rollup's state as needed (Wackerow, 2024).

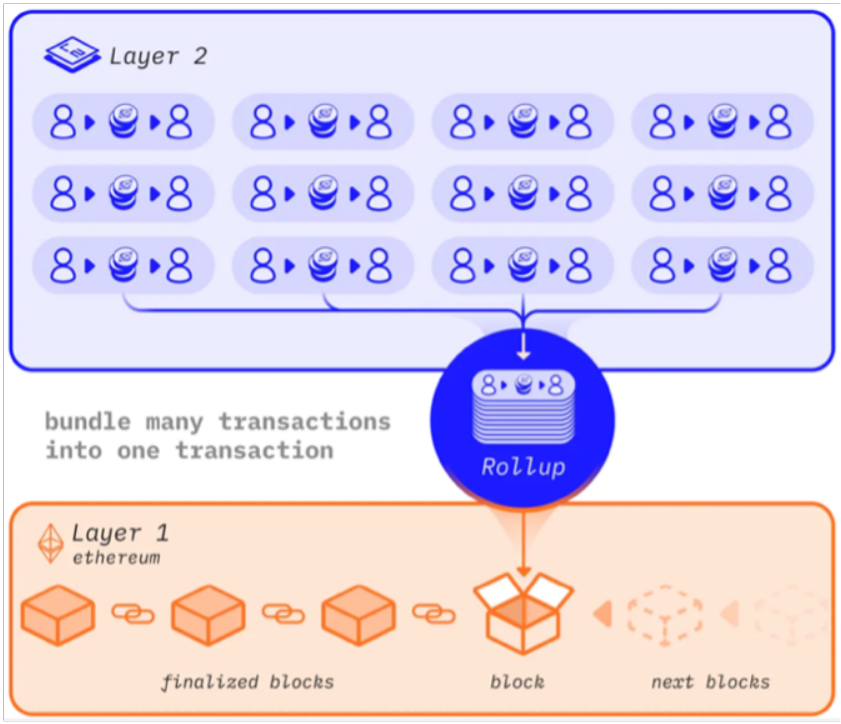


Figure 13.1: Rollups blockchain (Ethereum, n.d.).

Sidechains: A sidechain is the second type of Layer 2 discussed in this section. It is a separate blockchain network that connects to another blockchain called a parent blockchain or mainnet via a two-way peg. A two-way peg allows digital assets such as bitcoin to be transferred back and forth between the mainnet and the new sidechain. The "transfer" of a digital asset does not however actually occur; instead, they are simply locked on the mainnet while the equivalent amount is unlocked in the sidechain. No secondary actor is allowed to stop the transaction to happen between the two parties. The digital assets will be allowed to move without counterparty risks. This also implies that the two parties must act with genuine intentions to prevent frauds (Roth, 2022).

For the scope of this project, it was concluded that Arbitrum, an optimistic rollup, will be implemented in the execution of the blockchain platform. This choice is backed by the fact that Arbitrum cuts down the speed and costs of transactions by bundling them and processing them off-chain, capable of managing a total of 40,000 TPS, with transactions costing around two cents on average.

13.4 Arbitrum

13.4.1 Benefits and Challenges of Optimistic Rollups

Table 13.1: Advantages and disadvantages of ZK and Optimistic Rollups (Nervos, 2023).

	ZK	**Optimistic**
Benefits	Faster withdrawal time since there is no need for a dispute period. Everything is verified through cryptographic proofs.	Lower rollup costs since there is no need to use cryptographic proofs for every transaction block. Since every transaction is assumed to be valid until a fraud-proof claim, it saves a lot of costs for data submission.
Drawbacks	More expensive hardware requirements and costs to generate zero-knowledge proofs for validations.	Long withdrawal period (from Layer 2 to Layer 1) due to dispute period and fraud-proof mechanism which requires the existence of verifiers.

For users, the crucial difference between the two rollup types is the withdrawal time. Namely, because Optimistic rollups rely on validators to check each transaction, and potentially dispute it if they deem it not valid, the withdrawal time for assets can last from several days to up to two weeks. While the dispute period for various Optimistic rollup implementations may vary, it is nevertheless necessary, meaning that users must always wait a couple of days to withdraw their money on the base chain (Nervos, 2023).

13.4.2 Arbitrum (Orbit Stack) vs Optimism (OP Stack)

Arbitrum and Optimism are both Layer 2 chains helping Ethereum to share the workload. They use optimistic rollups to roll up hundreds of transactions into one and offload traffic from the Ethereum mainnet to the second layer. This reduces the network load for the first layer and allows for faster transaction processing and cheaper fees by doing the bulk of the computation on the Layer 2 chain.

Optimistic rollups derive their name from the optimistic assumption that all transaction data is valid when aggregated into batches for verification on the Layer 1 chain. Both chains use fraud proofs, which can be imagined as tests for the validity of the data. Because these rollups are trustless, transaction finality is instant and the blockchains produce a much higher throughput than Ethereum. The trade-off is that there is a seven-day challenge window for verifiers to challenge the validity of submitted transactions (Cryptoslav, 2023).

Arbitrum Orbit Stack:
Orbit relates to Arbitrum in the same way that Arbitrum relates to Ethereum. Essentially a rollup. It is the development framework for creating and deploying permissionless Layer 3s on top of the Arbitrum mainnet (Blocmates, 2023). It basically allows for the creation of a chain that settles to one of Arbitrum's public Layer 2 chains. Currently, Arbitrum One, Arbitrum Nova, and Arbitrum Goerli are public Layer 2 chains that settle on Ethereum. Ethereum is a public Layer 1 chain.

Arbitrum Orbit allows developers to launch Layer 3 solutions on top of Arbitrum without permission, leveraging its technology. The upcoming Stylus upgrade will introduce "EVM+", which will enable contracts written in languages like Rust, C, and C++ to interact synchronously with existing Solidity-based contracts. This will open doors to a wider developer community, improve network performance, and reduce fees (Codezeros, 2024).

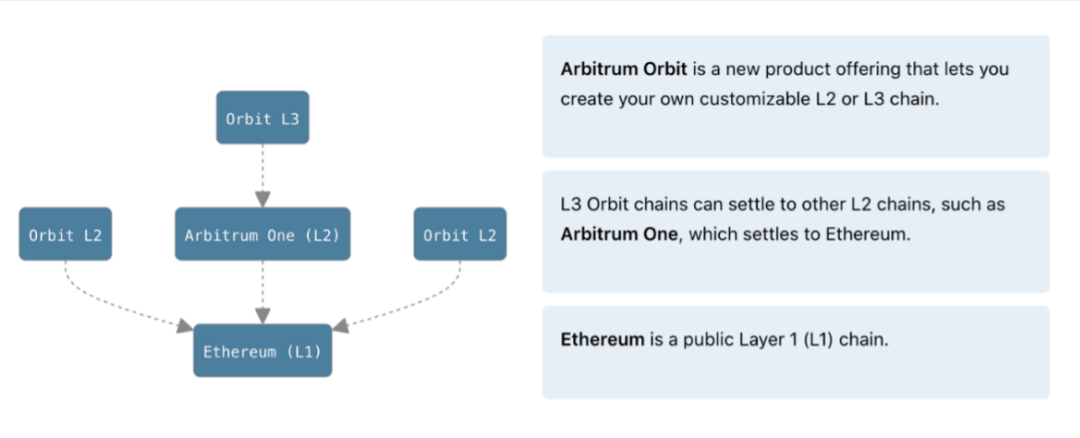


Figure 13.2: Arbitrum Orbit Stack Mechanism (Arbitrum, n.d.).

Optimism OP Stack:
OP Stack and Optimism Bedrock are components that enable scalability and interoperability for various Layer 2 solutions, not just optimistic rollups. Optimism Bedrock is the first release, which will improve the modularity, performance, and future proofing of the chain. It will also reduce transaction fees, optimise deposits and withdrawals, and improve node syncing (Codezeros, 2024).

The main technical difference between the two chains is that Optimism uses single-round fraud proofs, while Arbitrum uses multi-round fraud proofs. This means Optimism's method is faster but potentially more expensive. This is due to higher gas fees since it is executed on the Layer 1. Arbitrum's methodology takes more time but is more cost-effective.

Furthermore, Optimism uses the Ethereum Virtual Machine (EVM), while Arbitrum has its own Arbitrum Virtual Machine (AVM). That means Optimism's programming language is limited to Solidity. Arbitrum supports all EVM programming languages (Cryptoslav, 2023).

Moreover, Optimism is collaborating with Coinbase to develop a new blockchain that will use the OP Stack to create a network of interoperable rollups. This will allow seamless communication and infrastructure sharing between different Layer 2 networks. This partnership could lead to increased adoption and growth for Optimistic rollup solutions.

Table 13.2: Comparison of Arbitrum and Optimism (Codezeros, 2024).

Feature	Arbitrum	Optimism
Fraud-proofs	Multi-round fraud proofs	Single-round fraud proofs
Network performance	High: due to focus on a single point for transaction disagreement	Low: due to reliance on L1 to execute L2 transaction
Virtual Machine	Arbitrum Virtual Machine (AVM)	Ethereum Virtual Machine (EVM)
Programming Languages	Supports all EVM programming languages, such as Solidity, Vyper, Flint, LLL, YUL+, and others	Limited to a Solidity compiler for OVM bytecode
Token usage	Native ETH Support	Wrapped ETH (WETH)

As a startup, Whater will be prioritising costs rather than efficiency in the early stages of its existence. Building the blockchain on existing Arbitrum infrastructure is a promising start. With the help of Arbitrum Orbit, Whater will be able to develop smart contracts tailored to the aim of reducing carbon emissions in wastewater treatment plants.

13.5 Smart Contract Coding

Smart contracts were written in Solidity, deploying on the Arbitrum blockchain. They automate and streamline the process of emissions tracking, token allocation, and trading, ensuring compliance with government regulations. In the Whater platform, smart contracts facilitate the management of WHTR tokens, where each token is equivalent to one tonne of carbon dioxide emissions. The smart contract was coded in Solidity as seen in the code below, and achieves the following points:

- Enables companies to report carbon emissions to be stored on the blockchain.
- The contract owner can set permitted emission caps and the contract allocates WHTR tokens.
- Companies can stake WHTR tokens for specified periods or participate in governance.
- Facilitates the transfer and trading of WHTR tokens between companies on the blockchain marketplace.
- Companies exceeding their emission caps can buy additional WHTR tokens, while those with a surplus can sell them.
- Companies are categorised into bronze, silver, and gold tiers, based on the percentage of tokens saved, benefitting from transaction fees and enhanced publicity.
- Implements a yearly reduction in the total supply of WHTR tokens promoting emission reductions.
- Allows contract owners to update policies and compliance standards.
- Companies must adhere to these policies upon joining and participating in the blockchain.

Solidity Smart Contract Code:

```
// Contract Initialisation
// Establishes the smart contract on the blockchain and initialises key
    variables.

// Specify the Solidity compiler version
pragma solidity ^0.8.0;

// Import the ERC20 token standard, functionality to designate an owner for the
    contract, and SafeMath library for safe mathematical operations.
import "@openzeppelin/contracts/token/ERC20/ERC20.sol";
import "@openzeppelin/contracts/access/Ownable.sol";
import "@openzeppelin/contracts/utils/math/SafeMath.sol";

// Declare the main contract inheriting from Ownable
contract WhaterPlatform is Ownable {
    using SafeMath for uint256; // Enable SafeMath functions for uint256 types

    WHTRToken public token; // Declare a public variable for the WHTR token
        contract.
    uint256 public reductionYear; // Store the timestamp for the last reduction
        year.
    uint256 public reductionPercentage; // Store the annual reduction
        percentage.
    uint256 public capTimestamp; // Store the timestamp for setting emission
        caps.

    // 'Mapping' declarations to store emissions data, permitted emissions,
        staked tokens, initial allocations, and tier levels.
    mapping(address => uint256) public emissionsData;
    mapping(address => uint256) public permittedEmissions;
    mapping(address => uint256) public stakedTokens;
    mapping(address => uint256) public initialAllocations;
    mapping(address => uint256) public tiers;
    uint256 constant YEAR = 365 days; // Defines a constant for 1 year.

    // 'Event' declarations to log various activities.
    event EmissionReported(address indexed company, uint256 amount);
    event TokensAllocated(address indexed company, uint256 amount);
    event TokensStaked(address indexed company, uint256 amount);
    event TokensTraded(address indexed company, uint256 amount);
    event TierUpdated(address indexed company, uint256 newTier);

    // Define the contract constructor, initialising the WHTR token and setting
        the reduction year and percentage.
    constructor(uint256 initialSupply) {
        token = new WHTRToken(initialSupply);
        reductionYear = block.timestamp;
        reductionPercentage = 5; // Example reduction percentage per year
        transferOwnership(msg.sender); // Set contract deployer as the owner
    }

    // Emission Data Reporting
    // Allows firms to report their emission data.
    function reportEmissions(uint256 amount) public {
        // Store the reported emissions
        emissionsData[msg.sender] = amount;
        // Emit an event logging the emissions report
        emit EmissionReported(msg.sender, amount);
    }

    // Allow the owner to set permitted emissions for a company.
```

```
    function setPermittedEmissions(address company, uint256 amount) public
        onlyOwner {
        // Store the permitted emissions
        permittedEmissions[company] = amount;
        // Store initial allocation for tier calculation
        initialAllocations[company] = amount;
    }

    // Coin Allocation Based on Emissions
    // Allocated WHTR coins to firms based on their reported and permitted
        emissions.

    // Allow the owner to allocate coins based on emissions data.
    function allocateCoins(address company) public onlyOwner {
        // Retrieve permitted emissions.
        uint256 permitted = permittedEmissions[company];
        // Retrieve reported emissions.
        uint256 reported = emissionsData[company];
        // Calculate coins to allocate.
        uint256 coinsToAllocate = calculateAllocation(reported, permitted);
        // Transfers calculated coins to the company.
        token.transfer(company, coinsToAllocate);
        // Updates the company's tier level based on saved coins.
        updateTierLevel(company);
        // Emit an event logging the allocation.
        emit TokensAllocated(company, coinsToAllocate);
    }

    // Calculate the number of tokens to allocate. If reported emissions are
        within permitted limits, calculate the allocation.
    function calculateAllocation(uint256 reported, uint256 permitted) internal
        pure returns (uint256) {
        if (reported <= permitted) {
            return (permitted - reported) * 1e18; // Convert to token's
                smallest unit
        } else {
            return 0; // No coins if emissions exceed permitted
        }
    }

    // Trading and Transferring Coins
    // Facilitates the trading and transfer of WHTR coins between firms.

    // Allow a company to transfer coins to another address.
    function transferCoins(address to, uint256 amount) public {
        // Transfer the specified amount from the sender to the recipient.
        token.transferFrom(msg.sender, to, amount);
    }

    // Staking and Unstaking Tokens
    // Allows firms to stake and unstake their WHTR tokens for rewards or
        governance participation.
    function stakeTokens(uint256 amount) public {
        // Ensure the company has enough balance to stake.
        require(token.balanceOf(msg.sender) >= amount, "Insufficient balance to
            stake");
        // Transfer tokens from the company to the contract for staking.
        token.transferFrom(msg.sender, address(this), amount);
        // Record the staked tokens.
        stakedTokens[msg.sender] = stakedTokens[msg.sender].add(amount);
        // Emit an event logging the staking.
        emit TokensStaked(msg.sender, amount);
    }
```

```
    // Allows a company to unstake tokens.
    function unstakeTokens(uint256 amount) public {
        // Ensures the company has enough staked tokens to unstake.
        require(stakedTokens[msg.sender] >= amount, "Insufficient staked
            balance to unstake");
        // Records the unstaked tokens.
        stakedTokens[msg.sender] = stakedTokens[msg.sender].sub(amount);
        // Transfers the unstaked tokens back to the company.
        token.transfer(msg.sender, amount);
        // Emit an event logging the unstaking.
        emit TokensUnstaked(msg.sender, amount);
    }

    // External Audits and Adjustments
    // Allows for external audits and necessary adjustments to emissions
        reports and coin allocation.
    // Allows the owner to adjust the emission data for a company.
    function adjustEmissions(address company, uint256 newEmission) public
        onlyOwner {
        // Updates the company's emission data.
        emissionsData[company] = newEmission;
        // Call an internal function to reallocate coins based on the new
            emission data.
        reallocateCoins(company);
    }

    // Internal function to reallocate coins after emission adjustment.
    function reallocateCoins(address company) internal {
        // Retrieve the permitted emissions for the company.
        uint256 permitted = permittedEmissions[company];
        // Retrieve the reported emissions for the company.
        uint256 reported = emissionsData[company];
        // Calculate the number of coins to allocate based on updated emissions
            .
        uint256 coinsToAllocate = calculateAllocation(reported, permitted);
        // Transfer the calculated coins to the company.
        token.transfer(company, coinsToAllocate);
        // Update the company's tier level based on the new saved coins
        updateTierLevel(company);
    }

    // Governance and Policy Updates
    // Manages updates to blockchain policies and compliance standards.

    // Declare a public string to store the current policy.
    string public currentPolicy;
    // Allow the owner to update the policy.
    function updatePolicy(string memory newPolicy) public onlyOwner {
        // Set new policy.
        currentPolicy = newPolicy;
    }

    // Tier Level Management
    // Manages the tier levels of companies based on their token savings.
    // Internal function to update the tier level of a company.
    function updateTierLevel(address company) internal {
        // Retrieve the initial amount of coins allocated to the company.
        uint256 initialAmount = initialAllocations[company];
        // Retrieve the current balance of the company's coins.
        uint256 currentBalance = token.balanceOf(company);
        // Calculate the percentage of coins saved.
```

```
        uint256 percentSaved = (initialAmount.sub(currentBalance)).mul(100).div
            (initialAmount);
        // Determine new tier based on the percentage saved.
        uint256 newTier = determineTier(percentSaved);
        tiers[company] = newTier; // Updates the company's tier level.
        emit TierUpdated(company, newTier); // Emit an event logging the tier
            update.
    }

    // Determine the tier based on the percentage of coins saved.
    function determineTier(uint256 percentSaved) internal pure returns (uint256
        ) {
        // If 'percentSaves' is 20% or more, company is in Gold Tier
        // If between 10% and 20%, company is in Silver Tier.
        // If less than 10% company is in Bronze Tier.
        if (percentSaved >= 20) {
            return 3; // Gold Tier
        } else if (percentSaved >= 10) {
            return 2; // Silver Tier
        } else {
            return 1; // Bronze Tier
        }
    }
}

// Token Creation with Burn Functionality
// Define the WHTR token, inheriting from a standard ERC-20 token with burning
    capability.
contract WHTRToken is ERC20 {
    // Initialise the token with a given supply.
    constructor(uint256 initialSupply) ERC20("WhaterCoin", "WHTR") {
        _mint(msg.sender, initialSupply); // Mint the initial supply to the
            deployer's address.
    }
}
```

13.6 Blockchain Platform Coding

The Whater platform was developed using Solidity for managing carbon emissions in the wastewater industry. This platform leverages the Arbitrum layer, making it ideal for handling numerous transactions expected in the compliance market. To deploy and manage the smart contracts, nodes are created and maintained on the Arbitrium network. The nodes play a crucial role in validating transactions, maintaining the blockchain ledger. Rigorous testing had been conducted using Hardhat's testing framework to ensure the contract functions as intended. Explanations of the code alongside the code itself can be found in the code below.

Blockchain Platform Code:

```
// Hardhat configuration
require("@nomiclabs/hardhat-ethers");
require("@nomiclabs/hardhat-waffle");

module.exports = {
  solidity: "0.8.0",
  networks: {
    arbitrum: {
      url: "https://arb1.arbitrum.io/rpc",
      accounts: [`0x${YOUR_PRIVATE_KEY}`]
    }
  }
};

// Smart contract deployment
async function main() {
    const [deployer] = await ethers.getSigners();

    console.log("Deploying contracts with the account:", deployer.address);

    const initialSupply = ethers.utils.parseEther("1000000");
    const WhaterPlatform = await ethers.getContractFactory("WhaterPlatform");
    const platform = await WhaterPlatform.deploy(initialSupply);

    console.log("WhaterPlatform deployed to:", platform.address);
}

main()
    .then(() => process.exit(0))
    .catch((error) => {
      console.error(error);
      process.exit(1);
    });

// Deploy to Arbitrum
npx hardhat run scripts/deploy.js --network arbitrum
```

14 Beyond 2030

14.1 Water Trading

The opening of the Water Market in 2017, allows businesses, charities and public sector organisations to choose an approved water retailer to look after water services like billing, meter reading and customer service. This swerves the regional monopoly that underpins household water supply and thus allows for more competition in non-household water pricing (wave, n.d). The transfer of water rights is otherwise known as water trading and is a relatively common occurrence in the UK; water companies can trade large volumes of water with each other to account for differences in water availability. This phenomenon is only expected to increase in the coming years due to growth in demand and the impacts of climate change. The water market functions like any other utility market (e.g. electricity). Retailers buy wholesale services and offer packages to business customers. Regional water companies act as the wholesalers in the water market as opposed to being the sole entity involved in supplying water to non-eligible businesses and households.

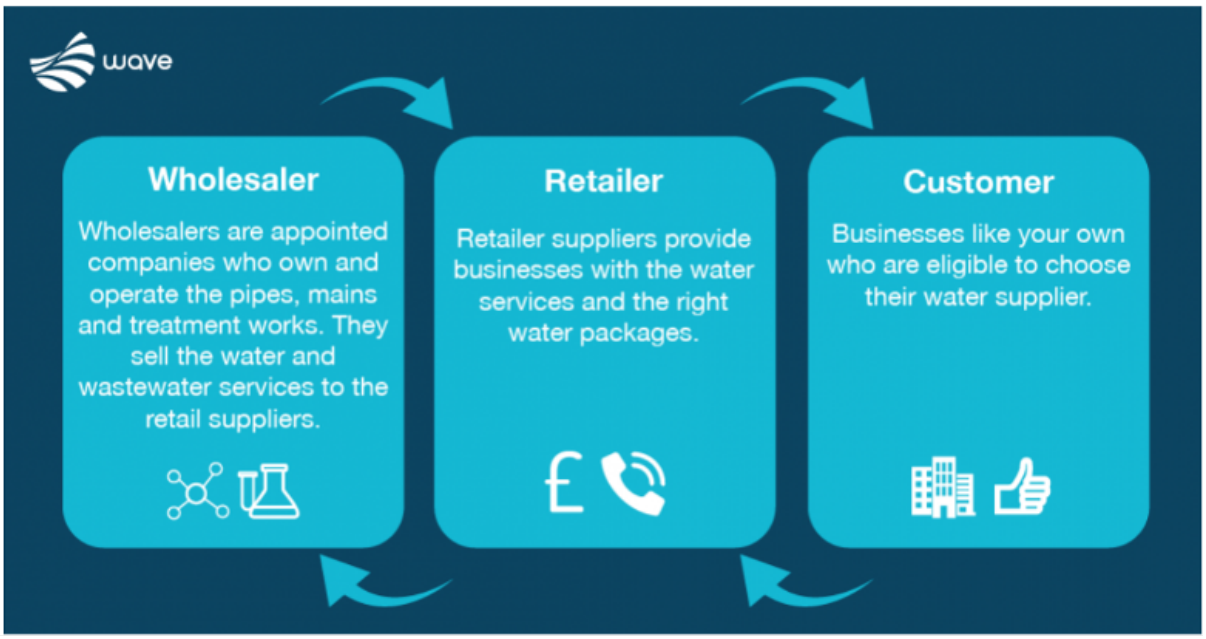


Figure 14.1: Overview of the water market (wave, n.d).

OFWAT, the water services regulation authority, has identified this area of the water industry as having perhaps the highest potential for blockchain based technology (Ofwat, 2017). If this market could be moved onto a blockchain network, regulators, water users and stakeholders would have access to the same copy of water trades and compliance information across a water network with no discrepancies. The blockchain would also offer increased transparency, efficiency, stakeholder engagement and cybersecurity.

14.2 Smart Monitoring

Smart meter technology is playing a crucial role in protecting future water resources and reducing demand in a water stressed region. The current proposal from Thames Water is to roll out this new technology which processes over 20 million readings a day and gives customers real-time data about their water consumption. On average, Thames Water's metered customers tend to

use 12% less water than in the past which reduces the amount of water abstracted from the environment by between 30 and 60Ml/d. Smart meters have already helped detect more than 80,000 leaks on customers' private supply pipes, which have been repaired, saving 57 million litres of water a day (Thames Water, 2023). There is a forecasted reduction in CO_2 emissions by an additional 965 tCO_2e by 2030 which aligns with the UK Government's aspirations of a national average usage of 110 litres-per-day by 2050.

14.2.1 Target Water Usage

Each customer is assigned a specific daily usage per capita in each household; using national statistics, the business model will set a limit of 151 litres per day, as is explained in Table 14.1. Usage is measured by smart meters, while they are also able to detect leakages. The Genesis Research and Technology Group in the US has developed a system to monitor tracking and groundwater quality (Flapper Therese, 2019). This process uses temperature, conductivity, turbidity, dissolved oxygen and pH sensors to analyse water quality during the tracking process. These records are stored on the Ethereum platform, making it possible to track and verify water quality and pump efficiency.

Table 14.1: Targets for water use in new homes (Emma Reffold et al., 2008).

Micro component	**Standard home (l/d/capita)**	**CSH Level 1/2 (120 l/d/capita)**	**CSH Level 3/4 (105 l/d/capita)**	**CSH Level 5 (80 l/d/capita)**
Toilet flushing	28.8	19.2[b]	16.8[d]	8.4 (8.4)[f]
Taps[a]	42.3	31.8	24.9	18
Shower	30.0	24	18	18
Bath	28.8	25.6[c]	25.6[c]	22.4[e]
Washing machine	16.7	15.3	15.3	7.65 (7.65)[f]
Dishwasher	3.9	3.6	3.6	3.6
Recycled water[f]	-	-	-	-16.1
Total per capita	**151**	**120**	**104**	**78**
Outdoor (garden)	11.5 – assumed	11.5	11.5	11.5
Total per home	**367**	**294**	**257**	**196**

[a] combines kitchen sink and wash hand basin

[b] 6/3 litre dual-flush toilet

[c] 160 litre bath filled to 40% capacity, frequency of use 0.4/day

[d] 4.5/3 litre dual-flush toilet

[e] 120 litre bath

[f] recycled water by rainwater harvesting (figures in brackets)

The Code for Sustainable Homes (CSH) is a UK standard for designing and constructing new homes to make them more sustainable. The CSH levels contain different ratings that indicate how sustainable a home is, with higher levels being more sustainable. CSH Level 1/2 involve simple measures that promote sustainability and improve efficiency compared to standard homes. CSH Level 5/6 uses advanced methods such as rainwater harvesting to achieve lower water usage within a household.

14.2.2 Tokenisation

If household usage is below the average, the customer will receive tokens for the equivalent value of water they offset. If household usage is above average, the customer will be required to pay an

extra amount of money per litre exceeded, or buy tokens from other households to come down to the cap. The offset will be measured at a certain period; either daily, weekly, or monthly. Using a similar concept to the previous business model, a token that equates to one litre of water saved will be created. Since the price of one meter cubed of water is approximately equal to £3 in the UK, the token-equivalent price of one meter cubed of water saved will be set to £10, which means that the price of a single token is £0.01 (Thames Water, 2021). Throughout Whater's blockchain economy, customers will be able to exchange their tokens. Tokens can be traded horizontally, between different households using the blockchain platform or through the water provision company itself. If a household has excess offset, they can also sell it back to the water provision company, through the developed user app explained in Section 14.2.7.

14.2.3 Leakage Monitoring

If a user has a leak in their plumbing which is causing waste of water and cannot afford to fix it, they may exceed the daily limit without actually consuming the daily water limit. Since the smart meters can detect leakages, the company would be alerted of the leak using the blockchain and GPT systems. They would offer the household a small allowance to exceed usage, to the leakage equivalent, above the daily limits. The water company will provide repair services at a subsidised cost to fix these leakages. However, this would be limited to a certain time period, after which the allowance will reduce back to normal levels.

14.2.4 Artificial Intelligence (GPT System)

Once the smart meter has detected a leak, GPT will help to predict the estimated losses over time, according to the monitored usage over time. It will then create an alert according to unusual statistics and provide the appropriate mitigation strategies as shown below.

Alert: We've noticed unusual water usage between 2 AM and 4 AM, which is inconsistent with your typical usage patterns. This could indicate a leaking toilet or an issue with an appliance such as a dishwasher running unexpectedly. Here are some steps to check:

- Inspect toilets for running water sounds.
- Ensure all water-using appliances are turned off properly.
- If the issue persists, consider scheduling a maintenance check.

The GPT system not only detects the anomaly but also provides a plausible explanation and clear steps to diagnose and fix the issue, improving the user's ability to respond effectively.

14.2.5 Carbon Equivalence

Each litre of water consumed has a corresponding quantitative emission of embodied carbon. The largest portion of the carbon emissions (89%) comes from water used directly within the home. For a single household, 2.2 kg CO_2e is emitted daily as the equivalent carbon emission from domestic services such as showering or flushing toilets, as seen in Figure 14.2.

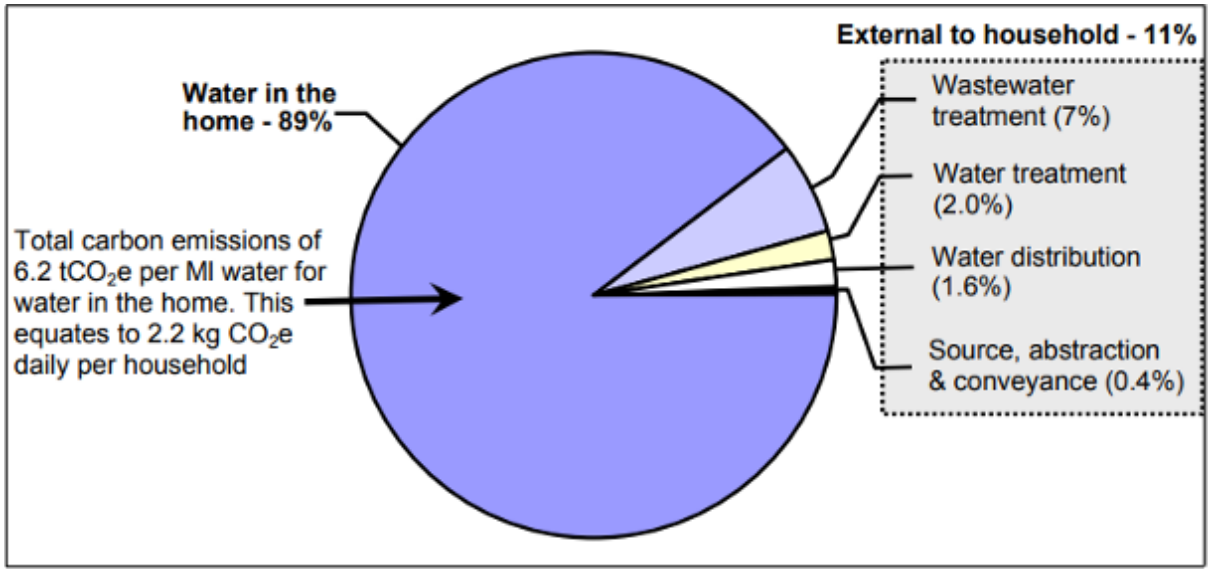


Figure 14.2: Breakdown of domestic water usage (Emma Reffold et al., 2008).

Table 14.2: Carbon cost modelling (Emma Reffold et al., 2008).

Water efficiency option	**Water Savings Ml per year**	**Carbon costs £ '000**	**Carbon savings £ '000**	**Net carbon emitted tCO_2e '000**
Water efficiency measures - model results for 1000 households over 60 years				
Metering	13 to 16	2 to 4	250 to 320	-5 to -6
Low flush toilet	9 to 12	¡1 to 5	10 to 20	-0.2 to -0.3
Bath/shower/tap	3 to 15	4 to 15	50 to 200	-0.8 to -4
White goods	1	80	30	1.8
Rainwater harvesting	40	160 to 280	50	2.4 to 4.8
Greywater recycling	25	180 to 295	35	3.0 to 5.4
Variable tariffs	7	0	125	-1.5
Water audits	4	0	125	-2.5
Leakage Control - model results based on available data				
Repair leaks detected	365 to 1500	250 to 1200	300 to 1300	-1 to 2
Repair leaks reported	5730	3500	4900	-21
Water mains renewal	365	345 to 800	310	3 to 16
Service pipes renewal	365	120	310	-3
Control pressure	6200	no data	5300	-110

In the long run (60 years), the forecasted savings in carbon emissions and costs by this system are shown in Table 14.2. The smart meters will provide better leakage control as the water efficiency measures suggested by the GPT system will allow a reduction in overall emissions. It illustrates the predicted positive outcomes for both consumers and water provision companies, who achieve their goals of lower water bills and net zero carbon emissions respectively.

14.2.6 Blockchain Application

Regulators, water users and stakeholders have the same copy of water trading and compliance information across a water network with no discrepancies which means the blockchain could bring benefits such as increased transparency, efficiency, stakeholder engagement, and cyber-security. The water company will be the principal manager of the public blockchain, ensuring personal customer information can only be visible to the specific household itself. This project also has an awareness-raising dimension, helping each user have a better understanding of their

daily water consumption.

14.2.7 App Development

Figure 14.3 shows how Whater's app interface would look like. Consumers would have an account from which they will be able to visualise how much water they saved. This would be through bronze, silver and gold status which will visually incentivise saving water. Rewards would be awarded for each level reached. As the virtual tanks get filled, there is progression to the next level and consumers will benefit from more substantial rewards as they progress. The AI assistant will give customised alerts based on the behaviour of the customers, as well as possible ways to improve their water management. Lastly, there would be a trading platform where customers can buy or sell WHTR coins. The token-equivalent price of one meter cubed of water saved will be £10, which means that the price of a single token is £0.01. This incentivises utilisation of the platform, as well as providing the customers a sustainable way to make money by saving their water resources.

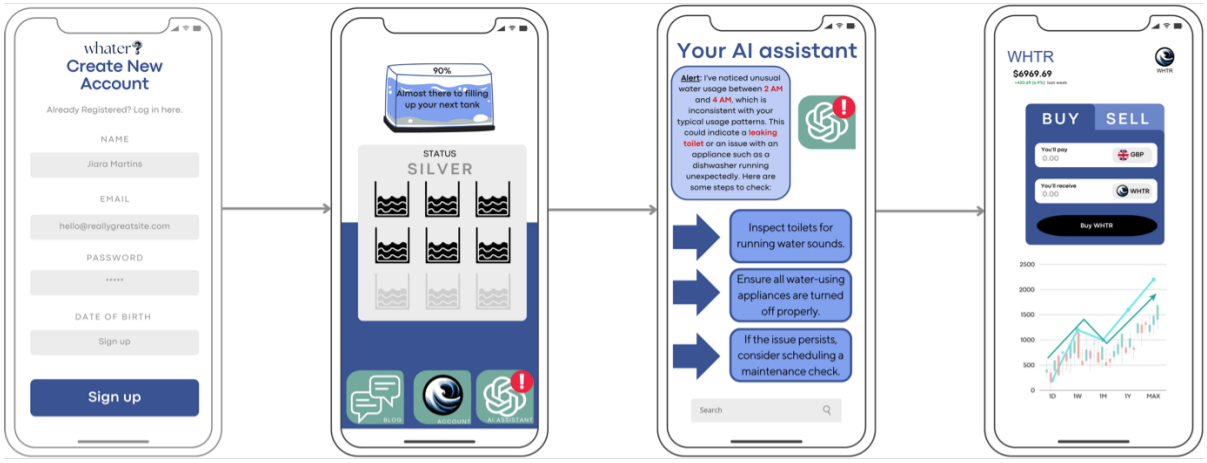


Figure 14.3: Prototype of app development.

14.3 Expanding to Other Industries and Countries

Another option for the operation of Whater after 2030 would be making the platform global and expanding beyond the UK. This would support broader efforts to achieve net-zero emissions. In such a way, water infrastructure companies in the UK would be able to trade WHTR coins with companies all around the world. Considering that carbon credit prices in the UK are more expensive than other countries, Whater would make profit by trading with such countries. Additionally, they may be allowed to trade with other industries as well.

However, this is not simple considering countries have different regulations. Whater would have to adhere to international and regional regulations such as the Kyoto Protocol, Paris Agreement, and the EU Emissions Trading System (Gryaznova & Piskulova, 2023). The system would also have to be designed for interoperability with existing systems and scalability for growing market demands. A user-friendly interface with multilingual support would be developed, and a transparent pricing mechanism that reflects real-time market dynamics would be established.

By 2030, wastewater companies will have reached net zero with the help of Whater's blockchain technology and WHTR tokens for efficient carbon trading. As the cap is lowered every year by the UK-ETS, the carbon credits available for trading within the Whater platform will be reduced by 2030 which creates a low liquidity in the carbon trading market. To account for

this, the Whater blockchain technology will be expanded to other industries such as fashion, transportation, and energy to help more companies reach net zero emissions. This would also increase the carbon credits in the market, ensuring higher liquidity of carbon credits.

Fashion is the third most polluting industry, accounting for about 10% of annual carbon footprint (Richards, 2021). To compare, it is more than all international flights and maritime shipping combined. In addition to GHG emissions, the fashion industry's water consumption represents enough water to quench the thirst of five million people every year (Bandera, 2024). There is a large margin of improvement in the fashion industry that would represent an interesting market (Plasencia, 2023a). By implementing blockchain technology and loT devices across the production line, this could enhance tracking and management of the wastewater usage and carbon footprint, thus improving energy efficiency and promoting sustainability, ultimately helping to reach net zero by 2050.

Transport is responsible for about one-fifth of GHG emissions. About 40% of these come from the transportation of merchandise, while the rest come from passenger travel, led by air travel (Plasencia, 2023b). Blockchain technology could help in the efficiency of merchandise transportation. This would range from resource distribution to approvals, in order to avoid empty-truckload traveling and reduce risk of products being held up or lost (WINNESOTA, 2023).

Considering the extraction and transportation of building materials, construction processes and everyday operations, buildings are estimated to emit about 40% of global emissions (Plasencia, 2023b). Immutable records on blockchain would reduce the risk of fraudulent claims about building materials or construction practices, ensuring that certifications are based on accurate data (Forough, 2023).

15 Webpage Interface

A prototype of Whater's website has been developed which conveys the business' operations philosophy and technology; it can be accessed here. Through this interface, users will be able to interact with the blockchain technology and app to work towards carbon net zero and material circularity.

The website entails Whater's missions, while it allows customers to manage their WHTR tokens and get information on the app. Its purpose is to convey how interested companies and individuals can get involved. Users are able to experience the functionality of the platform, realising the benefits of the blockchain technology, allowing them to develop trust in Whater.

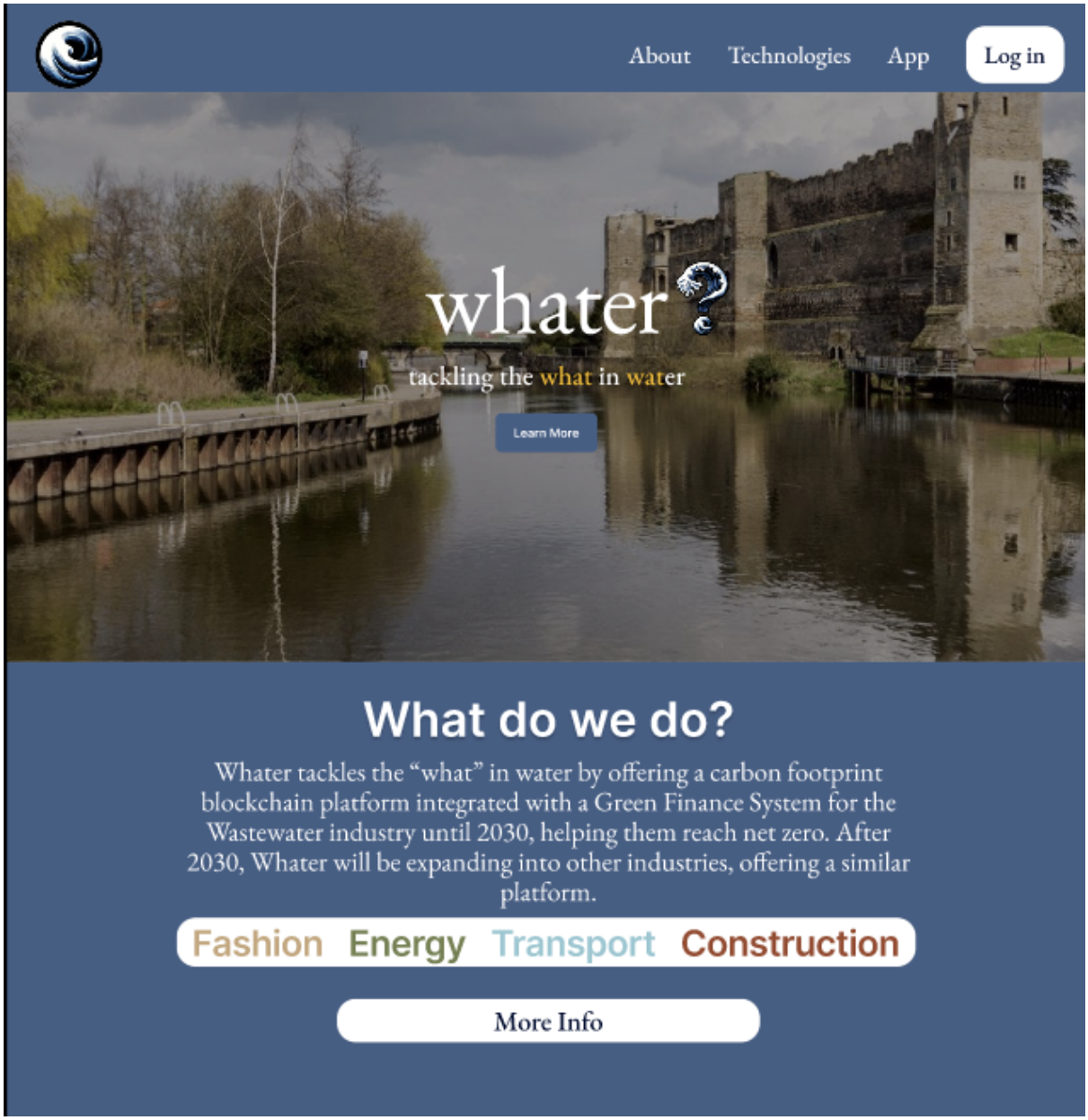


Figure 15.1: Landing page of Whater.

16 Risk Assessment

16.1 Stakeholder Analysis

The following section introduces the main stakeholders of Whater. These include the UK Government, the public, water companies, environmental agencies, investors, contractors, and NGOs.

16.1.1 UK Government

Objectives: The UK Government aims to reduce greenhouse gas emissions by 68% before 2030 in accordance with the Climate Change Act 2008 (GOV.UK, 2023). Reducing carbon emissions is a crucial goal for the UK government, especially in the context of meeting its commitments under international agreements like the Paris Agreement. Water management can play a key role in reducing these carbon emissions (Modeer, 2020). Furthermore, the UK government promotes sustainable projects and innovative technologies (Central Digital and Data Office, 2021).

Integration: To meet the demands and expectations of the UK Government, the blockchain platform must actively promote sustainability within the water industry, showing a reduction in carbon emissions with companies using the blockchain technology.

16.1.2 Public – Consumers/Communities

Objectives: The three main objectives for public consumers include adopting sustainable practices, informed decision-making, and promoting transparency. By reducing water consumption and supporting regenerative agriculture, they can contribute to climate change mitigation. Their feedback can enhance water supply quality and service levels, and their demand for transparency ensures accountability from water companies and policymakers, preventing crises like the Flint water issue where a lack of open and transparent communication led to a public health disaster (Langsdale & Cardwell, 2022).

Integration: Integrating public consumers into the carbon footprint blockchain platform for green finance in water infrastructure involves developing a user-friendly interface, incorporating gamification, tangible incentives to boost engagement, and ensuring data privacy and security. The platform should offer educational content and community-building features to increase awareness and collective action. Partnerships with local governments and NGOs will help promote the platform and validate its initiatives. Real-time impact tracking through blockchain will provide transparency, while a feedback mechanism will allow continuous improvement based on user input. These strategies will engage consumers, promote sustainable practices, and build trust in the platform.

16.1.3 Water Companies

Objectives: Water companies aim to manage water resources sustainably to minimise risks of water scarcity, pollution, and inadequate provision. They need to ensure open and transparent communication with all stakeholders to build trust and avoid crises. Additionally, water companies strive to innovate and improve efficiency in their operations, including using blockchain technology for secure and transparent water trading, as well as tackling their revenue gap in carbon trading.

Integration: Integrating water companies into a carbon footprint blockchain platform involves real-time data monitoring, using blockchain for secure water trading, and adopting sustainable practices verified on the blockchain. It enhances transparency through stakeholder collaboration and communication, incentivises sustainability with rewards, and simplifies regulatory compliance. Furthermore, it engages the community in water conservation efforts and supports innovation through pilot projects. These strategies collectively improve operational efficiency, reduce carbon footprints, and foster a collaborative ecosystem for sustainable water infrastructure.

16.1.4 Environmental Agencies/Regulatory Bodies

Objectives: Environmental Agencies will ensure environmental protection and will promote sustainability throughout the projects. They will be involved in the monitoring of carbon emissions, reducing this wherever possible. The regulatory bodies set essential standards and requirements to ensure compliance with safety, sustainability and government standards.

Integration: Environmental agencies and NGOs can collaborate on setting up blockchain monitoring that track and verifies carbon footprint data accurately. This should monitor which process generates carbon emissions and by how much. Use NGOs' expertise to validate the project's environmental benefits and enhance its public support through campaigns.

16.1.5 Investors

Objectives: Achieve good returns on investment, ensure project sustainability, and support eco-friendly projects (ESGs).

Integration: Real-time reports of Whater's outcomes and finances should be generated, such that investors can keep track of their investments. This transparency will build trust between investors and Whater, so that they can be reassured that their funds are going towards sustainable projects.

16.1.6 Contractors

Objectives: The objectives for contractors would be to enhance project management efficiency, reduce costs through financial transparency, and ensure compliance with sustainability standards.

Integration: Smart contracts automate project workflows and payments, ensuring a transparent supply chain by tracking materials on the blockchain, and monitoring sustainability performance. Additionally, the platform should facilitate collaboration between contractors and stakeholders through secure communication channels, and implement incentive programs to reward sustainability and efficiency.

16.1.7 NGOs

Objectives: NGOs aim to influence policy, advocating for stringent environmental regulations and the adoption of innovative technologies for greater transparency and accountability. They actively engage in community outreach and education, emphasising the importance of reducing carbon footprints and the benefits of blockchain for environmental transparency.

Integration: NGOs can participate in planning and stakeholder consultations, helping shape policies and ensuring community-aligned project designs. During implementation, they can partner in executing community engagement initiatives and independently monitor compliance and environmental impacts, enhancing transparency and accountability

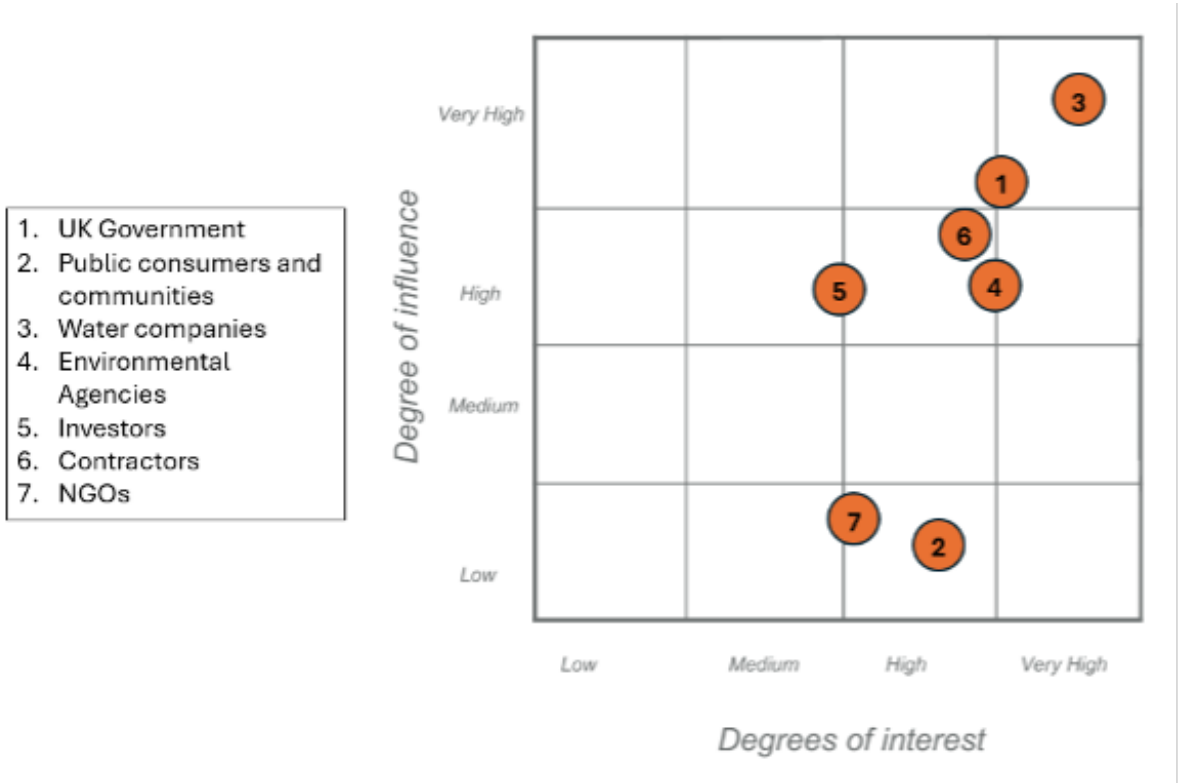


Figure 16.1: Stakeholder analysis diagram.

16.2 Risk Appetite Statement

Objective: Whater aims to develop an innovative blockchain platform to enhance material circularity, help reduce carbon emissions, and ultimately contribute towards a more sustainable future.

Having chosen to adopt quite a high-risk appetite, Whater can deem whether each risk is tolerable using Table 16.1 below. If the rating associated with a risk, as explained in the next section, results in it falling upon a red square, it is deemed intolerable, and the scope of the project must be altered to avoid all possibility of this risk materialising.

Table 16.1: Different types of risks and their tolerance.

Risk type	**Level of Tolerance**	**Description**
Technical	Moderate	There is a moderate risk appetite for technical risks because integrating blockchain technology can be complex. However, they offer significant advancements towards sustainability and operational efficiency. Effective risk management could help to ensure system stability and scalability.
Operational	Moderate	There is moderate risk appetite towards these risks. Human error during blockchain programming has the potential to compromise the security measures completely and derail the premise of project. To prevent confidential information leaks, the system should not be public until the code has been checked exhaustively. Testing and monitoring regularly is essential to avoid these very serious risks.
Regulatory	High	Blockchain startups offering a tokenised asset platform face the risk of legal uncertainty, compliance issues and regulatory changes. Although this category of risk is hard to mitigate against, hence Whater's high-risk appetite for it, legal experts should be consulted and regulators and policymakers should be engaged as much as possible.
Market	High	Blockchain technology is still in its infancy, so one must consider the risks of low demand, high competition, and price volatility. These risks are somewhat inherently associated with any emerging blockchain technology project and primarily need to be embraced. However, by undertaking extensive market research prior to the commencement of the project and by choosing the niche carefully, wastewater in this case, these risks can be limited.

16.3 Risk Assessment

16.3.1 Operational Risk

Operational risk is present in the daily functioning of the project once in use.

1. Cybersecurity Risk
Cyber threats such as data breaches, DDOS attacks, and smart contracts vulnerabilities pose significant risks. A combination of responses is necessary to guard against these various forms of cybersecurity risks. Primarily, these are risks that should be terminated. This can be done by eliminating features that excessively expose sensitive data, and the removal and restricted access that are vulnerable to DDoS. To support this, treatment by strong encryption, code review (testing), and protection solutions can defend in the long term. Unauthorized alteration or an attempt to manipulate one of the blocks in the chain (i.e., change in the Hash number).

2. Energy Consumption
Particularly high for proof-of-work systems, which is the process of verifying transactions and creating new blocks on the chain, thus contributing to significant greenhouse gas emissions.

16.3.2 Design Project Risk

Design project risks affect the successful delivery of the strategic vision.

3. Technical Risk
Technical challenges in blockchain technology include scalability challenges when handling large amounts of data, as well as complexity risks when it comes to merging it with established water infrastructure systems. The technology may not be compatible with existing frameworks, and given the rapid advancements in blockchain technology, continuous updates are essential to keep up with developments in the industry. Other difficulties can include operational problems with the platform, or even its crashing and disruptions in the technical supply chain.

4. Resource and Workforce Risk
Different resource-related challenges exist including scarcity of developers skilled in both blockchain and sustainability, inadequate computational resources for blockchain operations, dependencies on external data sources for accurate carbon footprint calculations, and the risk of material supply chain failures. A relatively new technology such as blockchain is required to have significant changes in both business processes and corporate culture.

5. Environmental Problems
Climate-related risks, especially concerning location play a crucial role in design phases. For example, locations prone to flooding or heavy rainfall may face challenges with water infrastructure. Blockchain applications designed to track and manage water allocations need to be highly accurate and responsive to changes in the availability of water. Different regions also have different regulations that could impact blockchain technology, including technology standards.

16.3.3 Strategic Risk

Strategic risks are long-term and affect the fundamental objectives or direction of the project.

6. Geopolitical Risk
Geopolitical risk can significantly impact blockchain technology through regulatory uncertainties and trade barriers between different countries, restricted access to funding, talent, and different markets. Furthermore, geopolitical tensions between countries can also raise concerns for cybersecurity risk as mentioned in the operational risk as well as affecting investors' confidence in the investments of blockchain technology.

7. Regulatory Risk
Government legislation about carbon emissions is increasingly strict given the growing climate awareness and so if there is increased regulation that affects how carbon can be traded or needs to be controlled then treating is the best response. This is achieved by proactive engagement with regulators, ensuring that the blockchain system remains compliant with existing and upcoming regulations, thus reducing the likelihood of non-compliance and associated penalties.

8. Market Risk
The blockchain technology can be influenced by market fluctuations. For example, in the carbon market, regulatory changes, economic factors, and geopolitical events can affect the value of the carbon credits and offsets tracked on the blockchain. The market volatility of the carbon credits may affect the decisions of the investors to participate in carbon trading and offsetting activities, thus changing the demand for carbon footprint blockchain solutions.

9. Funding Risk
The amount of funding for blockchain technology impacts its development, scalability, and commercialization. As mentioned above, changes in market conditions and investors' behaviours would affect the ability of the startup blockchain technology to secure essential capital to fund its research and operations. Moreover, economic downturns or regulatory uncertainties further contribute to the funding risk.

10. Stakeholder Risk
Engagement with stakeholders has its own risks. These can include a lack of cooperation with stakeholders, their reluctance to adopt blockchain technology due to not thorough understanding, stakeholders' resistance to providing necessary data, and failure to meet stakeholders' objectives.

11. Reputational Risk
Unlike fintech, blockchain is part of core infrastructure and will have to work with legacy infrastructure. Failure to do so could result in poor client experience and regulatory issues. Risk is a function of likelihood and impact, where impact can be measured by financial, reputational, regulatory, and safety concerns.

Table 16.2 below describes the risk score, while Table 16.3 ranks the likelihood and impact of each risk described above.

Table 16.2: Description associated with each risk score.

Likelihood (Probability Score) / Impact (Consequence Score)	
Risk Score	**Description**
1	Remote
2	Low
3	Medium
4	High
5	Very High

Table 16.3: Likelihood and impact ratings for all identified risks.

Risk	Description	Likelihood	Impact
1	Cybersecurity Risk	2	5
2	Energy Consumption	3	3
3	Technical Risk	4	4
4	Resource and Workforce Risk	2	2
5	Environmental Problems	2	1
6	Geopolitical Risk	4	3
7	Regulatory Risk	2	4
8	Market Risk	3	4
9	Funding Risk	2	4
10	Stakeholder Risk	4	3
11	Reputational Risk	1	3

Table 16.4 below indicates how the likelihood and impact ratings will change after mitigation has been applied to each of the risks.

Table 16.4: Likelihood and impact ratings for the inherent risks.

Risk	Description	Likelihood	Impact
1	Cybersecurity Risk	1	3
2	Energy Consumption	1	1
3	Technical Risk	2	4
4	Resource and Workforce Risk	1	1
5	Environmental Problems	1	1
6	Geopolitical Risk	4	1
7	Regulatory Risk	2	2
8	Market Risk	3	2
9	Funding Risk	1	2
10	Stakeholder Risk	2	2
11	Reputational Risk	1	2

Inherent risks have been identified, after which risk responses were used to mitigate the downside risk. The 4 risk responses are: Tolerate, Terminate, Transfer, Treat. Residual risks are the inherent risks after a risk response, and they all need to fall within the risk appetite. Table 16.5 below explains this process for each risk.

Table 16.5: Risks and the responses to mitigate risks.

Risk	Responses (4Ts)	Explanation
1	Terminate, Treat	Eliminate any vulnerable entry points and implement comprehensive security measures. Encryption, authentication and audits improve continuous protection against threats.
2	Treat	Proof-of-Work mechanism (which requires a large computing power) could be replaced by Proof-of-Stake one, known to be more energy efficient.
3	Treat	The likelihood can be reduced by staying informed on developments of the blockchain industry and updating the system. Regarding the processing of large volumes of data, the capacity would have to be adjusted accordingly.
4	Tolerate, Treat, Terminate	Accept that there will be initial skill gaps, but employees will obtain expertise given the proper support and training. Training could encourage people to join the industry, reducing the likelihood. Additionally, smart contracts have a conventional method of calculating carbon emissions so this risk can be terminated.
5	Treat	Regulations for smart contracts mandate the use of renewable resources to minimize carbon footprint. Stakeholders and water companies are required to adhere to these established regulations.
6	Treat, Transfer	Treat by staying updated with geotechnical trends that may impact the operations of blockchain technology. Transfer the risk by shifting the financial impact to third parties like insurance, and contractual clauses such as force majeure, and outsource certain operations to the relevant 3rd parties.
7	Treat	Ensure that the blockchain system remains compliant with existing and upcoming regulations and adapts the system accordingly.
8	Treat, Transfer	Treat by conducting detailed research on potential market needs, and developing tailored approaches to satisfy specific needs. Transfer the market risks by diversifying the partnerships with different.
9	Treat, Transfer	Treat by developing a strong business model to demonstrate its value to investors in order to attract more investments. Transfer the funding risks by seeking funding from different parties such as governments, venture capital firms and international organizations.
10	Treat	Creating feedback mechanisms, allowing transparent communication and a collaborative decision-making process will enhance the stakeholder trust and satisfaction.
11	Tolerate, Treat	Minor, unavoidable complaints do not significantly affect overall reputation and can be tolerated. However, major issues should be addressed with proactive communication, adequate brand management and a suitable crisis management plan.

Figure 16.3 places the identified risks on the defined risk appetite matrix both before and after mitigation. After mitigation, the majority of the risks fall under the green part of the matrix, with only 3 remaining in the orange part of the matrix.

It is also worth noting, that Black Swan events have been considered and have been mitigated by the inclusion of Decentralised Finance Insurance as explained in Section 10.5 of the report.

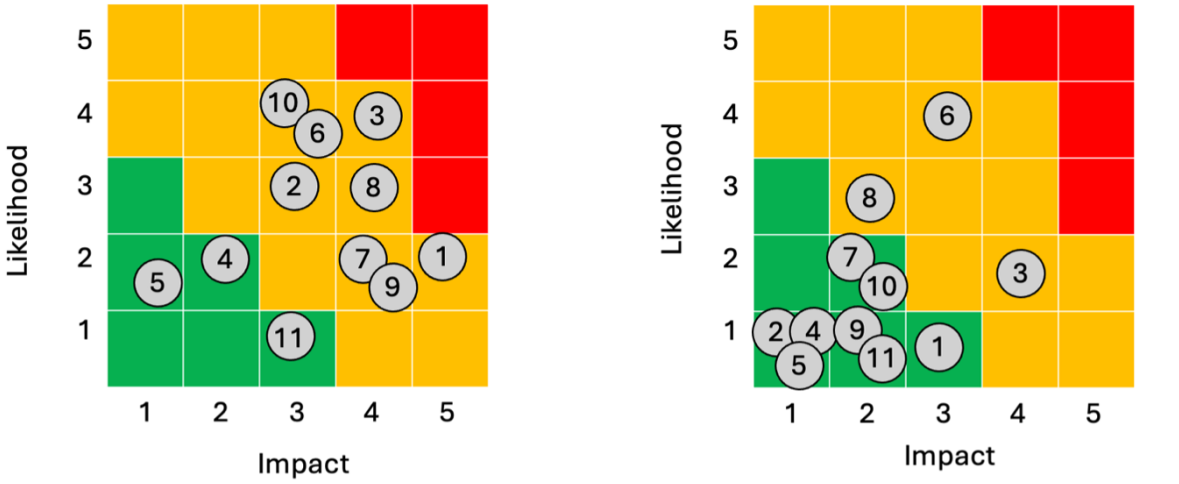


Figure 16.3: Risk likelihood-impact diagrams before (left) and after (right) risk mitigation.

16.4 Funding

16.4.1 Investors

The following institutions may contribute to funding, depending on the stage of the project:

1. Government Agencies and Public Sector Organisations:
    - Environmental Protection Agencies (EPA)
    - Department of Energy (DOE)
    - Ministry of Environment or Water Resources
    - Municipalities and Local Governments
    - Development Agencies focused on sustainability and infrastructure
    - Government grants and subsidies
2. Non-Governmental Organisations (NGOs) and Nonprofits:
    - Environmental Conservation Organisations
    - Water Advocacy Groups
    - Foundations with a focus on sustainability or environmental conservation
    - Research Institutions with interests in water management and sustainability
3. International Organisations and Initiatives:
    - United Nations programs and agencies focused on environmental sustainability (e.g., UN Environment Programme)

- International initiatives promoting sustainable development (e.g., Sustainable Development Goals)

4. Financial Institutions:
    - Green Banks
    - Development Banks (e.g. World Bank, Asian Development Bank)
    - Commercial Banks with ESG (Environmental, Social, and Governance) investment initiatives
    - Impact Investment Funds
    - Venture Capital firms focused on sustainable technologies
    - Companies with a vested interest in reducing their water footprint in their supply chains
5. Private Investors and High Net Worth Individuals:
    - Angel Investors with an interest in sustainable technologies and infrastructure
    - Family Offices with ESG investment strategies
    - Wealthy individuals passionate about environmental conservation and sustainability
6. Academic Institutions:
    - Universities and Research Centres with environmental science, engineering, or sustainability programs
    - Research grants from government agencies or private foundations
7. Crowdfunding Platforms and Community Funding:
    - Platforms dedicated to sustainable projects, such as Kickstarter or IndieGoGo
    - Local community organisations or initiatives supporting sustainability projects
8. Corporate Sector:
    - Water Utilities and Infrastructure Companies
    - Technology Companies with a focus on sustainability
    - Corporations with ESG initiatives, particularly those with interests in water management or environmental sustainability

16.4.2 Project Funding Timeline

2024-2025

Since governments and NGOs usually want to prioritise initiatives that address environmental concerns and promote sustainability and given Whater's focus on reducing carbon footprint in water management, there are high chances that these two institutions would believe in the potential of the Whater startup for significant environmental positive impact. Governments may invest early on in the project to support innovative technologies such as Whater's one that aligns with national and regional sustainability goals. Initial funding can focus on a broader initiative to encourage green technology startups and address pressing environmental challenges. NGOs are also more focused on environmental sustainability and might invest early on to support pioneering efforts in reducing carbon footprints and promoting green finance systems. Thames Water, as the main client, invests immediately to start using the blockchain platform to track and reduce its carbon footprint, enhancing both operational transparency and efficiency.

2026

Further governmental investment may come as the company demonstrates progress and potential for significant environmental impact, encouraging continued support. Banks may begin investing as the project shows initial success and potential for financial returns, aligning with their increasing interest in sustainable finance. Additional NGO investment might be driven by successful early results and the project's alignment with their environmental objectives. International organisations might invest to support global sustainability initiatives, particularly if the project shows promise for scalability and replication in other regions. Continued investment from Thames Water as the platform proves beneficial in its initial phase, encouraging further commitment.

2027

As the company demonstrates steady growth and reliable performance, more banks may invest, recognising the project's stability and potential for long-term returns. Further investment from international organisations to expand the project's impact and support broader adoption of the technology. Private investors might be attracted by the company's growing reputation and proven track record, seeing it as a viable investment opportunity. Thames Water continues its subscription, reflecting ongoing satisfaction with the platform's performance and benefits.

2028

A significant increase in bank investment as the project reaches a more mature stage, showing strong financial health and scalability potential. Increased investment from NGOs as the company scales its impact and aligns more closely with broader environmental goals. Continued support from international organisations to further promote global sustainability initiatives. Crowdfunding campaigns might be launched to attract small investors and raise public awareness, providing additional capital and community support. More private investors are likely to be drawn by the project's proven success and the increasing value of their investments. Ongoing subscription from Thames Water, indicating continued reliance on and trust in the platform.

2029

Corporations may invest as they recognise the value of integrating blockchain solutions for sustainability into their operations, driven by both regulatory pressures and corporate social responsibility goals. Academic institutions might invest in exchange for research opportunities and partnerships that align with their sustainability and technology programs. Further investment to continue supporting the project's expansion and impact. Additional crowdfunding to maintain community engagement and support, as well as to diversify funding sources. Continued investment from private investors as the company's market position strengthens. Increased investment from Thames Water as they leverage the platform more extensively to meet sustainability targets.

2030 (Net Zero Target)

Corporations might increase their investment significantly as they face the 2030 net zero target, seeking robust solutions to meet these goals. Continued academic investment to stay at the forefront of research and innovation in blockchain and sustainability. Substantial investment from private investors aiming to maximise returns before the company potentially reaches a

peak valuation at the net zero target year. Thames Water maintains its highest level of subscription as the platform becomes integral to achieving its net zero emissions target.

16.4.3 Quantitative calculations

Calculating the Internal Rate of Return

As Thames Water has a Net Zero objective by 2030, we plan on having a blockchain for carbon-reducing initiatives and achieving targeted reductions in carbon emissions in the next 6 years. To attract investors in the company, Whater would need to show them an appropriate Internal Rate of Return (IRR) for them to make profits on their investments. IRR can be worked out using the equation:

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} \tag{3}$$

Where:

$$\begin{aligned} NPV &= \text{Net Present Value} \\ N &= \text{Time period (years)} \\ n &= \text{Non-negative integer} \\ C_n &= \text{Cash flow (positive if revenues and negative if costs)} \\ r &= \text{Internal rate of return} \end{aligned}$$

Assumptions of initial investments, cash flow, and costs have been highlighted in much more detail in Section 12, however, the initial investments and costs can be summarised below:

- Blockchain Development (£700,000):
  - Justification: Thames Water allocates funds for innovation projects aimed at improving sustainability and operational efficiency. The blockchain development aligns with Thames Water's goals of reducing its carbon footprint and enhancing transparency in operations.
- Research and Development (£300,000):
  - Justification: Thames Water offers grants to support research initiatives focused on water management, environmental sustainability, and technology innovation. The research component of the project contributes to advancing knowledge in carbon footprint tracking and green finance integration, benefiting Thames Water's long-term sustainability goals.
- Marketing and Outreach (£200,000):
  - Justification: Thames Water allocates a portion of its budget for marketing and outreach activities aimed at promoting sustainability initiatives and engaging stakeholders. The marketing efforts for the blockchain platform and green finance infrastructure raise awareness among Thames Water's customers, investors, and regulatory bodies, fostering support and adoption.

The projected cash flows are summarised in Table 16.6 and Table 16.7.

Table 16.6: Estimated funding amounts from different stakeholders.

Stakeholder	**Funding from each stakeholder in 100,000 (£)**					
	2024-2025	**2026**	**2027**	**2028**	**2029**	**2030 (Net Zero Target)**
Governments	5	2				
Banks	1	1	2	3		
Corporate					5	
NGOs	2	1		3		
Academic			1	2	3	
United organisations		1	2	3	3	
Crowdfunding			2	1		
Private investor			3	5	5	10

Table 16.7: Costs, revenue, and overall cash flow for each year.

Year	**Cost (£)**	**Funding (£)**	**Revenue (£)**	**Net Cash flow (£)**
2024-2025	3,895,000	800,000	1,179,148	-1,915,852
2026	1,445,000	500,000	1,311,024	-1,578,156
2027	1,445,000	700,000	1,497,724	-863,936
2028	1,445,000	1,800,000	1,740,704	1,182,624
2029	1,445,000	1,000,000	2,036,664	2,714,224
2030	1,445,000	1,600,000	2,387,392	5,185,752

Making use of Python's scipty library to calculate the Internal Rate of Return (IRR):

```
# First, install the numpy-financial package
!pip install numpy-financial

from numpy_financial import irr

# Net cash flows as provided
net_cash_flows = [-1915852, -1578156, -863936, 1182624, 2714224, 5185752]

# Calculate IRR
project_irr = irr(net_cash_flows)
project_irr_percentage = project_irr * 100
print(f"The IRR is {project_irr_percentage:.2f}%")
```

Internal Rate of Return with yearly cash flows from 2024-2030 = **22.05%**

Industry and Market Considerations

High-Risk, High-Reward Sector: Start-ups, especially those in innovative fields like blockchain and green finance, generally carry higher risks. Investors in these sectors often look for higher returns to compensate for the increased risk. Growth Potential: The potential for significant growth and market disruption in environmental tech can justify aiming for higher IRRs. Blockchain technology in carbon footprint management can provide scalable and efficient solutions, making the business attractive to investors.

Specific Business Context

Early-stage companies often aim for higher IRRs to attract venture capital and other forms of investment. This compensates for the higher risk associated with new ventures. Whater's ability to scale solutions for a major client like Thames Water can enhance the attractiveness of the investment. Demonstrating the potential to reduce carbon emissions and address Thames Water's £14.7 billion debt issue with innovative technology could significantly boost investor confidence.

Financial and Strategic Considerations

Given the increasing focus on environmental, social, and governance (ESG) criteria, Whater might attract impact investors who are willing to accept slightly lower financial returns in exchange for substantial environmental benefits. However, the IRR should still be competitive. Furthermore, compared with other companies in the green tech and blockchain sectors, IRRs often range from 20% to 40%. For example, Fintech and blockchain start-ups typically target an IRR of around 30% to 40% to appeal to venture capitalists. Finally, considering the cost of capital and expected returns from alternative investments is also essential as IRR should ideally be higher than the cost of capital to ensure that the investment adds value.

17 Conclusions

In conclusion, this report has explored Whater's potential as an innovative startup, developing a carbon footprint blockchain platform integrated with a green finance system. Technologies have been leveraged to address pressing sustainability challenges within the water industry and beyond. By creating a green finance ecosystem through the application of Blockchain and Artificial Intelligence, Whater aims to achieve net zero emissions by 2030 and improve the efficiency and transparency of water management.

The case study analyses of existing blockchain technologies helped to identify challenges in the industry, as well as realise the potential of blockchain technology in the civil engineering field. Moreover, a thorough investigation was conducted into the bottlenecks of the water industry. This investigation led to the identification that the high emissions of water industry companies are due to their wastewater operations. Hence, Whater was developed to focus on the wastewater operations emissions, helping solve the climate crisis in the UK twenty years before the deadline set by the government.

Whater's two-phase plan outlines a clear path to sustainability. In the pre-2030 phase, Whater focuses on developing a blockchain finance system to incentivise water companies to reduce emissions using WHTR tokens. The developed carbon trading and material circularity business models were thoroughly developed to benefit all stakeholders, creating incentives to join the blockchain. They were created to aid collaboration between the supply chain and all stakeholders, supporting the circular economy in the global decentralised waste management ecosystem. Post-2030, Whater aims to expand its technology to other industries and countries, incorporating smart meters to further engage households in sustainable practices, influencing human behaviour.

This report has also explored the technical considerations of blockchain technology, investigating the different types of blockchain and eventually deciding on the utilisation of a public blockchain on the Ethereum platform. The smart contracts were coded using Solidity, utilising Layer 2 and Arbitrum. A comprehensive risk analysis was also done, identifying possible risks and their corresponding mitigation measures.

With a dedicated team from Imperial College London, Whater is committed to drive change and creating a positive impact on the environment and society. Working with industry professionals, Whater's collaborative efforts and innovative solutions will enable the pathway for a sustainable future, ensuring that the water industry meets its sustainability targets while promoting economic growth and community well-being. Whater is committed to expand sustainable blockchain solutions to multiple industries and unlock the potential for applying Fintech to civil engineering projects in energy, transport, construction, and more. This report has laid the foundations to building a greener, more efficient, and transparent water industry for future generations and looks toward the future where many opportunities await this rapidly developing technology.

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