Master's degree thesis

LOG953 Sustainable Energy Logistics

How can blockchain make the food supply chain more sustainable? A case study of Norwegian fishing supply chain

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Preface

Blockchain technology can develop a decentralized database and tamper-proof system in supply chain management (SCM). This technology would bring with it potential benefits in supply chain (SC) since stakeholders such as suppliers, retailers, manufacturers, and distributors can access a shared database. It means that developing a blockchain network in SC improves efficiency, transparency, access to financing , traceability, track the source of raw material, increases trust, reduces fraud, and makes certain the products delivered on schedule and in excellent condition. However, it should not be forgotten that this technology has some challenges, integration of current supply chain systems with blockchain technology is complicated and costly, and issue of cyber-security, to name but a few.

Blockchain technology has already become a significant technological trend in multiple industries. On the other hand, Norway is a major exporter of fishery commodities and is placed as a second rank of fish exporters in the world. Thus, there might be some questions such as how blockchain technology would make Norwegian fishing supply chain more sustainable and how this technology contributes to meet the issues. This thesis seeks to analyse challenges within the Norwegian fishing supply chain, explore current technologies addressing these issues, and consider potential improvements.

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Farzad Solgi
Molde university college

List of abbreviations

SCM Supply Chain Management

SC Supply Chain

FCS Food Supply Chain

GHGE Greenhouse Gas Emission(s)

FAO Food and Agriculture Organization

AI Artificial Intelligence

GVC Global Value Chain

UN United Nations

SCT Supply Chain Transparency

NGO Non-Governmental Organization

AI Artificial Intelligence

ICT Information and Communications Technology

NFI National Fisheries Institute

SDG Sustainable Development Goal

GDP Gross Domestic Product

ICT Information and Communication Technology

IT Information Technology

UI Unreported and illegal

IoT Internet of Things

RFID Radio Frequency Identification

DLT Distributed Ledger Technology

P2P Peer-to-Peer

DAO Decentralized Autonomous Organization

EVM Ethereum Virtual Machine

FAD Food and Drug Administration

IPFS Interplanetary File System

Abstract

Title: How can blockchain make the food supply chain (FSC) more sustainable? A case study of Norwegian fishing supply chain.

From the perspective of sustainability, FSC has a variety of problems. Some crucial issues are as follows:

Inefficient transportation and distribution: This can lead to higher costs and potential waste if food spoils or is damaged during transportation. (Cabell 2013)

Sustainability and environmental impacts: The production and transportation of food can have significant environmental impacts, including greenhouse gas emissions (GHGE), water usage, and waste. (Ziegler et al. 2013)

The current-day enterprise system provides the ability to record transactions and does interparty transactions efficiently. However, they are centralized and open to human errors, and data does not flow well across organizational boundaries. Companies do not want to share their business data even with partners. This results in an opaque system where the consumer has no idea of the sustainable claims around food brands. (Ziegler et al. 2013)

Blockchain is often seen as a platform that could transform food sustainability. This thesis aims to explore the problems cited in the literature for the Norwegian fishing industry and then present the current state-of-the-art implementations and future developments using blockchain technology.

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1.0 Introduction

1.1 Introduction/ Motivation/ Background for the thesis

In several places of the world, fish has been one of the main sources of food since fish contains a large source of protein and a high amount of omega-3. In people's daily lives, fish as a food source demonstrates nutritional value contributing to the prevention of dangerous diseases such as neurological disorders and various heart-related diseases. In Figure 1, Food and Agriculture Organization (FAO) data depicts that in the twenty-first century, the importance of the fishing industry to global food security and nourishment is becoming more widely acknowledged, thus, the need for transparency in the fishery industry from the perspective of future sustainability is necessary.

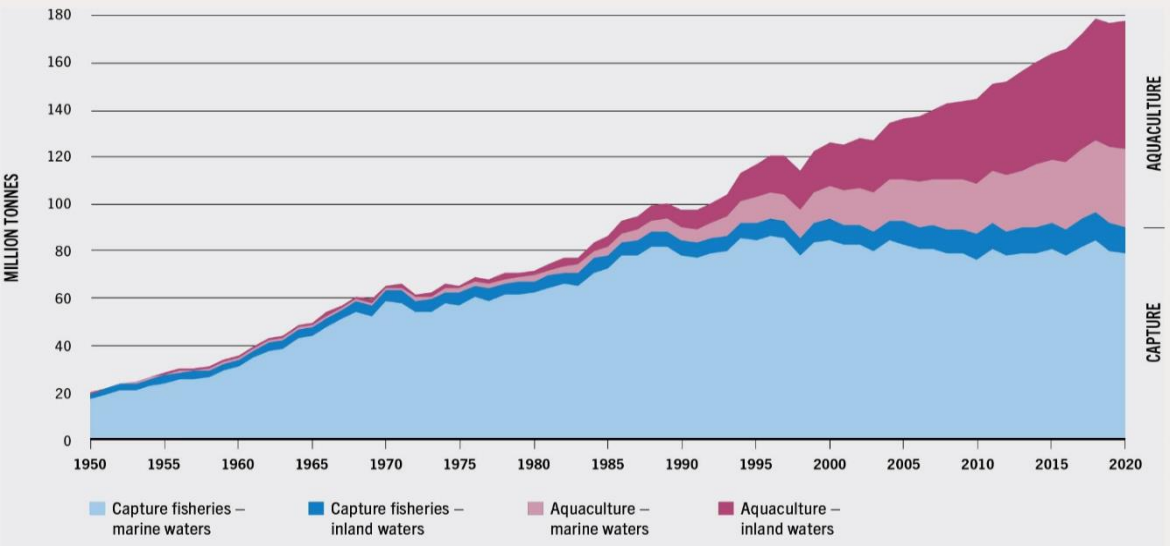


Figure 1: World capture fisheries and aquaculture production[1]

According to a 2019 United Nations (UN) report about different ocean-related issues, it is mentioned that global oceans are encountering multifarious problems that have reached a level of alert. Just to be more precise, some unreported and illegal (UI) fishing methods are opposed to regulated and legal-based fishing activities, not only has the food security been threatened but also executing sustainable fishing regulations has experienced major and significant issues. Furthermore, from biological point of view due to the effects of overconsumption and overfishing around the world, the sustainable percentage of fish stocks from 1974 to 2015 has significantly reduced by 23 % (90% in 1974 decreased to 67% in 2015). In addition to these important factors, other externalities such as plastic waste disposal in the sea – roughly 8 million tons annually – and other harmful waste

[1] https://www.fao.org/3/cc0461en/online/sofia/2022/world-fisheries-aquaculture.html

(materials) have jeopardized and restricted fishing capabilities and activities. Even though it is clearly stated that some food producers in the fishing industry and global conservation organizations have proposed useful and practical techniques and strategies to tackle these issues, participation and collaboration of organizations and communities related to the fishing industry will be required to execute approaches and decrease distrust that consumers have for the origin of fish. One of the best solutions that has been recently taken into consideration by conservation organizations and seafood producers is blockchain approach. (Howson 2020).

In order to perform and manage the majority of activities and operations, human beings on a global scale are relying more and more on digital and information technologies (IT). There are various explanations for digitalization, according to (Mondejar et al. 2021), the process of conversion of received data via tools such as sensors and knowledge into a language that can be used by computers is known as digitalization. In reality, IT plays a crucial role in human activities, and digitalization consisting of incorporating digital technologies into daily life has caused significant changes on socio-economic and environmental level which has led to sustainability applications such as the development of cloud-based software applications. As a result of such a framework, a complicated networks would be created by numerous components via the internet, application software, data gathering devices and sensors. The management and controlling of huge amounts of data along with these networks which is known as big data might be simpler performed by using real-time analytics, artificial intelligence (AI), and machine learning for creating actionable insights. (Rowan 2022).

A distributed electronic database which is known as blockchain is accessible and available for all users who can track any single transaction which have been created on the respective network. One of the great advantages of blockchain that sets it unique from other databases is the fact that such a system cannot be simply hacked since blockchain does not demonstrate a “single point of authority” which is quite vulnerable to potential mistakes and finally a major system collapse. To be more specific, the reason for such a characteristic is that automated agreement protocols allow the data passed on through the blockchain network to be saved and created protected blocks while remained unchanged and subsequently it would be almost impossible for the data to be corrupted. This blockchain technology is being widely used in multifarious industries which provide different services particularly in seafood and fishing industry as well as conservation

organizations to have access to clear data which could contribute to sustainable fishing practices. (Howson 2020).

Understanding how blockchain in the supply chain (SC) functions, initially, the authenticity of a transaction created by a network user which is known as a node would be evaluated. In order for a transaction to be accessible for everyone on a public ledger and included in a block, this block is required to comply with blockchain requirements employing numerous computations to be considered as an authentic and secured block, and after such confirmation, the respective block provides a value of 8 decimals called hash value which is a specific value for a unique block. Due to the fact that there is a series of connected blocks for each transaction, it is called a blockchain and when a new block is introduced in this network, the previous blocks become almost unchangeable because recalculating the hash value for each block would be unfeasible and extremely expensive. (Tolentino-Zondervan, Ngoc, and Roskam 2022).

The demands of the stakeholders in global value chains (GVC) determine the sort of blockchain. Basically, blockchains can be classified into two groups- public and private blockchains. Public blockchains are equivalent to unlimited blockchains which develop a lot of blocks containing data that are publicly accessible and consequently hard to hack since they are so well protected. Public blockchains have an extremely decentralized structure in which all participants take part in an agreement to confirm operations, see open transactions, and may interact with the network. Therefore, these particular blockchains have a lot of benefits, in which it is accessible and available to all users and no single body is in charge of managing the platform and also because of decentralized structure and openness feature are seen as more trustworthy than private ones. Bitcoins and Ethereum are two well-known instances of public blockchains which use a peer-to-peer technique to authenticate network transactions. (Tolentino-Zondervan, Ngoc, and Roskam 2022)

In contrast, public blockchains have several drawbacks such as consensus algorithms for example “Proof-of-Work and Proof-of-Stake” would require an agreement which must be reached across the whole network, and also public blockchains can only handle a certain number of transactions per second, and public blockchains require a lot of computer power, which leads the operation to be expensive and slows down the process. The limitations of public blockchains including data privacy, capacity of transaction flow, and system efficiency are addressed by private blockchains. It means several business apps employ private blockchains and only users with authorization may access their network. In

addition, due to the fact that only a small number of users maintain private blockchains, they are significantly scalable and cause to greater handle, and also less expensive than public blockchains. Hyperledger frameworks are a good instance of private blockchains generally only allow access to the network to a select group of reliable users. Although this framework favoured several businesses including Carrefour, Walmart and Nestle in IBM Food Trust for guaranteeing the sustainability of food supply chain (FSC), due to the low transaction volume brought on by a small number of nodes, these private blockchains are less secure and more open to assaults. (Tolentino-Zondervan, Ngoc, and Roskam 2022)

In order to know how blockchain is used in GVCs, it is necessary to comprehend the role that blockchain plays in the globalization of commerce both in "the vertical and horizontal dimensions of value chains". According to figure 2, the movement of items includes fish merchants, distributors, tracking seafood commodities through fishermen, brands, processors, buyers, and retailers from suppliers to consumers and the flow of data between suppliers, consumers and retailers are both addressed by the vertical dimension. The exchange of information also covers market sustainability needs such as using sustainable fishing methods and following safety and quality requirements. To address concerns around incentive distribution and how products are coordinated by brands and merchants and also specify conditions for value chain partners to participate, blockchain enables traceability, organizing the value chain's transaction needs with smart contracts, peer-to-peer exchanges that cut out intermediaries, and sharing product stories.

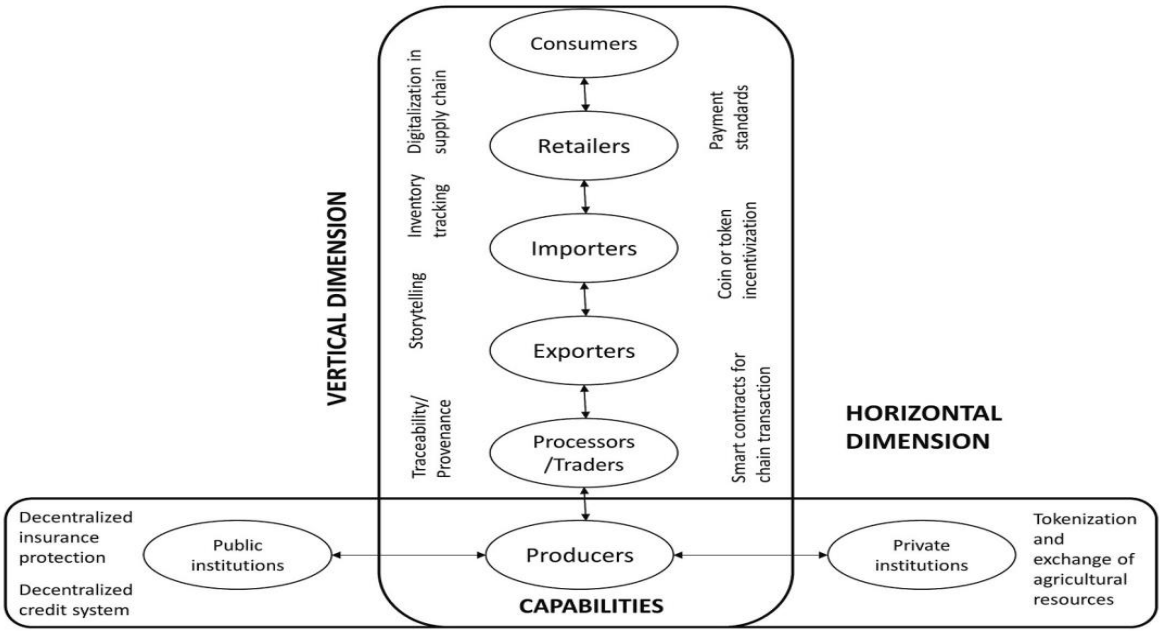


Figure 2: Use cases for blockchain utilizing GVC's horizontal and vertical dimensions (Tolentino-Zondervan, Ngoc, and Roskam 2022)

In order to establish the capacities that will allow producers to take part in the value chain, institutional assistance from private as well as public players outside the value chain is provided. This is referred to as the horizontal dimension of the value chain. In fact, the horizontal dimension aims to tackle concerns about inequality and local producers' access to finance to strengthen their ability to engage in the GVC. With regard to fishing, this comprises the regulations for certificates, catch quotas, and equipment as well as the assistance offered to fishermen including education, training and financing from both government and non-government institutions. (Tolentino-Zondervan, Ngoc, and Roskam 2022)

Many countries using various applications of blockchain technology particularly in the fishing industry. As one of the top exporters of seafood, Norway has a significant position in the world and only in 2022 the country made almost 150 billion NOK in income by exporting close to 3 million tons of seafood products. Although Norwegian fishing industry as a significant source of income creates more job opportunities and influences on Norwegian economy, unreported and illegal (UI) fishing activities in Norway endangered this industry and food security. Implementing a tracking software system across the fishing supply chain is one possible way to reduce fisheries crimes since such a system may guarantee that organizations comply with regulations, gain consumer trust, and improve SCM. The shortcomings and limitations of traditional SCM are addressed by the main features of blockchain technology such as unchangeability, transparency, and decentralisation. In order to improve SC traceability, automated procedures, removing the necessity for a middleman, and the inability to manipulate data, blockchain technology and smart contracts combination may provide potential solutions. (Godtliebsen 2023)

In the next chapters of this paper, the benefits of blockchain technology in Norwegian fishing SC and limitations and challenges of integration of this technology with current technologies, the concept of smart contracts, and the architecture of blockchain will be discussed.

1.2 Research

1.2.1 Research objective

The main objective of the thesis is to report the challenges in the Norwegian fishing industry and explore the current technologies to meet the challenges and consider potential improvements.

1.2.2 Research questions

The research objective leads to some research questions. More specifically this research will answer the following questions:

1. What advantages does blockchain technology offer to the supply chains of the fish industry?
2. In what ways does blockchain technology provide advantages or benefits?
3. What are the challenges in the fish supply chain from the perspective of sustainability reporting?

1.2.3 Research design

For research question 1: Literature review of industry articles, newspapers, magazines and peer reviewed research to find out the problem in Norwegian fishing industry. We will follow a grounded theory approach which will provide us with factors that influence this industry. This research will have a limited scope and we will conduct this based on easily accessible information in public or the college library. At this time, we plan to do interviews with industry experts; that could be a future research direction.

For research question 2: We will look at the technological implementations in this area from public sources and identify one area that has been addressed or an important area that has not been addressed by these technological implementations.

For research questions 3: Applying grounded theory concepts from objective 1.

1.3 Structure of the thesis

To help readers understand the content, **chapter 2** presents theoretical framework including traceability and transparency concept, definition of blockchain, and the formation of blockchain-based system, along with the components of a block. In the following, an overview of fishing industry in Norway and its place in market globally. In this chapter farmed salmon production and processing cycle will be evaluated as well as the importance of sustainable fishing activities, distributed ledger technology (DLT), the consensus mechanism, smart contract on blockchain, and smart contract platforms, will be discussed. The second part of **chapter 2** will present the methodology and literature review.

Chapter 3 will be dedicated to the examination of how blockchain technology, including IBM Food Trust modules, is utilized by Norwegian fishing companies. The improvements and challenges brought about by blockchain technology in this context will be explored. **Chapter 4** will discuss conclusions and provide suggestions for future research.

2.0 Methodology/ Theoretical framework/ Literature review

2.1 Methodology

An organized and systematic approach to addressing the research topic is known as research methodology. The methods, strategies, and processes that researchers use to collect and analyse data are all included in research methodology. (Kothari 2004) Once the problem has been identified, information and data must be obtained, analysed, and then potential solutions must be suggested.

Types of research can be categorized into two primary approaches: quantitative research and qualitative research.

Quantitative research: "Quantitative research is based on the measurement of quantity or amount". (Kothari 2004) Quantitative research applies to phenomena that have a quantitative form. For example, measuring the satisfaction levels of customers at a grocery store is a quantitative form since it involves collecting numerical data and variables that could be quantified.

Qualitative research: In contrast to quantitative research, qualitative research is descriptive and non-numerical in nature. Qualitative phenomena are the focus, for example, interviewing workers in order to understand more about their perspectives on job satisfaction. Research of this kind helps in determining the reasons for (why) and methods of (how).

A qualitative approach in this study including semi-structured interviews is used as the primary research method. The use of blockchain technology in Norwegian fish supply networks is the focus of this study, and an assessment about why the blockchain technology could be beneficial in SCM and how blockchain technology may bring improvements will be considered. The reason of selecting a qualitative research for this thesis is because of insufficient practical examples that accurately represent the details and difficulties of blockchain deployment in this particular situation.

This study contains a wide range of topics since a comprehensive understanding of supply chain management (particularly fish supply chains), blockchain technology, and the role of IT in SCM is required to evaluate the study aim. This part of the essay deals with a group of keywords including blockchain technology in supply chain, fish supply chain, features of ledger technology, challenges of fish supply chain, combining blockchain and AI, Norwegian fishing industry, and worldwide fishery value chains.

To select the papers regarded to be most relevant, the essays from the databases (Google Scholar, Science Direct) were evaluated by title, year of publication, and abstract. Therefore, several essays, mostly taken from Elsevier articles, were analysed because doing literature studies can provide the researcher with a comprehensive perspective on the depth of prior research. In addition to, a lot of material and information has been gathered from organizations and institutes such as Foods and Agriculture Organization of the United Nations (FAO), Norwegian Seafood Federation (NSF) and the Norwegian Ministry of Fisheries.

It is important to note that collaborating with Norwegian Seafood Trust (NST) has been chosen as a strategy to overcome lack of literature. This collaboration has a number of significant benefits that contribute to the overall effectiveness of the study. "The Norwegian Seafood Trust, together with the technology companies Atea and IBM, will offer a tracking service that will follow the entire value chain of the fish."[2]

For this qualitative research, a methodology associated with case study research is selected. This thesis's case study methodology is based on a structured and systematic approach to conducting case study research. One of the most often used methodological frameworks for case studies is Eisenhardt's process which was first introduced in 1989. The procedure starts with stating the research questions and concludes with a theoretical framework. "Process of building theory from case study research" contains eight activities. (Nazari 2010 ; Eisenhardt 1989)

1. Definition of research questions and constructs
2. Choosing cases
3. Crafting instruments and protocols (multiple data collection methods)
4. Entering the field (Refers to assessing blockchain projects in this research, and comprehensive study of Norwegian fish supply chain)
5. Analysing within-case data
6. Shaping hypotheses
7. Enfolding literature ("Comparison of the emergent concepts, theory, or hypotheses with the extant literature") (Eisenhardt 1989)
8. Finalizing

[2] https://norwegianseafoodtrust.no/

2.2 Theoretical ftramework

2.2.1 Traceability defination

Supply chain (SC) locates at the centre of the delivery of products process to end consumers at the appropriate time and right cost without attention to what sort of goods is produced or sold. People's health, meal security and stability, global warming, and animal protection are all unprecedented problems for the food supply chain. In dealing with these issues, for reducing food loss & waste and helping to ensure food security, the terms transparency and traceability are becoming important topics.

The following definitions are a brief primer on terminology and ideas related to the blockchain-based traceability system. Governments all over the world are increasingly gaining attention to traceability as a foundational component of SCM as a way of assuring protection of consumers and product safety. Traceability systems in the past relied on paper-based recordkeeping, which was inexpensive but time-consuming, exhausting, and prone to mistake while Information and Communications Technology (ICT) methods may execute real-time modifications of product data and instantly communicate such modifications to both customers and trading partners. It might be concluded that ICT methods not only offer great benefits from the aspects of profitability, competing, and transparency but also ICT innovations for low power Radio Frequency Identification (RFID) tools and Internet of Things (IoT) devices could create the possibility for further advance the way goods are monitored throughout a supply chain. (Syed et al. 2022)

(J.P. Olsen et al. 2022) presents different definitions for 'traceability term', and the capability of tracing, tracking, and monitoring the information of a product during the whole supply chain is most common definition without explaining precisely what "trace" refers to in this context. Previous definitions for traceability are neither exact nor comprehensive, and ideal definitions would need to integrate a definition that combines the finest elements of numerous others (P. Olsen and Borit 2013), thus, the ideal one would be:

“The ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications” (P. Olsen and Borit 2013; J.P. Olsen et al. 2022).

The mentioned definition has several benefits. For instance, it strongly matches the characteristics of traceability systems utilized in the food sector specifically and the

industrial sector generally (P. Olsen and Borit 2013), and also any object or item may be tracked at any stage of its life cycle (J.P. Olsen et al. 2022).

The two main views that may be used to categorize traceability would be:

- ✓ Internal traceability: The firm's internal traceability or a network known as internal traceability which is the foundation of traceability (J.P. Olsen et al. 2022).
- ✓ Chain traceability: Traceability between networks and businesses depends on the information sent by the internal traceability system's data records (J.P. Olsen et al. 2022).

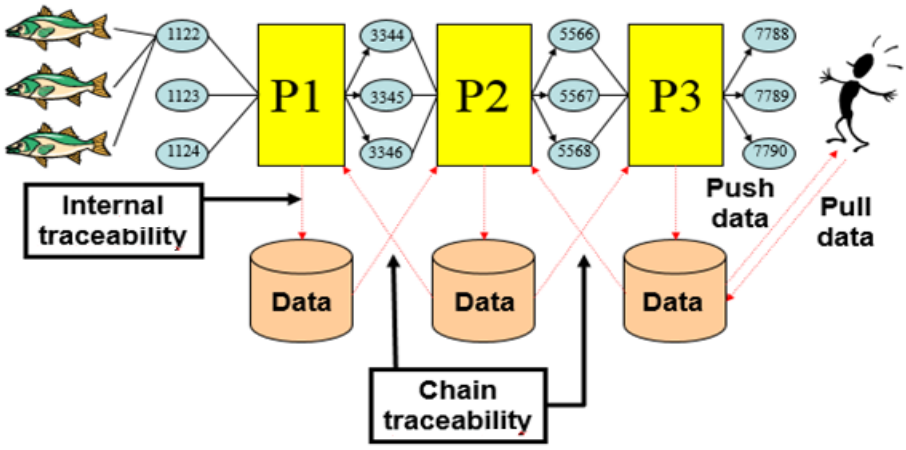


Figure 3: Internal traceability versus chain traceability (J.P. Olsen et al. 2022).

2.2.2 Transparency concept

There are various definitions of transparency that vary in their scope. Transparency is the subject of more interdisciplinary studies and is crucial for supply chain networks since it has a strong relationship with traceability (Sunmola and Burgess 2023), and also supply chain transparency (SCT) may result from the utilization of traceability (Hidayati et al. 2023). A key use of blockchain technology is to build trust, and it is probably a prerequisite for transparency (Sunmola and Burgess 2023). Transparency in the supply chain allows for sharing of precise information about operations, procedures, and products, resulting in improved efficiency. In fact, “transparency is the disclosure of information” (Hidayati et al. 2023). Blockchain technology is necessary for commercial competitiveness in order to provide transparency and traceability in the market. (Tolentino-Zondervan, Ngoc, and Roskam 2022)

2.2.3 Blockchain technology

The concept and idea behind decentralized ledger back to the beginning of the 1990s when two academics, Stuart Haber and W. Scott Stornetta, in Morristown, New Jersey attempted

to protect information and process data using a digital network of blocks to address epistemological issues concerning what human beings perceive to be real in the digital era and how they trust (Whitaker 2019). The research of these two scientists was mainly based on two political and philosophical questions which are: How can people understand and accept the facts about the past if the way to manipulate the data and information of documents on PCs is very simple? And the second one is: If we do not need to rely on a centralized authority to maintain the record, how can people believe what they understand of the past? (Whitaker 2019). However, it is widely assumed that in 2008 the utilization of distributed networks started by an anonymous researcher or group of people. An article "Bitcoin: A Peer-to-Peer (P2P) Electronic Cash System" was published by Satoshi Nakamoto who has never been recognized so far. It explained a new type of digital money known as Bitcoin, and Haber and Stornetta hypothesised online transformation without a third-party intermediary (Popovski, Soussou, and Webb 2018). It means that blockchain technology enabled Bitcoin to be a decentralized currency, allowing users to trade directly with one another without the need for a financial organizations. The article mentioned "an electronic payment system based on cryptographic proof instead of trust," presented the idea of a decentralised distributed network without requiring a central authority to store and maintain all transactions on a network. (Popovski, Soussou, and Webb 2018) Although the first strategy was to create an algorithm that would prevent hacking while also provide a timestamp for the stored data, this concept could not be implemented in practice due to technological limitations at the time. Consequently, Bitcoin was introduced in 2009 while other digital currencies such as Litecoin, Ripple, and Ethereum were developed over time, each with its own unique and distinct blockchain design.

Blockchains are a specific kind of archive that store digital records of transactions in blocks while blockchain technology is a technology that permanently stores records, making it hard to hack the system or manipulate the information saved on it, consequently making it safe and unchangeable. Blockchain technology has been predicted to fundamentally change several established business sectors since its inception in 2008, and it has evolved into a versatile technology with the ability to change a wide range of sectors. Blockchain technology is distributed among all computers which connect to the network with no admins to modify or delete data rather than being located on one or more particular servers (figure 4). It is worth to be noticed that as opposed to relational or non-relational databases that are capable of CRUD operations (Create, Read, Update and Delete), blockchain are incapable of performing CRUD operations and only read and write

activities are permitted on a blockchain. Transactions, asymmetric key encryption, and the consensus process make up the three major parts of a blockchain. (Ramadhan, Pane, and Wardhana 2023)

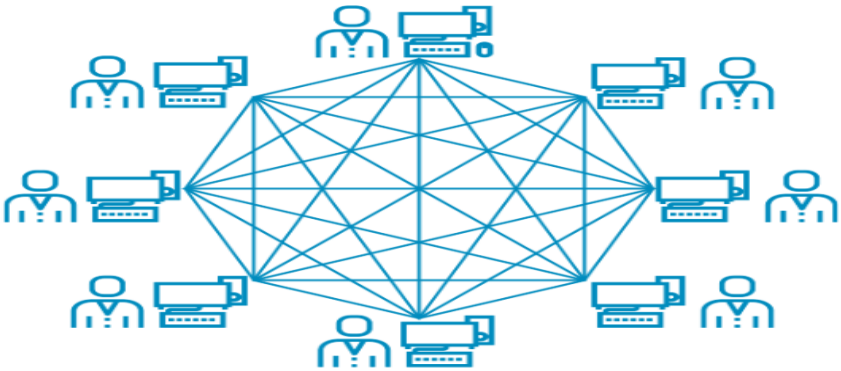


Figure 4: A P2P network

The term blockchain is made of two words: block and chain. Each block has its unique header, hash, the block's previous hash and all of the information.(Agbo, Mahmoud, and Eklund 2019) The hash algorithm would determine a block's distinct code at creation and each change in the block will change the hash. Hash is a practical and useful tool to detect any change in a block.

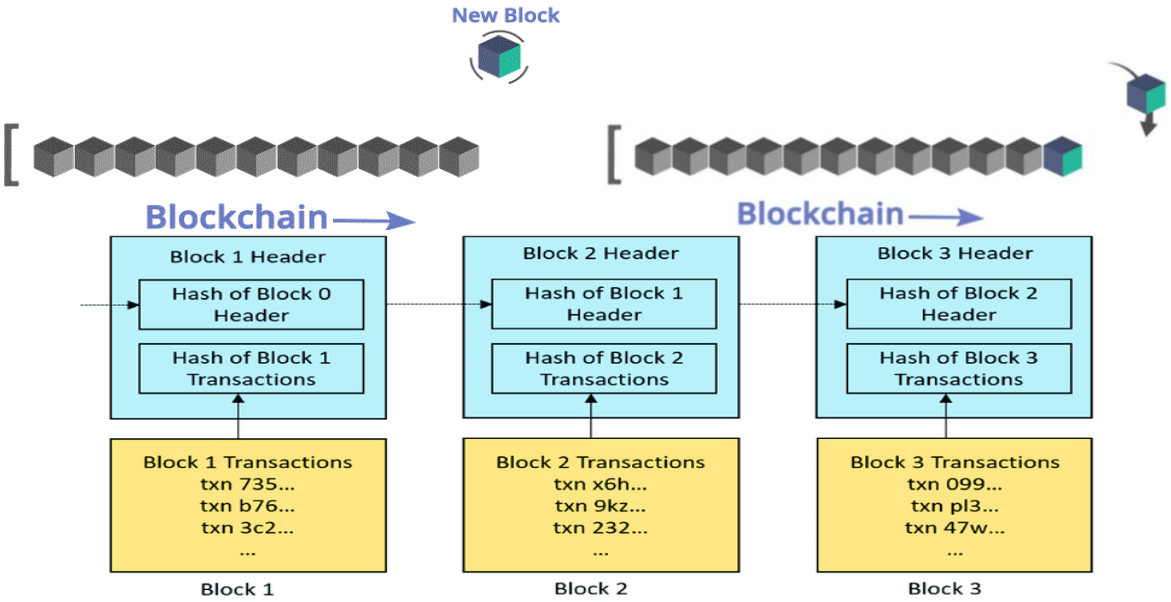
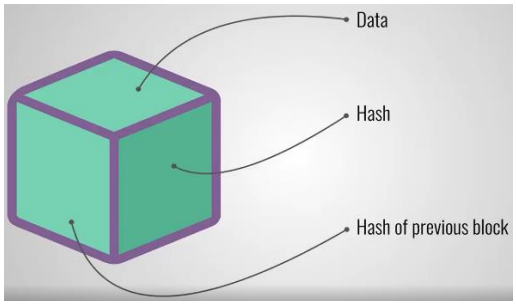


Figure 5: "A simplified example of how blocks are chained to form a blockchain" (Agbo, Mahmoud, and Eklund 2019)

Before transactions become a portion of the blockchain, they are reviewed and verified through some kind of required consensus process. According to the illustration in figure 5, it is no longer feasible to alter or manipulate the data by building encrypted links between transactions and previous transactions.

In the following, the elements of a block that are essential to data protection and integrity, concept of hash and hash function will be discussed.

2.2.4 The components of a block, concept of hash and hash functions

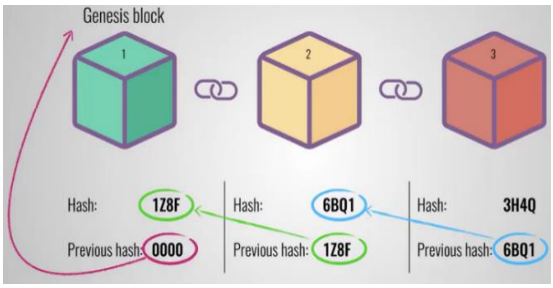


A chain of blocks forming the blockchain is what holds data about transactions. In a block, there are three primary components: hash, hash of previous block and data. “Hashing is a method of converting any size of data into a unique code that is fixed in size and collision-restricted”.(Yadav et al. 2023) Hashing is the process of converting inputs with arbitrary length into encrypted outputs of a fixed length throughout a mathematical and algorithms process which is known as the hash function. (Agbo, Mahmoud, and Eklund 2019) Each block's hash is distinctive, like a person's fingerprint. The most widely used hashing algorithms are MD5, SHA-3, and SHA-256.(Yadav et al. 2023) As an example, Bitcoin blockchains use a secure hash algorithm SHA-256^2 (also recognized as double SHA-256) that generates 256 bits or 64 characters of a combination of a set of letters from A to Z and numbers.(Kim and Sarin 2018)

Table 1: Valid hash functions convert any input value into a fixed-length text string.

Hello world!	**c0535e4be2b79ffd93291305436bf889314e4a3faec05ecffcbb7df31ad9e51a**
Every fish has a story.	**1a0cdc2cdd37251cf51f38dff311f9c2eaec34e355ec3997c9b3389f564a03fe**
how can blockchain make the food supply chain more sustainable?	**b172367c2ef1c5831090a7d4b4fa7e734d23f51ea94b7aee45026f1ca7c7fd9f**

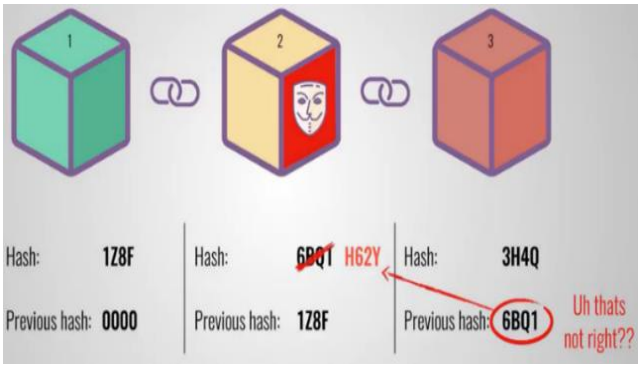
Table 1 illustrates that the hash function SHA-255^2 converts the inputs as a mixture of numbers and letters in a 64 unique characters string without considering the length of inputs.



Every block contains a previous block's code and a unique hash, but it is worth noticing that for the first block of a blockchain, there is no previous hash, thus it is named a genesis block and contains essential information about

the blockchain's creation such as a timestamp and a unique identifier.

The slightest alteration in a block's contents completely alters its hash, thus the modified block's hash won't longer match into the next block's hash and all subsequent blocks are rendered invalid. (Kim and Sarin 2018)



In conclusion, key characteristics of blockchain technology consist of unalterable network, decentralized, distributed, and will boost security, trust, data traceability throughout the whole network, and transparency. Numerous industries such as agriculture, fisheries, healthcare, SCM, and the financial sector can benefit from the usage of blockchain technology.

Blockchain technology allows for low-cost interactions and good impact on manufacturing pricing structure, one of the main advantages of blockchain technology. Another important benefits of blockchain technology in Norwegian fishing industry and generally as well would be improved management over recollection procedures (Barnett et al. 2016). Since the potential to collect comprehensive records with accurate traceability is a major element of blockchain technology, it would be simpler to pinpoint particular exact quantities or goods that are impacted and must be returned. This decentralized component of implementation increases procurement management by facilitating availability, reliability, traceability, and productivity, and eventually, all information is sent to supply chain partners.

2.2.5 Blockchain types

According to (Paul et al. 2021 ; J.P. Olsen et al. 2022), any new users (nodes) on the blockchain network are required to get permission since only administrators are responsible for administering the users' activities. There are three types of blockchain and each of types include a cluster of nodes that operate on P2P network environment. Each node of the blockchain network has a copy of the shared ledger, which includes a record of all transactions, and the data is regularly updated.

Blockchain technology is categorized into three groups including private blockchain, public blockchain, and hybrid blockchains (consortium or federated blockchain)

1. **Public blockchain**

This blockchain network is open source, distributed ledger system, accessible to anyone, and non-restrictive. It means that anybody can access and use this kind of distributed ledger technology, launch a public node after validation process, and take part in the consensus procedure without getting permission. Bitcoin, Litecoin, Ethereum, Monero are some of the general examples of public blockchain. Public blockchain has some benefits and characteristics such as anonymous character, transparency, open source, high safety and security, distributed network, and no fraud. Besides, server and system administration maintenance is not required, and authenticity is not necessary. Public blockchain can have certain flaws despite the advantages outlined above. Due to the existence of many nodes in the public blockchain network, a large network will be created. Therefore, some issues regarding the huge network refers to scalability, and the low rate of transactions since the process of verification of transactions by all nodes may take time, and substantial energy consumption. (Paul et al. 2021 ; J.P. Olsen et al. 2022)

2. Private blockchain

This type of blockchains are not open and accessible to everyone, and highly restricted. Private blockchain may be seen as a centralized network since a private blockchain is constrained, permissioned, and entirely under the authority of one company or organization. A system administrator can provide authorization for a transaction on this blockchain network. Although a particular group or members of an organization may benefit from this kind of blockchain by internally authenticating transactions, those who manage the blockchain face the risk of security breaches. MONAX and Multichain are some of the general examples of private blockchain. Private blockchain has several advantages and features including more scalability and flexibility, privacy, high efficiency, and compared to public blockchains, private blockchains have higher transaction rate per second. Private blockchain may have several weakness including lower security and more prone to hacking, thus, it might be said that private blockchains are not reliable. (Paul et al. 2021 ; J.P. Olsen et al. 2022)

3. Hybrid blockchain (consortium or federated blockchain)

Private and public blockchain components are combined in hybrid blockchain architecture. Hybrid blockchain technology may be used for a variety of aims and provide a versatile solution for different organizations and businesses and deliver the needs of both decentralized and centralized networks (systems). As such, hybrid blockchains have the aim of combining and utilizing the highest-quality characteristics such as transparency,

safety, data integrity of private and public blockchain technology. (Paul et al. 2021 ; J.P. Olsen et al. 2022)

Some of the benefits that consortium or federated blockchain network may deliver are as following:

- Enhanced transparency and security across the network
- Flexibility- users are able to join network easily (user-friendly-environment)
- High scalability and speed- efficient and rapid process of transactions (cost efficiency)
- Assuring comprehensive, valid, and accurate data (data integrity)

"Examples of consortium blockchain are R3 (Banks), EWF (Energy), B3i (Insurance), and Corda" (J.P. Olsen et al. 2022) In the banking industry, hybrid blockchains are frequently used to solve many major problems. It is critical to remember that based on the use case, organizations may choose a certain type of blockchain. It cannot be assumed that one type of blockchain network is superior to other types. (Paul et al. 2021 ; J.P. Olsen et al. 2022)

Table 2 from (J.P. Olsen et al. 2022) article provides a concise overview of different types of blockchain networks along with their features.

Table 2: A summary of different types of blockchain network (J.P. Olsen et al. 2022)

	Public	Consortium/Federated	Private
Consensus determination	everyone	selected (few)	single authority
Read permission	public	public, partly public, restricted	public, partly public, restricted
Immutability	nearly impossible	possible with majority of validators	possible
Efficiency	low	high	high
Centralised	no	partially	yes
Consensus process	permissionless	permissioned	permissioned

2.2.6 Distributed ledger technology

The term "distributed ledger technology (DLT)" is related to a modern and rapid developing method of storing and distributing same information throughout several data ledgers. The distributed ledger of transactions and events is at the core of blockchain technology. To be more precise, when a transaction created by a network user which is known as a node, a new block containing transaction records will be generated and simultaneously after validation process the information of new block will be distributed among the whole networks. According to figure 6, the shared data of transactions and

evens are known as a distributed ledger, due to the fact that each user in the network can access a duplicate of the ledger. (Natarajan, Krause, and Gradstein 2017)

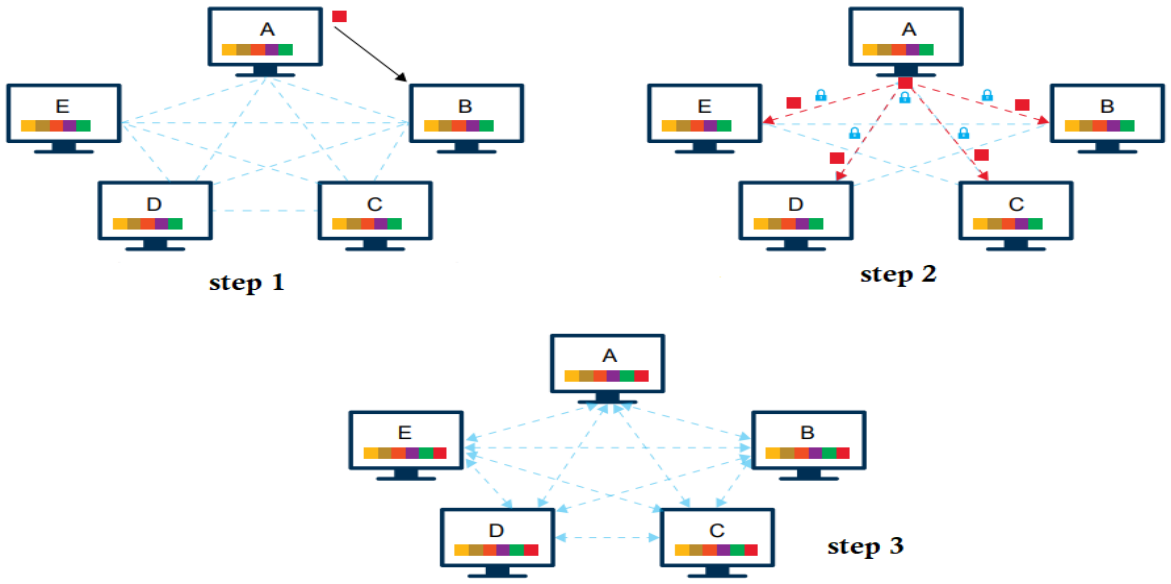


Figure 6: How blockchain-based DLT Works (Natarajan, Krause, and Gradstein 2017)

Figure 6 shows that chain blocks are fundamental elements of distributed ledger technology (DLT) platforms, and they are tamper-proof and secure which each contain data and transaction records. A block containing data about transactions made by user A (a new node) and a transaction from user A to user B is created in the first phase. The whole network is then informed about this new block in the second phase. It should be noticed that information of new block is encrypted in order to prevent disclosure of transactional information. Consensus mechanism, a validation procedure which is defined in advance, is considered by all network users to evaluate the block's authenticity. The new block containing encrypted data will be added to each user's ledger once it has been validated. To ensure that every network user has an accurate copy of the whole ledger, any possible modifications that may occur to the ledger will be duplicated throughout the whole network via this process. (Natarajan, Krause, and Gradstein 2017) According to (Natarajan, Krause, and Gradstein 2017), DLT-based architecture has two fundamental characteristics: capacity to share data between several users in an electronic format (P2P) without the requirement for a mutual trust and an official record-keeper. The second one is preventing duplicate spending, which implies that only one party may obtain the same asset. It is worthy to state that one of the key difficulties of a blockchain-based system would scalability. It implies that as more nodes join the blockchain, the network's capacity to process and validate transactions efficiently will be strained. In order to overcome the blockchain's storage restrictions, (Patro et al. 2022) states the Interplanetary File System

(IPFS), an illustration of systems that could store data including videos and photos of species of fish and also other significant reports and documents to overcome the blockchain's storage limitations. In conclusion, the hash values of data can be saved on blockchain ledger while due to unchangeability characteristic associated with blockchain technology, stakeholders can access data once it has been uploaded to the IPFS system.

2.2.7 Smart contracts

In 1994, Szabo proposed the concept of smart contracts, but the idea was not realized until the advent of blockchain technology. The academic literature has covered a variety of explanations for smart contracts, and all descriptions were categorized into "smart contract code and smart legal contract". Smart contracts may be created on certain types of platforms using programming languages with high levels of functionality. Smart contracts on blockchain-based platforms is executable code including functions modifiers, functions, and variables to run terms and conditions of a contract or an agreement automatically and independently of any intermediary. The agreement's code is immutable as soon as it has been executed into the blockchain. Smart contracts are replicated to all nodes to protect against agreements manipulation. (Alharby and Van Moorsel 2017)

Two different forms of smart contracts exist. The first type of smart contract is called deterministic smart contract. For this type, no data is required outside of blockchain network. The second type, known as a non-deterministic smart contract, requires. Considering a contract that needs to operate and is dependent on the latest climate information, which is not present on the blockchain could be an example of a non-deterministic smart contract. (Khan et al. 2021)

Despite the latest improvements, there are still several obstacles such as performance problems, legal and private barriers that smart contracts have to overcome. In addition, on June 17 in 2016, a hacker was able to acquire 2 million Ether, which was then valued around $50 million, by taking advantage of a flaw in the Decentralized Autonomous Organization's layout. (Khan et al. 2021) A vulnerability in the Decentralized Autonomous Organization (DAO) software, which is operated on Ethereum platform, was exploited by a hacker. This is an instance of an attempt to take advantage of application vulnerabilities (system weakness) that occur at the application layer. Apart from technical flaws, integration of automatic smart contracts with distributed ledger technology (DLT) may increase a variety of regulatory and legal problems such as jurisdiction and amendments issues. (Natarajan, Krause, and Gradstein 2017)

2.2.8 Platforms for smart contracts

Several blockchain frameworks such as Bitcoin, Ethereum, and NXT make it possible deployment and the development of smart contracts, and each frameworks offer unique characteristics for managing the development of smart contracts. For implementing smart contracts currently the most popular framework is Ethereum. (Alharby and Van Moorsel 2017) The possible issues may be handled, and the present fish monitoring processes can be improved by using a public blockchain-based platform like Ethereum. (Patro et al. 2022)

All parties involved in the fishery SC must be informed regarding the transfer of the goods. The Food and Drug Administration registers "all stakeholders such as fish farmers, fish seed companies, fish processors, and IPFS with the registration of farmed fish smart contracts on the blockchain system."(Patro et al. 2022) In addition, FDA has responsibility for controlling that whole participants who are legitimate in the blockchain network are in accordance with the regulations, and in the case that standards are not followed, the FDA is also responsible for penalizing the culpable parties. The Norwegian Medicines Agency, or Legemiddelverket, is the equivalent of the FDA. Once whole stakeholders are registered, and smart contract is deployed, the blockchain technology provides a distinct code to track the transactions. In the process the fish seed firm as one stakeholder refreshes data regarding farmed fish seeds once farmed fish smart contract is implemented. The company utilizes the IPFS in order to distribute data and large-sized documents that stakeholders can access. (Patro et al. 2022) Solidity, Serpent, and Low-level Lisp-like Language (LLL) are a few examples of advanced programming languages that may be utilized for developing smart contracts with the Ethereum platform. Ethereum Virtual Machine (EVM) is a programming environment that executes the code of smart contracts.

2.3 Literature review

2.3.1 Norway fishing industry

The Norwegian fishing industry goes back hundreds of years or even further back, to the Stone Age, Bronze Age, and Iron Age. For many years, fishing has been one of the major sources of food in Norway. There are several cities, rural areas, and coastal regions throughout Norway which are ideal for fishing, and species of fishes are the most valuable commodities to export in the country. In other words, the fishing industry is an integral part of Norway's coastal culture and the industry's potential has received attention in last

years and significantly played an important role in the country's economy (Sandberg and Steinseide 2016).

Norway is one of the most important exporter countries of fishery commodities, and globally this country is placed in second rank only after China and the world's biggest supplier of salmon (Ziegler and Hilborn 2023). Norway has a substantial salmonid livestock industry, and "targeting cod, herring, mackerel, and other whitefish and small pelagic species" (F. FAO 2018). In 2016, trade of fisheries and aquaculture products in Norway remarkably increased by 17.2% in comparison to 2015 due to the rising expenses for a number of its most important species (F. FAO 2018).

Table 3 shows top ten countries accounted for 52.4% of total exporters in 2016, and the share of Norway among these countries is 7.4%. Therefore, export of fish in Norway is globally significant and the fishery industry from the perspective of economy for Norwegian government is important. Norway fishery industry creates more job opportunities, and fish was one of the first goods to export other countries, having the EU as the primary market (F. FAO 2018).

Table 3: "Top ten exporters of fish and fishery products" (Jaya et al. 2019)

Countries	2006		2016		APR* (%)
	Value (US$ million)	Share (%)	Value (US$ million)	Share (%)	
China	8,968	10.4	20,131	14.1	8.4
Norway	5,503	6.4	10,770	7.6	6.9
Viet Nam	3,372	3.9	7,320	5.1	8.1
Thailand	5,267	6.1	5,893	4.1	1.1
United States of America	4,143	4.8	5,812	4.1	3.4
India	1,763	2.0	5,546	3.9	12.1
Chile	3,557	4.1	5,143	3.6	3.8
Canada	3,669	4.2	5,004	3.5	3.2
Denmark	3,987	4.6	4,696	3.3	1.7
Sweden	1,551	1.8	4,418	3.1	11.0
Top ten sub-total	**41,771**	**48.4**	**74,734**	**52.4**	**6.0**
Rest of the world total	**44,523**	**51.6**	**67,796**	**47.6**	**4.3**
World total	**86,293**	**100.0**	**142,530**	**100.0**	**5.1**

Fishing industry has always been significant in Norway and harvesting without depleting ecosystems for this industry is crucial. Protecting environment and sustainable approaches are important as well since the future generation will be able to use it.

Several stakeholders in Norway and other countries like Turkey and Nicaragua say that the addition of environmental issues has greatly enhanced the validity of the strategic environmental mechanism. The necessity to mitigate effects on natural habitats, along with the consultations, has contributed to reducing disagreement and increasing collaboration

between the aquaculture and fisheries areas, eventually leading to much more ecological sustainability (F. FAO 2018). Therefore, the importance of sustainability in fishing industry particularly in Norway is important since Norway is the second largest exporters globally. Following fishing rules would be demonstrated by the fact that perhaps the Norwegian Coast Guard works almost 70 percent of the entire of its time making sure that the rules are obeyed properly (Aune 2021). By recognizing concerns and conducting actual remedies, blockchain technology can aid in the achievement of specific Sustainable Development Goals (SDGs) connected to food production, the ecosystem, and livelihoods (Tsolakis et al. 2021).

Generally, the fishery industry is divided into two important segments which are capture production and aquaculture production. Fisheries and fish farmers are terms used to describe the producers. Both industries will be given a brief overview to show where they differ.

2.3.2 Aquaculture production

Aquaculture production has been around for decades and is a significant sector in Norway. This industry began to grow significantly in the 1970s and also aquaculture production has increased dramatically in recent decades and could be one of Norway's most significant answers to the global issue of producing enough healthy food for a population that is expanding quickly (Afewerki et al. 2022; Hansen et al. 2000).

Fishermen are switching to aquaculture to raise fish in a controlled environment and modern technology has allowed the business to raise Atlantic salmon (Salmo salar) and also rainbow trout (Oncorhynchus mykiss) in sweat-water cages (F. FAO 2018).

Although the dietary needs of both salmonids, rainbow trout and Atlantic salmon, are remarkably similar, the trout have a different body composition because of their increased fat content, and as a result, they utilize energy and macronutrients differently than the other species (Aas, Åsgård, and Ytrestøyl 2022). The farming of the two species uses the same rules, technology, and practices but more feed is consumed by rainbow trout than by Atlantic salmon. It might be noticed that the amount of feed that salmon consumes may

temporarily decrease at stressful times such as handling, delousing, period of illness, or unfavourable weather (Aas, Åsgård, and Ytrestøyl 2022).

Atlantic salmon is the main focus of the production accounting for 80% of all aquaculture production in Norway and according to figure 7 the production of salmon will take almost three years. The rainbow trout, which accounts for the majority of the remaining aquaculture production, is the second-most significant species and even in 2022 based on figure 7 and figure 8, rainbow trout remains important farmed species (Aas, Åsgård, and Ytrestøyl 2022).

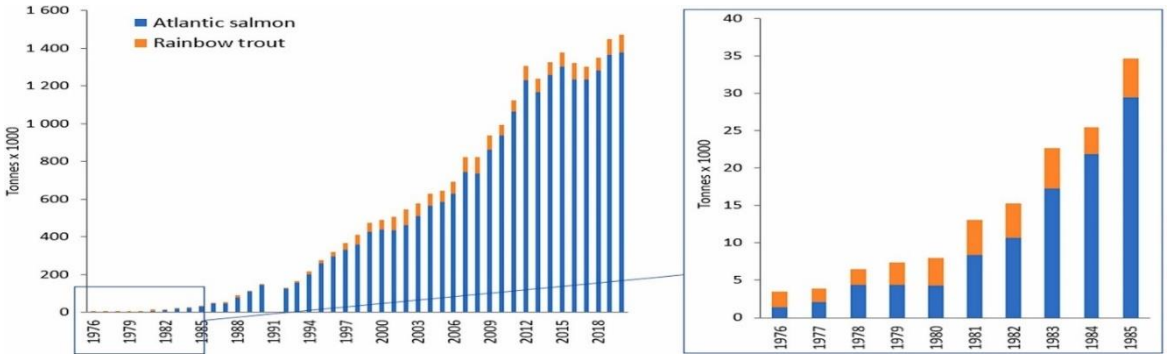


Figure 7: "Annual sale of farmed Atlantic salmon and rainbow trout in Norway in 1976-2020" (Aas, Åsgård, and Ytrestøyl 2022)

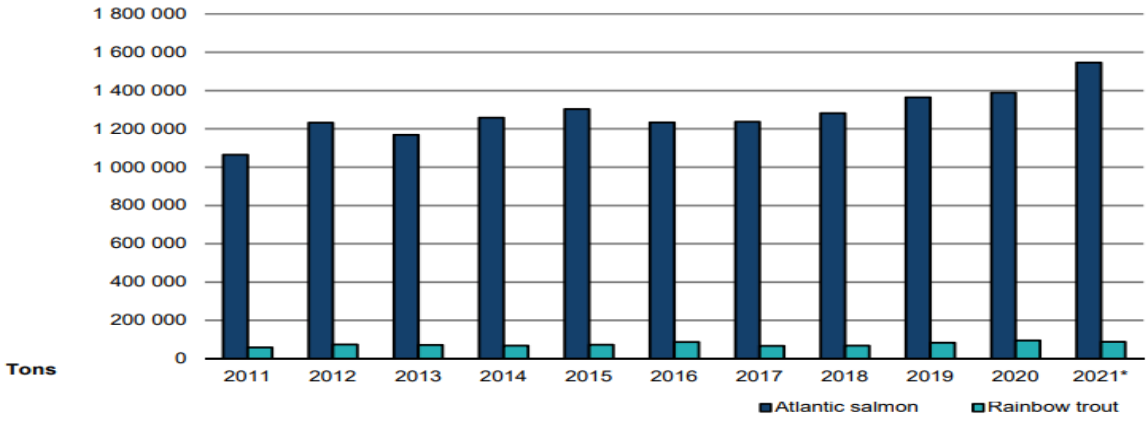


Figure 8: "Sale of Atlantic salmon and rainbow trout" (grow out production) 2011-2021[3]

Saltwater and freshwater for processing biological cycle of farmed Atlantic salmon are necessary. The processing cycle as mentioned earlier will take 3 years which consists of six main steps. During the period 10-16 months, in a regulated freshwater setting, eggs undergo fertilization and fish grow in weight to 100g. Next process would be Smoltification process- Smoltification is the process by which a fish undergoes

[3] https://www.fiskeridir.no/English/Aquaculture/Statistics/Booklets

physiological alterations from freshwater to saltwater. By transporting fish to saltwater enclosures, fish will grow to almost 4-5 kg over a 12–24 month span. Salmon harvestable size then is shipped to processing plants and next steps would be slaughtering, gutting, cutting, packing and others.[4] It should be noticed temperatures in the saltwater have a significant impact on the growth and also (Alver, Føre, and Alfredsen 2023) found that better efficiency is most likely to be achieved with larger cages because when the enclosure gets bigger, the ratio of surface area to volume goes down and consequently "the relative water exchange rate is reduced".

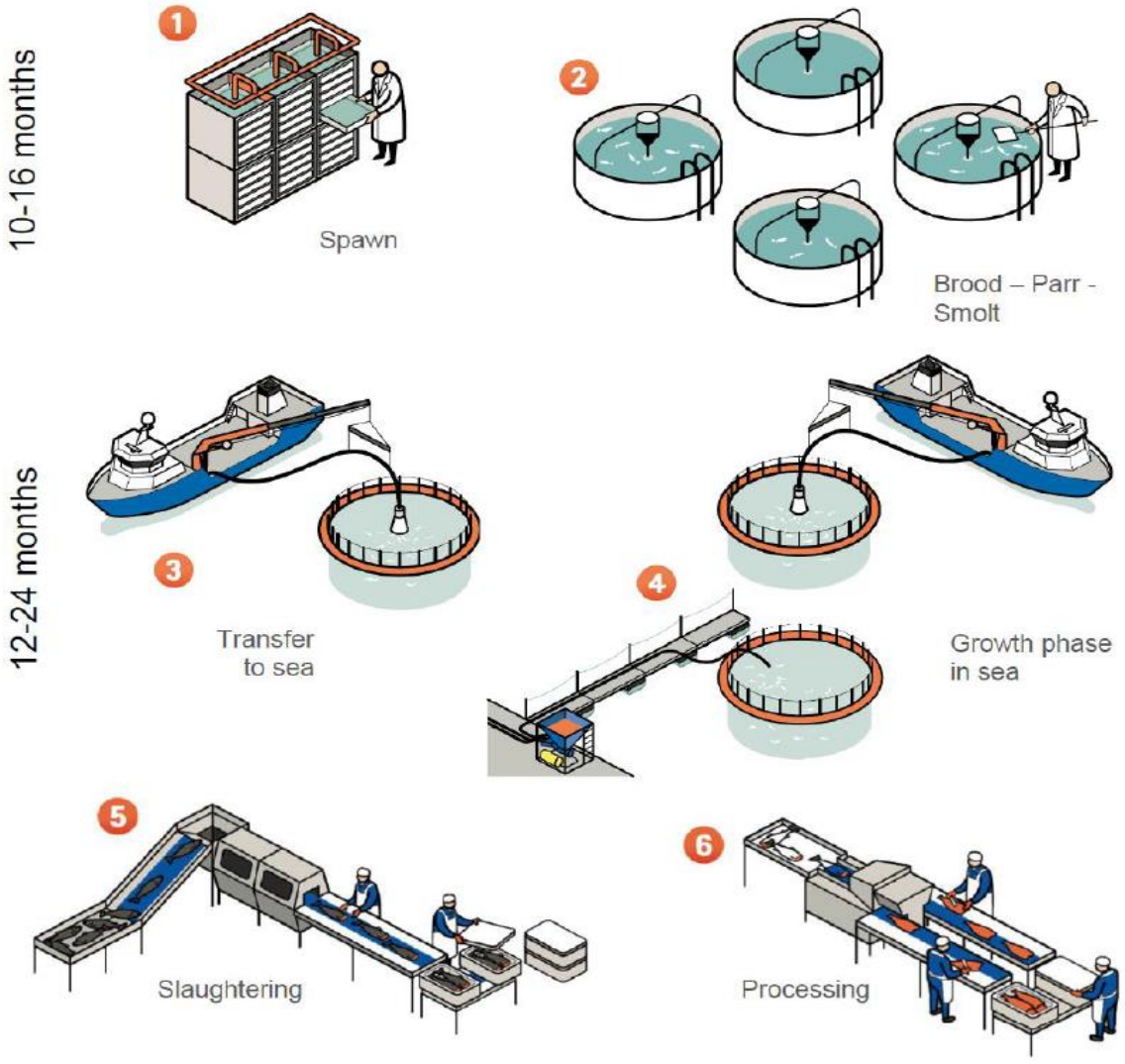


Figure 9: Farmed salmon production and processing cycle (Mowi 2020)[5]

[4] https://www.eumofa.eu/documents/20178/367933/PTAT_Organic+salmon.pdf

[5] https://www.eumofa.eu/documents/20178/367933/PTAT_Organic+salmon.pdf

Although low oxygen level is another major problem and could have negatively impact fish metabolism and eventually health, (Alver, Føre, and Alfredsen 2023) states that this issue is not currently known to be a significant problem in Norway's open cage installations. To a large extent, dry feed is the only type of feed utilized for salmon and trout. Feed contributes around 50% of the entire cost of production in terms of aquaculture-related costs (F. FAO 2018). Additionally, salmon sea-lice issues have caused significant increases in production costs in recent years (Aanesen and Mikkelsen 2020). Although aquaculture production has grown tremendously in Norway and plays an important role in economic activities and job opportunities, there are a number of big challenges and concerns for this industry. For example, disease and lice could spread rapidly because millions of fish are placed together in extremely small marine cages, resulting in one of the most significant concerns for this industry.

Furthermore, One major factor limiting new salmon farming licenses starting in 2013 is the difficulties handling lice (Aanesen and Mikkelsen 2020). Another crucial challenge that this industry currently faces is environmental sustainability (Hansen et al. 2000 ; Afewerki et al. 2022).

Last but not least problem would be the devastating effect that this industry could have on natural ocean biodiversity since a dense layer of sludge full of pesticides comprised of fish poop, germs, and unconsumed feed cover the whole ocean floor.

2.3.3 Capture production

A significant percentage of the world's population-nearly one-third of all people-gets their protein from capture fishing. In 2020, according to the FAO, "178 million tonnes of aquatic animals" were produced worldwide, and 90 million tonnes, or 51%, originated from capture fisheries (Hayes 2023). Haddock (Melanogrammus aeglefinus), herring (Clupea harengus), blue whiting (Micromesistius potassium), saithe (Pollachius virens), mackerel (Scomber scombrus), Atlantic Cod, and capelin or caplin (Mallotus villosus) are

the major capture species. Greenland halibut, ling, and prawns are additionally captured in fewer amounts but they have significant economic value.

In Norway, “Blue whiting (Micromesistius potassium), herring (Clupea harengus), and mackerel (Scomber scombrus)” are pelagic species that are good sources of digestible protein, and make up approximately 57% of all capture production and are the most frequently captured species when assessed in tons. One of the species that Europe targets the most is the Northeast Atlantic mackerel (Scomber scombrus) due to its importance to the European economy (Anders et al. 2023). Mackerel is extremely vulnerable to environmental stresses (Anders et al. 2023). Refrigerated sea water containers are frequently used in Norwegian mackerel fisheries to store captured fish for a few days or longer, although this approach is as opposed to the standard method of pre-freezing storing (Anders et al. 2023). They are then moved to processing centers including the drying, salting, packgaing and freezing steps. As a final point, the number of fishing boats in Norway recentely has significantly dropped because of increased industrialization and effectiveness in the fishing industry, as well as higher registration costs for fishing boats (F. FAO 2018).

2.3.4 The importance of sustainable fishing industry

Answering demand without thinking about the future risks would destroy our natural resources. The concept of sustainable fishing would be “react to demand for fish and other seafood without depleting the number of species beyond repair or damaging the local ecosystem and climate.” Consequently, a standard is set for sustainable fishing industry and importantly the standard is founded on three concepts (Aune 2021).

Food and Agriculture Organization (FAO) of the united nations (UN) stated “Unsustainable fishing practices put at risk the long-term viability of fisheries and livelihoods of fishers and fishing communities, which depend upon them” (FAO). Therefore, sustainable fishing for society is crucial.

Sustainable fishing preserves the flora and fauna observed in our waterways and this aspect is one of the most noticeable benefits of sustainable fishing since marine ecosystems are safeguarded and allowed fish populations to reproduce. Equally important, there is less use for dangerous substances in sustainable community development, and energy consumption is kept to a minimum, and last but not least, rather than wasting resources in order to gain a fast buck, a sustainable fishing industry permits creatures and aquaculture to persist for generations. This approach consequently generates businesses

and provides economic advantages for a significantly longer number of years and future generation will benefit from it as well (Aune 2021).

2.3.5 The value chain of white fish industry in Norway

The Norwegian fish industry's primary sources are Atlantic salmon aquaculture, white fish, and wild capture of pelagic fish. In contrast to aquaculture, the species of white fish are mainly harvested offshore. (Richardsen et al. 2017)

The primary subjects of (Hjellnes, Rustad, and Falch 2020) will be the Norwegian white fish industry's value chain, including its history, current situation, and possibilities for growth. The term ‘white fish’ used to the species “tusk (Brosme brosme), cod (Gadus morhua), haddock (Melanogrammus aeglefinus), saithe (Pollachius virens), and ling (Molva molva).” (Hjellnes, Rustad, and Falch 2020)

Norway's population has easy access to sea food resources because to its extensive coastlines. The seafood sector and the oil and gas industries both contribute significantly to the Norwegian economy. According to (StatisticsNorway, 2019) report, in 2017 value of all exported commodities including petroleum was estimated to 860692 Million NOK, and also Crustaceans, fish, and mollusks provided 92241 Million NOK. The desire to produce marine products for the international trade grew as wealth increased in several nations including Norway throughout the latter half of the 20th century. The gross domestic product (GDP) contribution of the fish sector to the economy in 2017 in Norway was estimated 3.9%. Additionally, in 2016, the sector with the highest turnover (79535 Million NOK) was the seafood trade, and the second-biggest number of jobs, 11280, were created in that year. Equally important, 95% of Norway's wild-caught fish and farmed are exported, putting Norway after China in the second place as a seafood exporter in the international market. (Hjellnes, Rustad, and Falch 2020)

Based on (Hjellnes, Rustad, and Falch 2020) explanation, the whole operations needed for a cycle that leads to value creation through the various stages, distribution to end consumer, and disposal after consumption can be referred to as the value chain. According to figure 10, value chain in the white fish sector describes chain-steps that begin with fishing, sorting, continue with processing and distributing, and ultimately end with export or sales to shoppers. The value chain will not be linear in relation to the fish wet weight due to a sizable proportion waste during the value chain. The opportunity for value creation that would be advantageous to the Norwegian economy disappears without the processing of fish.

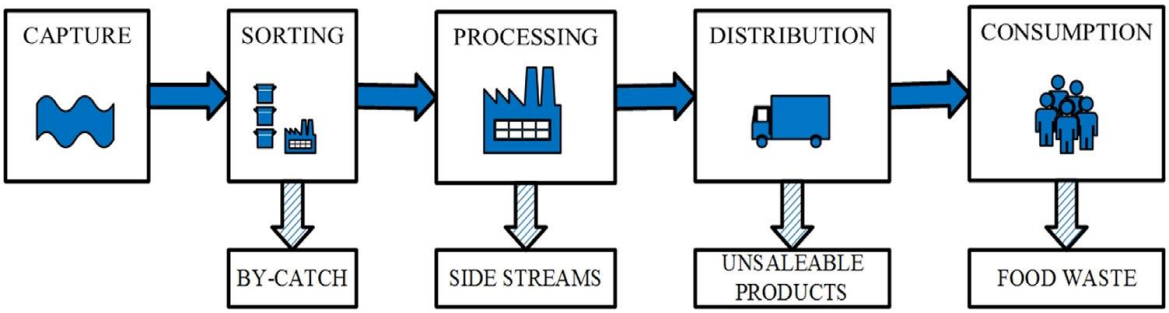


Figure 10: The value chain of the white fish industry in Norway (Hjellnes, Rustad, and Falch 2020)

According to a Norwegian report in 2016 regarding accessible raw material, fish industry includes 3.3 Million Tons. 43% of the amount accounts for wild-caught pelagic fish, 34% aquaculture, and 23% white fish produced. Just one fish species is grown extensively for food in Norway, and that is Atlantic salmon. Despite the fact that farming cod presents more concerns and problems than producing Atlantic salmon, in the beginning of the twenty-first century, the Norwegian aquaculture sector also regarded cod farming with considerable excitement since it is still a dependable supply of enough raw materials for the business. The process of cod is mostly dried, frozen, salted, and filleted in Norway before being ready for export. (Hjellnes, Rustad, and Falch 2020)

The efficient application of enabling technologies to the white fish business depends on a number of factors, including the assessment of potential barriers in the processing line as well as comprehension of the value chain. Adopting either enhanced manufacturing or transportation methods is known as process innovation. It means process innovation refers to modification to manufacturing procedures, logistics and value chain, and tools and devices. Production of raw materials left and minimizing the processes before export are two elements of white fish business might advantage from process innovation. Additionally, process innovation might promote conservation and a more sustainable use of resources by applying technological advances that enables higher exploitation of marine residual raw material. In reality, not only food waste reduction would be advantageous for the environment, but it would additionally guarantee more sustainably managed resource utilization. The remaining raw materials is needed to be procced in accordance with the healthy regulations in order to be suitable as both livestock feed and people food. Depending on how remaining raw components are proceed in Norway, they might be classified. For instance, if the remaining raw materials are proceeded in accordance with the law and regulations for byproduct , providing that the quality is high, they might be utilized as feed for livestock. In case of poor quality, they might be used to make fertilizers

or other biofuels. It is important to note that in Norway, food for animals and other less valuable goods account for almost 50% of the usage of marine raw materials. (Hjellnes, Rustad, and Falch 2020)

The low level of remaining raw material usage is caused by a number of factors, one of which is the difficulty with technology and logistics, especially for seagoing vessels due to the fact that rest raw material from the fish is highly prone to instability and decay quickly. Transporting the remaining raw materials would provide the sector with extra obstacles and concerns. For example, additional excursions to shore might be required for the transportation of the remaining raw materials, increasing fuel usage that is harmful for the environment. Transportation obstacles could give rise to delays, which would disrupt plans for manufacturing, impose financial burden, and maintenance costs for vessels might have a detrimental effect on the profitability of the sector as a whole. One effective method to increase the likelihood of continued processing to produce high-quality goods is to freeze the remaining raw materials in trawlers before returning to on-shore equipment for processing. Therefore, preservation at temperatures that are low, quick cooling, and a quick period throughout catching and manufacturing are essential. With this strategy, the catch is not only kept fresh and healthy but the danger of spoiling during transit is also reduced. Consequently, an ideal finished product that meets the highest standards for both nutritional value and taste will be produced. Furthermore, the advancement and utilization of an environmental chamber or a climate chamber for the goal of investigating spoilage-preventative storage methods, may represent a promising and innovative avenue within the fish business. In a controlled environment with predictable climate conditions, a climate chamber is a closed-room used to meticulously study and understand how various climatic elements impact biological objects. It is expected that more investigations, studies, and financial incentives will be necessary for advancement and adaption of processing technology. (Hjellnes, Rustad, and Falch 2020)

According to a design thinking technique, research by (Hjellnes 2021) shows that there are several logistical, legal, and industry-specific challenges that might make it more challenging to maximize the use of the remaining raw materials. Figure 11 is a summary of the issues that have drawn attention and the recommended remedies to enhance the industry, human usage, and technology of white fish. The figure demonstrates to determine which innovative approaches are the best, further investigations and studies are required, and also the necessity for more investigation in order to visualize all potential issues.

Besides, it creates suitable answers that may be an effective and organized model for further projects. (Hjellnes, Rustad, and Falch 2020)

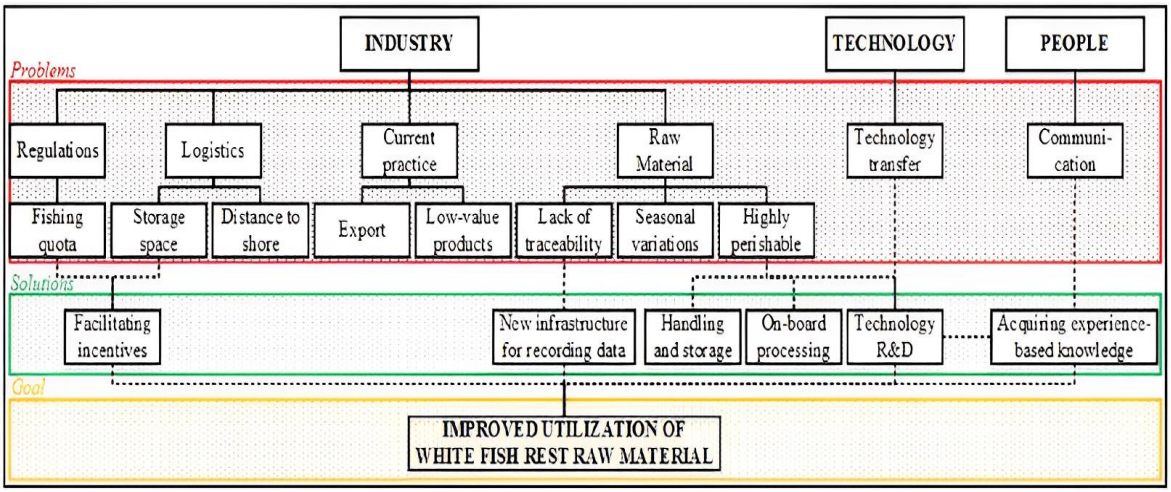


Figure 11: A summary of the issues and recommended remedies to maximize the use of the remaining raw materials (Hjellnes, Rustad, and Falch 2020).

2.3.6 Blockchain applications in worldwide fishery/ aquaculture value chains

Considering the fact that blockchain technology is being used by the aquaculture and fisheries industries for improving value chain transparency and traceability as well as prevent unreported and illegal (UI) fishing activities, the present situation and possible future applications of blockchain in international aquaculture and fisheries are described in (Tolentino-Zondervan, Ngoc, and Roskam 2022). The methodology of the paper (Tolentino-Zondervan, Ngoc, and Roskam 2022) uses PRISMA, "Preferred Reporting Items for Systematic Reviews and Meta Analyse", to provide a comprehensive analysis of the literature. Besides, to find areas for improvement and make quantifiable recommendations regarding possibilities for future applications of blockchain in fishing industry, (Tolentino-Zondervan, Ngoc, and Roskam 2022) utilizes text mining. A data science method called as text mining is used to extract reliable data through the articles and provide observations in order to supplement the investigation into the literature study. Insights are presented through text mining, infographics, data analysis, and statistics.

Figure 12 depicts the usage of blockchain technology in the global aquaculture and fishery industry. Several developed and developing countries are utilizing blockchain technology in the fishing industry. Blockchain technology is widely and extensively used in developed nations like Norway (IBM Blockchain Transparent), the United States, and Australia. Similarly, blockchain technology in developing nations including Pacific Island nations,

Indonesia, Ecuador, Philippines, and Thailand on a limited-scale is utilized in the fishing industry. Implementation of blockchain technology is appropriate in the described use cases since there are multiple organizations including Non-Governmental Organizations (NGOs), governments, private businesses, and specialized fisheries needing auditing, transparency, distributing data. For example, the blockchain technology project's primary objective in Norway is to present information on the quality, source, and diet of fish to ensure that seafood is healthier and less hazardous for customers throughout the world. Additionally, in many business activities such as the Norwegian salmon business, blockchain promotes trust. The distinction between public and private blockchains is reshaping interactions between stakeholders in fishing industry. It means that fisheries utilize public blockchains to meet their specific business requirements, whereas brands, organizations, and retailers utilize private blockchains. (Tolentino-Zondervan, Ngoc, and Roskam 2022)

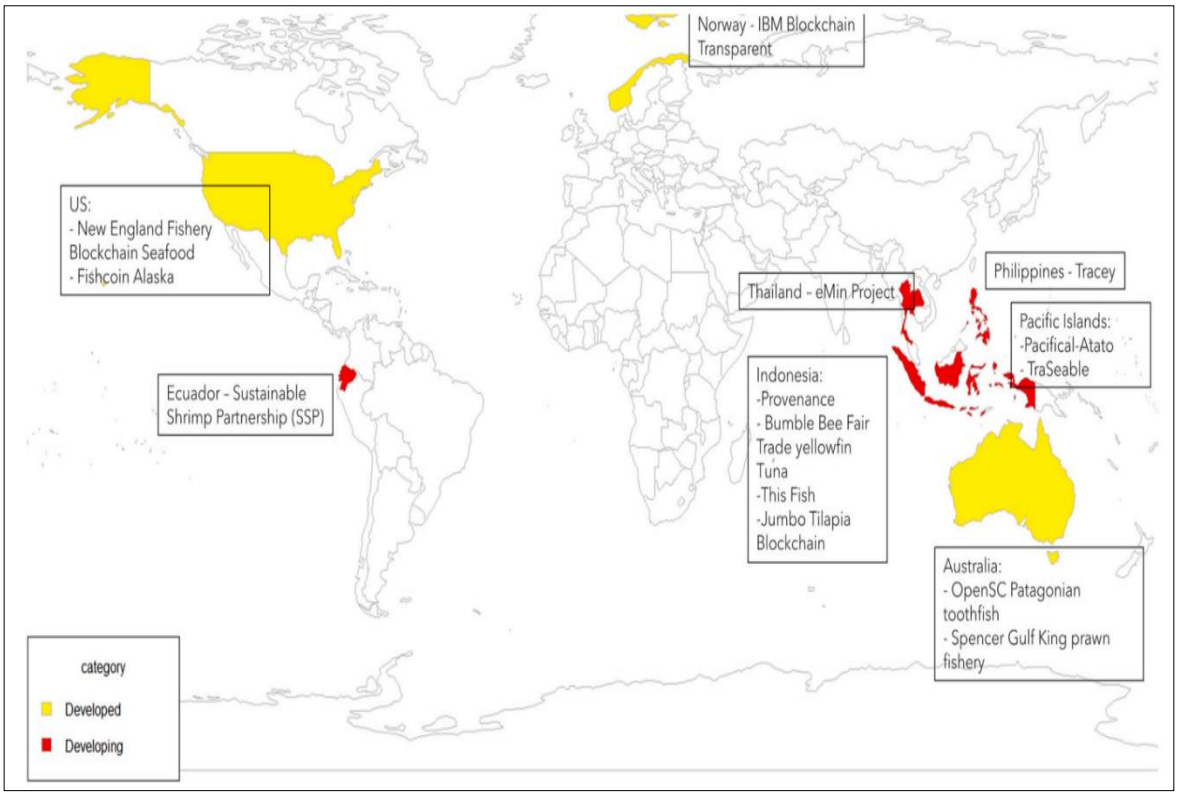


Figure 12: The implementation of blockchain in aquaculture and fishery globally (Tolentino-Zondervan, Ngoc, and Roskam 2022)

(Tolentino-Zondervan, Ngoc, and Roskam 2022) classified blockchain technology usage for market-oriented projects in aquaculture and fishing value chain in two following groups:

1. Blockchain technology usage in vertical dimension
2. Blockchain technology usage in horizontal dimension

In the first one (vertical dimension), there are two examples of using blockchain technology including implementation of blockchain technology for the purpose of traceability as well as utilization of blockchain technology regarding payments. For the seafood products and also fish, the goal of traceability would be to evaluate criteria such as market demands, quality, mislabelling, and evidence of a sustainable source. In the packaging and bags (boxes), QR-codes in the market are mainly used in order to track and trace solutions from catching to ultimately human consumption.

The purpose of using traceability may vary depending on the projects. It means that a data company which is known as Traseable Solutions in Australia uses traceability technology for other purposes in addition to track and trace fish. Another goal for the Australian company would be to prevent unreported and illegal fishing (UI) activities as well as violations of human rights in the seafood industry. (Blaha and Katafono 2020) On the other hand, blockchain technology is used in Norway (by the Norwegian salmon fisheries) to describe some factors such as water quality, origin of products, and the history of the feeding to end-users. New England scallop fishery with the goal of putting customers in direct contact with manufacturers. (Tolentino-Zondervan, Ngoc, and Roskam 2022)

There are several essential components in traceability, one of which would be trust. Integration of Internet of Things (IoT) and automated procedures may decrease the human-made errors and increase trust. Regarding data management, which is one of the standards for determining trust, Norwegian fish farming companies can securely distribute and share information regarding traceability and maintain membership on the IBM Blockchain platform. Therefore, trust among whole SC participants and stakeholders will be significantly increased. The second case of using blockchain technology in vertical dimension is related to payments/ presenting chain participants incentives. The examples of second case will be the Tracey project and Fishcoin application. “Tracey project, which provides income to fishers by monetizing their catch and trade data to Streamr Marketplace.” (Tolentino-Zondervan, Ngoc, and Roskam 2022) Through direct and indirect monetisation, third-parties including retailers, organizations, and end-users will be able to obtain data via the Streamr Marketplace. Fishcoin app presents incentive to fishers to share information in the distributed network by transferring tokens. Fishcoin (tokens)

could eventually be used in order to cover the expenses by the users. Regarding aquaculture and fishing value chain, (Tolentino-Zondervan, Ngoc, and Roskam 2022) explains that the main goal of distributed network in vertical dimension is to deliver transparency and traceability data related to product quality, unreported and illegal (UI) fishing activities, safety of food, and scam.

Regarding blockchain usage in horizontal dimension, only one categorization in the project Tracey in Philippines has been recognized. The utilization of distributed network technology in both Centralized and Decentralized Finance. In order to improve transparency, fishers are requested for sharing data in the distributed network. In exchange, the financial institutes use the shared information on the network to evaluate fishers' financial request.

2.3.7 The effect of contemporary technologies in fisheries and aquaculture

(Rowan 2022) noted that aquaculture industry is under intense pressure to keep innovating in order to help achieve sustainability. Some of these pressures involve waste reduction, disease prevention, prevention of environmental damage and contamination, and improved fish production. FAO researchers stress that new strategies and approaches for fisheries and aquaculture growth is closely related to the adoption of latest technologies. The fast development of digitalization and advancement of information technology and the extended usage of software in the distribution network contribute to considerable advances in traceability systems (Subramanian et al. 2020). The third industrial revolution, or digital revolution, is discussed in the article as a way to assist and satisfy the demands of the fishing sector's expansion. The author examines the role of contemporary technologies including blockchain technology, Artificial Intelligence (AI), Internet of Things (IoT), Machine Learning (ML), robotics, sensors, and Information and communications technology (ICT) in the fisheries/aquaculture industries since integration of these technologies with fisheries/aquaculture industries bring potential gains for GVC, and equally important, the role of Quadruple Helix Hub, four key players including government, science, industry and society, in offering a comprehensive strategy to address the different requirements of the fishing industry. In addition, digital revolution could impact on world economic stability. Integrating transregional, international, and national digital innovation hubs would be helpful as well to reduce key risks for the aquaculture and fisheries sector. Examples of these dangers include worldwide pandemics, global

warming, and conflicts because might put the supply networks for fish and seafood in danger. (Rowan 2022 ; Andronova, Belova, and Yakimovich 2019)

End-to-end monitoring for manufacturing and SC in order to boost efficiency and optimize performance in operations is becoming more widespread in fisheries and aquaculture industry. This objective might be accomplished through utilization of precise digital technologies. Table 4 demonstrates the utilization of some digital technologies in fisheries and aquaculture. For example, cloud edge computing is a safe, responsive, and flexible application-aware network which can detect and adjust to changing demands. It utilizes AI to manage and monitor water quality, understanding fish behaviour, increase reaction time, make immediate decisions, enhance effectiveness of feeders, decrease labour intensive, improve harvesting, and fish species classification. (Rowan 2022 ; Saraswat et al. 2023)

The implementation of digital technology services may have been somewhat slow due to economic issue, lack of trust among various participants, technical difficulties, despite the fact that digital technologies have the ability to gather and analyse data and tackle challenges in the fisheries and aquaculture industries. (Rowan 2022)

Combined implementation of AI and blockchain technology would be advantages in fishing industry since not only transparency and traceability in global trade activities would be improved, one of the most significant benefits since every stage of the fish's trip can be tracked and transactions cannot be tampered with as a result, but also AI plays an important role in tracking and “monitoring fish harvesting and downstream industrial processing”. (Tsolakis et al. 2023) AI can also contribute to reducing operational expenditures in the fishing industry by addressing various cost-related challenges associated with equipment, human labour, energy usage for transportation and also production, and mistakes made by humans. By improving energy conversion and logistical efficiency, AI could be useful in decreasing fuel usage. For example, by enhancing weather prediction accuracy and maximizing energy storage, AI may also increase the effectiveness and reliability of renewable energy sources. (Tsolakis et al. 2023)

Adopting artificial intelligence presents challenges across a range of domains. The challenges were characterized as the following by (Tsolakis et al. 2023):

1. **Technical**

The accessibility and use of information is a significant technological barrier to the adoption of AI in corporate operations since companies may access unstructured data, and structuring the data is quite expensive.

2. **Legal**

Violation of privacy rights while utilizing data for AI presents another challenge. Authorities, governments or competitors, for instance, may violate farmers' private rights since they may use AI-enabled traceability of goods along a supply chain.

3. **Managerial**

The performance of the complex AI systems may suffer from a shortage of training data, and also the selection of the best AI solution may be challenging due to the absence of information standardization. Solutions based on AI are currently available in trial demos and only provide a small number of real-world solutions because they are still in the early phases of research and deployment.

4. **Ethical**

Using AI may lead to social issues related to ethnic and racial profiling. In other words, as a result of biases inherited from training data, AI systems may provide discriminatory results, and this is an ongoing ethical concern.

5. **Socio-economic**

Despite the advantages, there are a number of societal dangers associated with using AI in an industrial environment since tensions in social and technological engineering will increase if AI-driven solutions replace human labour, potentially leading to significant problems that require careful consideration and management.

Table 4: Utilization of digital technologies in fisheries and aquaculture

Digital technologies	Usages	References
Artificial Intelligence (AI)	• Managing and monitoring water quality • Understanding fish behaviour • Fish species classification • Increase reaction time and make immediate decisions • Enhance effectiveness of feeders • Decrease labour intensive • Improve harvesting	(Rowan 2022) (Saraswat et al. 2023)
Drones	• Hole detection in broken (damaged) cages • Collecting data regarding improving the operations of aquaculture by integrating AI and cloud computing • Observing fish farms	(Rowan 2022)
Blockchain	• Exchanging reliable and secure data • Traceability and transparency along value chain • Minimizing food waste • Creating the origins of food products • Transactions processing • Combatting fraud	(Rowan 2022) (Rejeb et al. 2020)
Sensors	• Fish heart rate (beats), fish stress level • Gathering real time measurements (parameters) related to water • Evaluating the state of fish feeding • Navigation	(Rowan 2022) (Andronova, Belova, and Yakimovich 2019)
Robotics	• Remotely Operated Vehicle (ROV) equipment to service cages • Cage maintenance and net repair • Eliminating sick fish	(Rowan 2022)

In order to effectively address both current and future demands for the industry, the Quadruple Helix Hub Model is referring to an integrating sustainable involvement from government, science, industry and society. Higher efficiency and productivity will be supported by the Quadruple Helix Hub Model, and the model also could support more sustained innovation. The four fundamental elements of an innovation system interact in a dynamic and reciprocal manner. The model emphasises the important of society as a dominant paradigm in the system. To provide instantaneous solutions for the industry sector, the model makes it easier to have access to specialist tools and advanced knowledge. With this method, information may be acquired to support sustainability techniques including material flow analysis, life cycle assessment, and principal component analysis to characterize operations and procedures. (Schütz, Heidingsfelder, and Schraudner 2019 ; Rowan 2022) These authors provided two example including drones and robotics equipped with AI capabilities to increase efficiency and decrease dependency on human labour for dangerous activities, as well as cloud edge computing for E2E value chain management. Other usage of the Quadruple Helix Hub Model is developed to address main problems to find immediate solutions. According to (Rowan 2022), five linked sections are commonly used by innovation hubs to meet the requirements of entrepreneurs. The five sections are including as following:

1. Commencing planned strategic initiatives
2. Returning or revisiting to applications that are already in progress
3. upgrading and improving stakeholder strategic organizations
4. Coordinating infrastructure
5. Establishing strategic communities

The emphasis on technological advancement and development has lately changed. Industry 5.0 aims to achieve an appropriate equilibrium between advanced technologies and the active participation of human workforce in contrast to industry 4 strongly emphasizing IoT, automated processes, and connectivity. Human-centric idea may be helpful for leading social organizations and community for low carbon technology and increasing societal understanding of modern sustainable innovation. The advancement of human-centric ideas may require the integration of human intelligence, AI, and robotics, thus, a dependable and strong interconnection may be provided by the Quadruple Helix Hub Model for the purpose of supporting micro-enterprise, as well as small and large

organizations throughout the various ecosystems, including aquaculture and fisheries. (Rowan 2022)

2.3.8 Challenges and benefits of using blockchain in fishing industry

Implementing of blockchain technology has undergone of several limitations despite the great benefits that this technology has brought for fishing industry. The global fish production in 2018 according to FAO report in 2020 was estimated 179 million tons while a few of fisheries utilized blockchain technology. According to this report, it might be concluded that the implementation of blockchain technology in global fishing industry is still relatively limited and often at a smaller scale. (Tolentino-Zondervan, Ngoc, and Roskam 2022) describes that limited adoption of blockchain technology in the fishing sector is mostly due to three factors:

1. **Blockchain's suitability for a certain problem**

The first step would be to understand the necessity of blockchain technology in fishing industry. Based on figure 13, the fishery companies may determine whether their organizations require blockchain technology. To be more precise, the necessity of blockchain technology in fishery sector depends on some important factors such as need for storing data, tamperproof data storage, contribution of several entities. A blockchain-based solution to fishing issues is more possible if all these components are present in the particular fishery instance. Identifying a type of blockchain to be utilized would be the following step if there is a requirement for blockchain adoption. In order to ascertain if there will be a long-term gain or loss, the third phase is comparing blockchain technology with other options and doing a cost-benefit analysis, and finding the decision-maker in the blockchain is the last step. This structured approach allows fishery companies to make decisions regarding the adoption of blockchain technology. (Tolentino-Zondervan, Ngoc, and Roskam 2022)

Regarding the challenges in fish supply chain, (Tsolakis et al. 2023) stated that providing a valid traceability system would be a great challenge since all stakeholders must be commitment and participate in the value chain in order to deliver reliable and accurate data. Numerous seafood groups stated that inconsistent worldwide technology and varied traceability standards are major obstacles to providing full-chain tracking. To reduce food fraud in global scale, Good Manufacturing Practices, HACCP (ISO 9001) are the most common standards.

2. **Incentive (s) to encourage fishers to use blockchain**

There are several reasons for unsuccessful blockchain-based projects after their initial launches, and one of the critical factors contributing to these failures is the absence of sufficient incentives for all stakeholders involved in the ecosystem. (Nodehi et al. 2022) For the adoption of blockchain, incentives present both a barrier and an opportunity. Tangible incentives can play a significant role in promoting the rate of acceptance of blockchain technology in the context of sustainability of fishery and aquaculture. (Tolentino-Zondervan, Ngoc, and Roskam 2022)

3. Trust in the application of blockchain technology

Increasing trust is a key factor in enhancing the adoption of blockchain technology in the fishing and aquaculture industries. One of the significant challenges in blockchain usage is data authenticity since the majority of fisheries rely on contribution of human to enter data and this may occur data entry errors. To tackle this issue and enhance the reliability of data recorded on the blockchain, many fisheries are turning to IoT devices since these IoT devices play an important role in delivering automated data onto the blockchain network. (Tolentino-Zondervan, Ngoc, and Roskam 2022) If the data is unable to be trusted, it is possible to ignore availability of data and information signals since industries for data verification related to fish storage refer to certification organizations or governments. Besides, inquiries into certification procedures in the network of seafood supply may raise more questions concerning the reliability of the ecolabels.(Tsolakis et al. 2023)

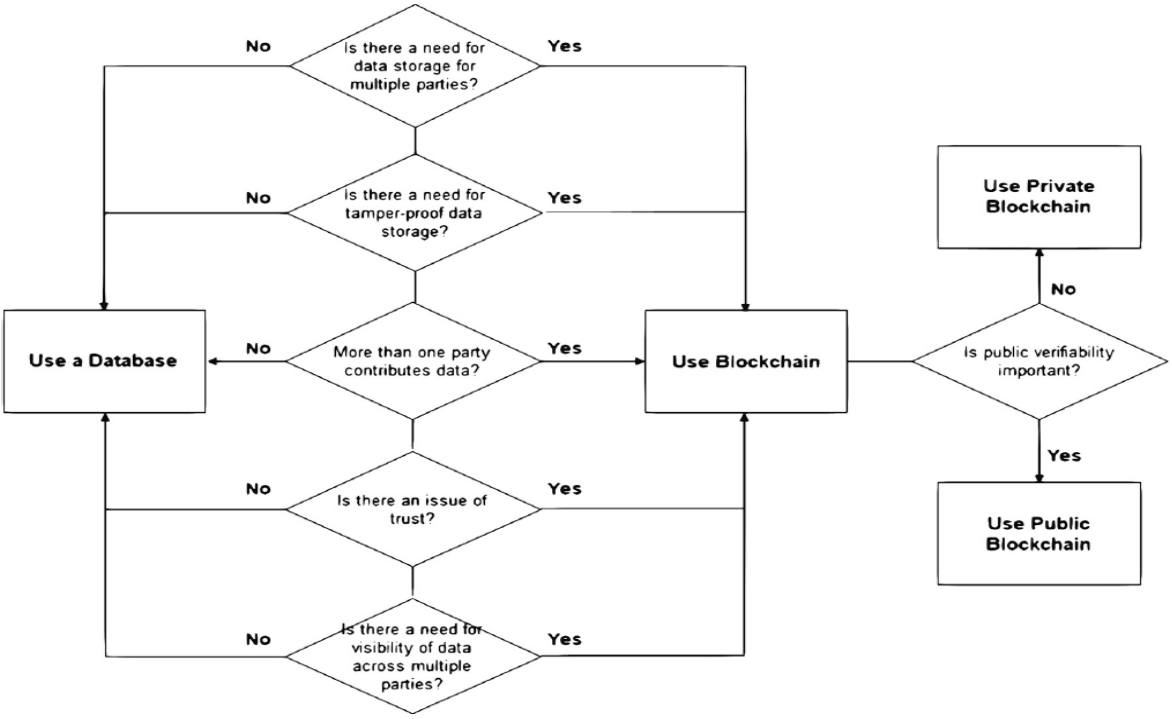


Figure 13: Decision-making framework for blockchain adoption and its type (Tolentino-Zondervan, Ngoc, and Roskam 2022)

3.0 Analysis and Results

3.1 Introduction of selected companies in the Norwegian fishing SC

In order to allow the reader to gain a comprehensive understanding of the specific companies under consideration, the author provides a summary of five companies including their backgrounds, headquarter, and related activities. As indicated in Table 5, brief descriptions outlining the scope of work for each of the five specific companies are provided for reference and clarification.

In Norway, seafood is the third-largest export sector[6] and over the past several years, different companies in Norway have recognized the potential of blockchain technology as a powerful tool for delivering transparency and reliability in sharing the complete life story of different species of fish.

Atea is one of leading IT infrastructure and system integration companies and the company is headquartered in Oslo, Norway. Around 1,750 people work at Atea, where there are 22 offices in different locations in Norway. The company had a turnover of approximately NOK 47 billion in 2022 and is listed on the Oslo Stock Exchange[7]. Atea involves in blockchain technology projects, particularly in the fishing industry in Norway. A few of Atea's objectives include:

1. High-quality IT solutions and services
2. Offering robust cybersecurity solutions
3. Helping clients with sustainability initiatives
4. Social responsibility

Norwegian Seafood Trust (NST) provides a tracking service that will trace the whole value chain of the fish in collaboration with Atea and IBM. Paper done by (J.P. Olsen et al. 2022) reveals that the Norwegian Seafood Trust (NST) attempted to achieve five aims to support the Norwegian seafood industry. These consist of:

1. Exchanging information and experiences
2. An edge in the marketplace
3. More value being added to Norwegian goods and services
4. “Leverage each other’s expertise”
5. In the future, provide consumer protection in a competitive marketplace

[6] https://www.ibm.com/blog/blockchain-stories-giving-norwegian-seafood-a-competitive-edge/

[7] https://www.atea.no/

IBM "integrates technology and expertise, providing infrastructure, software and consulting services for clients as they purse the digital transformation for the whole's mission-critical businesses." Innovation, client success, positive impact on society and the environment, industry solutions, security and trust are some of IBM's goals and mission. [8]

On 14 January 2020, a blockchain-based food monitoring tool was initiated through a collaborative effort involving Atea company, the Norwegian Seafood Trust, and IBM. The primary objective of this ambitious project was to introduce a comprehensive tracking service that would meticulously trace every stage of the fish's journey throughout the entire value chain.[9]

Table 5: five specific companies as illustrative examples

Company	Related activities	Headquarter
Atea	IT Services and IT Consulting	Oslo
Norwegian Seafood Trust (NST)	Tracking technology	Trondheim, Trøndelag
IBM	Computing	New York (Norway, Oslo)
Nova Sea AS	Salmon producer	Lovund, Nordland
Kvarøy Fiskeoppdrett	Salmon producer	Lurøy

Kvarøy Fiskeoppdrett AS is one of the oldest salmon producer in Norway. The company is a small-scale, family-owned enterprise located around the island of Kvarøy in northern Norway in 1976, and in 2020 the company used IBM blockchain-based technology to create a traceability record. According to CEO of the company, transparency, sustainability, maintaining and improving the quality of salmon products, and improving farming techniques are some of the fundamental goals of the company. The production of salmon by Kvarøy Fiskeoppdrett AS is around 8 tonnes annually, or 0.6% of the total production of Norway.

Nova Sea AS is one of the largest salmon farming companies and has locations along the entire coast of Helgeland in Norway. In 2021, the company announced it would become a member of the Norwegian Seafood Trust, a national seafood tracking network enabled by

[8] https://www.ibm.com/uk-en/about?lnk=intro

[9] https://norwegianseafoodtrust.no/om-oss/

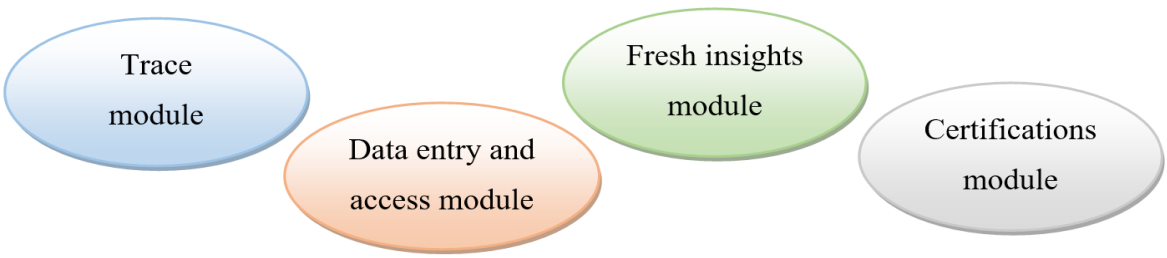
IBM blockchain technology. According to Nova Sea's sustainability report 2022, some of company's objectives include reducing the environmental footprint of salmon farming operations, providing customers with information about the origin and quality of their products, and improving the quality of seafood products.

3.2 Data sources

Several steps have been taken to conduct this research. At first, sustainability-related surveys, annual reports, and any other relevant data from companies' websites have been gathered. The next step is to prepare a comprehensive questionnaire containing several questions related to the reasons motivating companies to adopt blockchain technology, improvements that blockchain technology has brought to companies, main benefits they've realized through blockchain integration, impact on sustainability initiatives, investment they've allocated to blockchain projects, and their vision for the future of blockchain. Besides, an investigation of the difficulties and complexity that have emerged when incorporating blockchain technology into this special industry will be provided. The questionnaire is available for reference in the Appendix section. Through an examination of their experiences and outcomes, the author highlights the benefits, operational efficiencies, and enhanced trustworthiness that these companies have gained as a direct result of their integration of blockchain solutions.

3.3 IBM Food Trust

According to (J.P. Olsen et al. 2022 ; Kawaguchi 2019), IBM Food Trust magazine [10], and IBM website[11], "IBM Food Trust uses the blockchain solution" improves supply chain transparency and provides users to access their encrypted blockchain data and control over who has permission to access data. Just authorized transaction partners have access to the data on blockchain network. A smart contract in IBM Food Trust in a private channel established among two or more network users can be used. IBM Food Trust is a platform that has been designed with an integration of four modules.

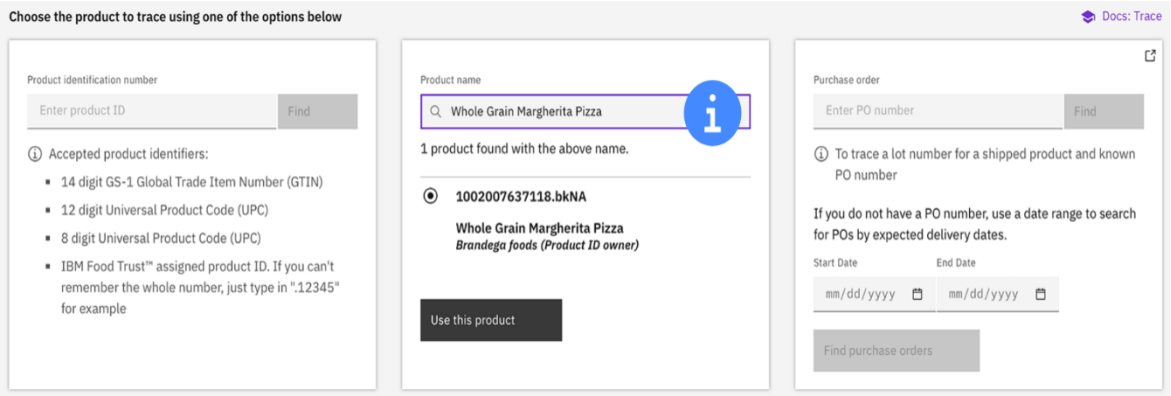


[10] https://www.ibm.com/downloads/cas/EX1MA1OX

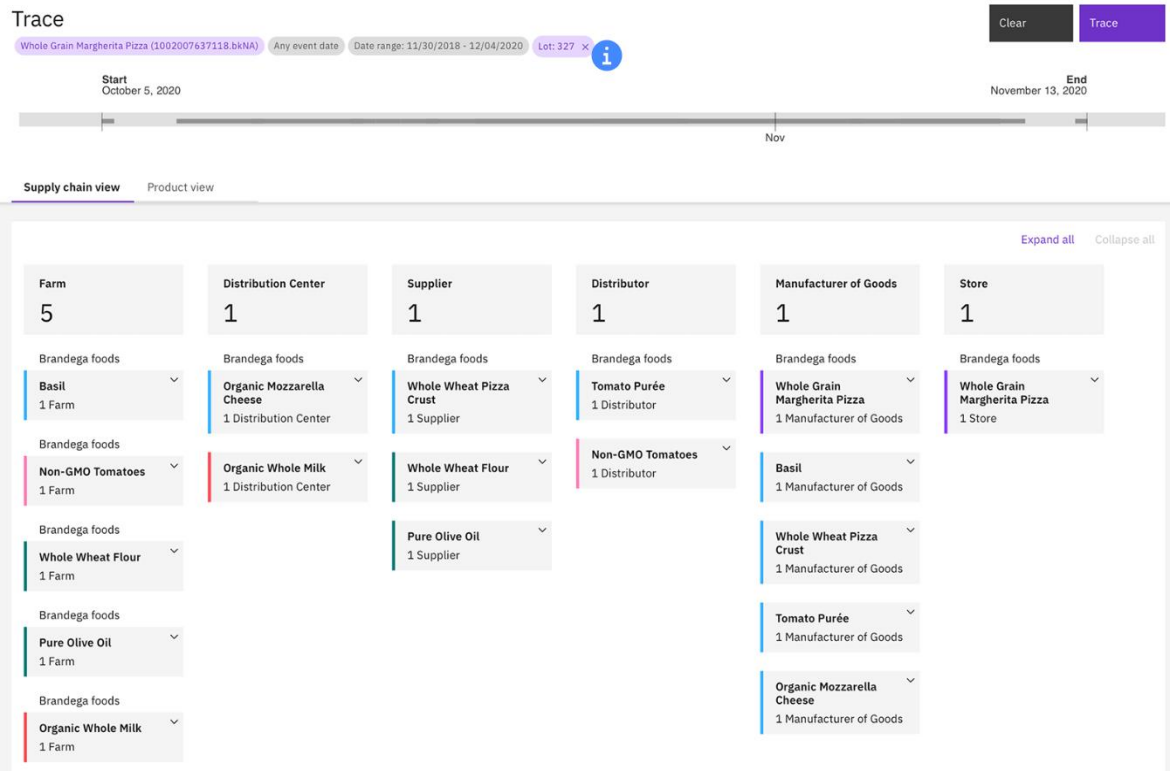
[11] https://www.ibm.com/

1. Trace module

Trace module offers a range of options that empower users to quickly track the origin of products according to their specific needs. Users can choose from multiple search criteria, including product ID, purchase order (PO) number, or product name, ensuring that they can access the exact information they require with ease. In addition, users can search based on anticipated delivery dates. Users simply need to input an expected date range, and the system will efficiently retrieve all relevant POs associated with deliveries scheduled within that specified time.



Trace module enables users to quickly access to End-2-End(E2E) information of products. In this module the origin of fish, real-time location, and current status of products can be transparently traced. It means that the module displays a transparent view of product ingredients at every stage of the supply chain.



Here are some of impact of trace module:

- Identifying the origin of products
- Preventing mislabelling
- Real-time monitoring
- Supply chain transparency
- Reduce food fraud

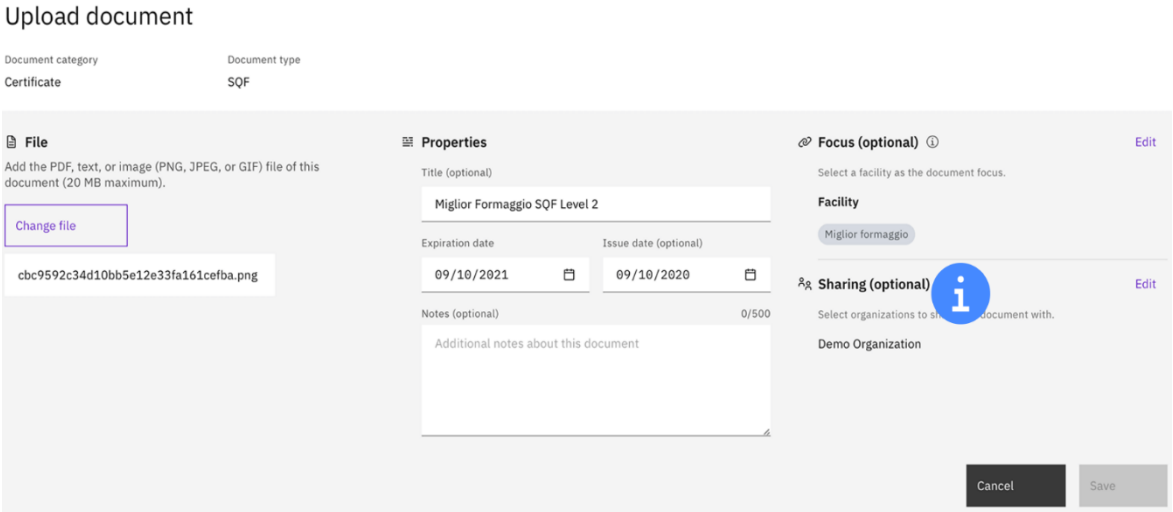
2. Fresh insights module

To enable users with the knowledge to maximize product freshness and extend shelf life, fresh insights module is designed and provides a set of features. Users can gain valuable insights into cold chain management, dwell-time optimization, and identify inefficiencies. Therefore, the benefits of this modules will be:

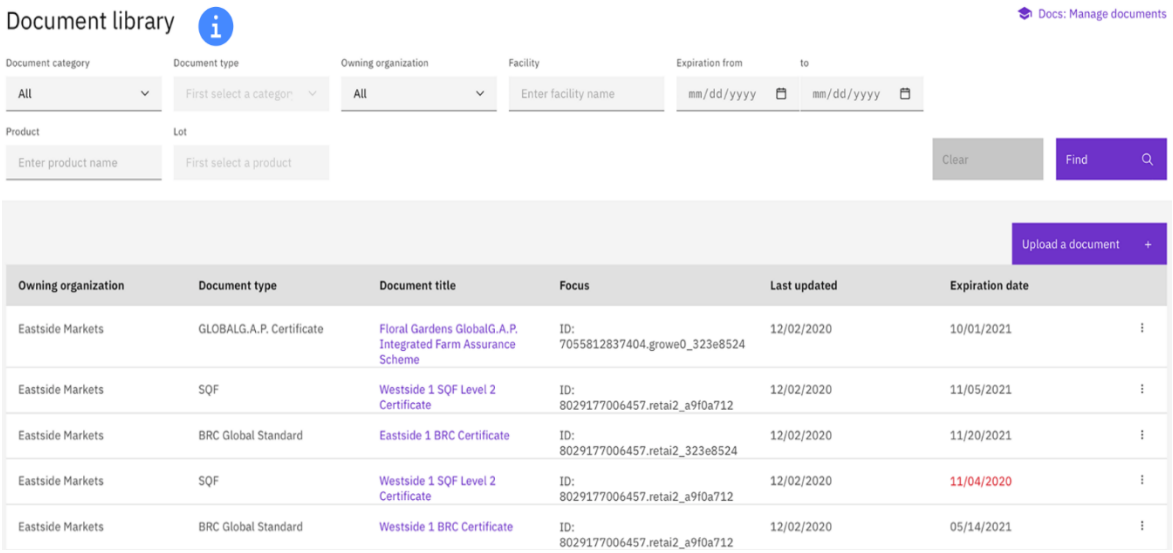
- Reducing wate
- Extend shelf life
- Cold chain management
- Enhancing product quality
- Identifying inefficiencies

3. Certifications module

The data quality and visibility across the supply chain is an outcome of users gaining the capability to digitally upgrade and digitize certifications. The upload of all digital documents to the blockchain brings several significant advantages, most notably improved data security and resistance to fraudulent activities.



Certifications module includes various sections and each serving a specific purpose. The library section is a valuable resource and in this section, users can access a list of documents that have been made available and authorized for their organization.



Therefore, some of the main goals of the certifications modules will be:

- Increased brand trust
- Reduce food fraud
- Data security
- Efficient information management

4. Consumer module

By giving consumers access to review blockchain data, the consumer module gives your company the means to tell your end users the story behind the products. Origin and journey of goods can be viewed by scanning a Quick Response (QR) code on the package, which will make it easier for consumers to gain a deeper appreciation of your brand's commitment to quality and the excellence of your products. Some of the advantages will be:

- Trust building
- Transparency
- Consumer Empowerment
- Competitive Advantage

For example, customers are provided with an extensive array of detailed information only after scanning the QR code found on the packaging of Kvarøy Arctic salmon products. Consumers may access details including background of the company, the source of products, values of quality, details on nutritional content, and ingredients and origin.

To sum up, each module in IBM food trust offers a special supply chain network option, and allows players to quickly browse and register items, transfer data and provide it to supply chain members, trace goods, and manage users.

3.3.1 Hyperledger Fabric

With Fabric, many parties may collaborate on a network while maintaining the privacy of parts of their data. This is due to of great features of Hyperledger Fabric such as private data and channels. For instance, a buyer may collaborate with several vendors, and the buyer and each seller's transactional connection needs to be kept confidential and hidden from other sellers. Fabric allows for private deals and confidential agreements on a flexible and secure platform. This system considers the current business trends of responsibility, transparency, and trust, making it possible to customize Fabric solutions for any industry. These aspects are the foundation of how Hyperledger Fabric was created, and it has an edge over many other similar platforms in this field. A few of the main characteristics of Hyperledger Fabric that set it apart from other distributed ledger solution may include accessible data through queries (JSON queries), support for several language smart contracts like JavaScript, Go, and Java, customizable consensus mechanism, quick confirmation, and created for ongoing activities, among other characteristics.[12]

3.4 Motivations behind implementing blockchain technology

In 2020, Kvarøy Fiskeoppdrett AS joined the Norwegian Seafood Trust (NST) and as a first salmon producer used IBM's blockchain solution. Kvarøy Fiskeoppdrett AS implemented blockchain technology for several primary reasons including:

1. Consumer protection – In response to customers who wanted more details
2. Traceable and transparent production
3. Building trust with consumers
4. Data customization and customer empowerment
5. Accessing automatic data and sharing within the blockchain network, ensuring transparency and enhancing the integrity of the supply chain.

The CEO of Kvarøy Fiskeoppdrett AS believes that salmon industry has a lot of data that they do not use it. They have camera systems with machine learning, drone technology, loggers, sensors, and struggling to connecting all the dots in between was the amazing thing with blockchain and IBM Food Trust for the company. From the perspective of the Kvarøy CEO, fishing industry includes a lot of cheating – a lot of mislabelling, thus gathering data straight from the system was a motivation to use blockchain network since it gives trust to the customers, and it can change the way fishing companies do business.

[12] https://www.ibm.com/downloads/cas/0XMOQJNP

Nova Sea AS demonstrated its commitment to addressing the concerns of its customers, which included critical aspects such as sustainability, food safety, and animal welfare,[13] in 2021, the company joined Norwegian Seafood Trust (NST). According to sale director, improving IT infrastructure and using modern technology is one of the company's goals in order to strengthen its position with customers.

Norwegian fishing firms are in a good position to satisfy the needs of the present seafood market and make sure that their sector continues to operate in an environmentally conscious manner.

The motivation behind the implementation of blockchain technology by fishing companies in Norway is rooted in the desire for transparency, traceability, quality assurance, fraud prevention, sustainability, and market competitiveness. As these companies continue to adopt blockchain technology, they are contributing to the broader goals of responsible and sustainable fishing practices. Therefore, both Kvarøy Fiskeoppdrett AS and Nova Sea AS share several common points and motivations for implementing blockchain technology in their operations.

3.5 Possible improvements by IBM Food Trust

The application of blockchain technology in the fishing supply chain offers several improvements. Table 6 shows that it can improve transparency and traceability, enhance quality, build trust, and foster sustainability while reducing waste.

Table 6: Possible improvements by IBM Food Trust

Improvement area	Key findings and insights
Transparency and traceability	❖ Through trace module users can track seafood products in the SC with security and transparency. ❖ Comprehensive monitoring and transparency throughout the entire SC process. ❖ Discover the origins of the seafood products, from source to plate.
Quality enhancement	❖ Through fresh insights module and optimizing dwell times in the supply chain. ❖ When stakeholders in SC work together and share information transparently, the quality of products gets better.

[13] https://novasea.no

	❖ E2E traceability ensures that products are efficiently managed from source to consumers. (through consumer module) ❖ E2E traceability can make a positive impact on both freshness and sustainability.
Trust and credibility	❖ Through consumer and trace module, when fish companies make an effort to provide transparent data about the quality and origins of the seafood products, it goes a long way in building brand trust and loyalty. ❖ Through certifications module, the upload of all digital documents to the blockchain brings security and resistance to fraudulent activities. ❖ Commitment to transparency sets seafood companies apart and creates a strong and unique presence in the market. ❖ Transparency builds trust and makes everything in the SC journey better for everyone involved. ❖ Gathering data automatically by sensors and share among blockchain network can give the trust to the consumers.
Sustainability	❖ E2E transparency and traceability through SC may allow people to better understand where sustainability issues and inefficiencies are located. ❖ E2E transparency and traceability through the SC can guarantee the authenticity of fish products. ❖ The aquaculture sectors may be able to track fish capture locations and methods using blockchain technology.
waste	❖ Waste is a result of customers who are in doubt about the quality of the products. ❖ Possibilities to decrease waste can be observed with more supply chain transparency. ❖ Improving recall response effectiveness can contribute to waste reduction.

3.6 Challenges and limitations

Although blockchain technology has brought significant improvements particularly in food supply chain, the implementation of this technology is not without challenges and still now

it is unable to address every issue with the traditional traceable methods. In this research, the challenges of implementing blockchain technology in the Norwegian fishing supply chain are categorized into different areas, including financial, motivation, technical, collaboration, and fraud challenge, each presenting unique obstacles and complexities to be addressed.

Financial challenge: The implementation of blockchain technology requires a substantial financial amount, and this requirement may pose a challenge. For example, based on CEO statements the initial investment for Kvarøy Fiskeoppdrett AS was notably high, and it took from one and a half years to three years to successfully implement the necessary changes in the company's procedures. Even though it has been pretty long time since Kvarøy Fiskeoppdrett AS first adopted blockchain technology, the company has not recovered its initial investment yet. This indicates the extended period of time that other fishing companies may experience for their return on investment. The investment may include the cost of hardware, software, maintenance and upgrades, consulting services, electricity, and network management.

Motivation challenge: As discussed earlier, in 2020, three companies (Atea, IBM, and NST) came together to launch the first blockchain-based application in Norway. Therefore, it can be said that blockchain technology is relatively early stage of development. It means that this technology continually changing, evolving, and discovering new possibilities to be useful. As a result, some companies are cautious about adopting this technology and take it slow since companies often want to choose safer solutions in order to ensure that their investments are profitable.

Technical challenge: A significant challenges that arises in the implementation of blockchain technology is its inherent complexity. This complexity mainly stems from the fact that blockchain is based on complex algorithms and mathematical concepts. Thus, companies willing to adopt blockchain technology through supply chain operations may find it difficult. A strategic decision regarding how to deal with the complexity of blockchain technology may depend on the organization's goals, financial resources, timeline, and human resources.

Collaboration challenge: Data from every node in the supply chain must be collected in order to determine a product's origin. All supply chain participants need “to use the same blockchain protocol” in order to fully benefit from blockchain technology and record data as it flows downstream. Therefore, It could be challenging to bring every supply chain

players together, and to establish the connections to create a provenance system among different stakeholders may take long time. (Mathisen 2018)

Fraud challenge: The CEO of Kvarøy Fiskeoppdrett AS believes that the fish business has seen a great deal of fraud, with people selling products that are not what they appear to be. The seafood fraud industry is a billion-dollar business. (Mathisen 2018) also reveals that recording an event for SC participants who wish to use the blockchain network to commit fraud is still feasible while also avoiding similar events.

Applications built on blockchain technology have significantly improved Norway's fishing supply chain. There are a lot of data in fishing activities still companies do not use it. The companies use a variety of sensors, machine-learning-enabled camera systems, drones, recorders, and robot systems because they are eager to collect data from farms and utilize it to continuously enhance what they do. For seafood companies the necessary for being transparent, doing sustainable activities, tracking products, enhancing trust among stakeholders, reducing fraud, and building trust with consumers can be some important factors. Companies will make investments in it in order to avoid fraud as well as protect their consumers. It implies that even when a product is actually something else, actors from all over the world have a desire to market it as Norwegian seafood. The whole supply chain can be authenticated due to blockchain technology.

4.0 Conclusion

In summary, The development of the Norwegian fishing sector is an outcome of a complicated relationship between economic, environmental, and technical issues. Norway's fishing sector is essential to the country's economic and cultural heritage. Norway is the world's second-largest exporter of fisheries products, and the aquaculture sector has grown significantly in the industry since the 1970s, especially in the production of Atlantic salmon and rainbow trout. However, some problems loke disease, sea lice, and environmental sustainability concerns may exist in the industry.

Around the world, the fishing and fish farming business is starting to use blockchain technology more to make things more sustainable, keep better track of where the fish come from, and transparency. Blockchain technology is being used by both developed and developing countries in the fishing sector. Blockchain adoption in the early stages is observed in the US, Australia, and Norway, with an emphasis on ensuring that the source, and quality of fish for worldwide customers are addressed. In addition, the integration of modern technologies, such as robots, sensors, machine learning, artificial intelligence (AI),

the Internet of Things (IoT), robotics, and information and communications technology (ICT), is also recognized as a major driver of innovation in fisheries and aquaculture. However, there are some challenges such as ensuring that blockchain technology is appropriate for certain issues, giving stakeholders sufficient incentives to adopt it, and fostering confidence in its application are all critical stages in the process.

New and creative solutions to solve problems, such as the IBM Food Trust with different modules, are made by collaboration together. This collaboration includes companies like Atea, Norwegian Seafood Trust (NST), and IBM. The IBM Food Trust has different modules, like trace, fresh insights, certifications, and consumer, that can be helpful with different sections of the seafood supply chain. Also, the IBM Food Trust, which is made using Hyperledger Fabric, provides a powerful platform including different parts that can increase transparency, track products better, improve product quality, and build trust with consumers. Using blockchain technology has shown to be helpful in reaching these goals, as seen in the positive changes it brings to how the fishing industry works. Although there are advantages of using blockchain in fishing industry, there are also challenges and limitations. These include the need for financial investments, the constantly changing nature of blockchain technology, technical complexities, the necessity for collaboration, and the problem of fraud in the industry. Nevertheless, the benefits such as reduced waste, improved sustainability, and increased consumer trust might outweigh mentioned challenges. The studies of Kvarøy Fiskeoppdrett AS and Nova Sea AS shows that using of blockchain technology is in early stage and it enables fishing companies to use data from different sources including sensors, machine learning, drones, and recorders, to increase their operations. In addition to guaranteeing authenticity and transparency across the supply chain, the technology tackles seafood fraud, a major problem for the sector.

4.1 Suggestions for further research

The many aspects of blockchain technology are not extensively discussed in research. The majority of research mainly concentrates on describing the functionality of the technology and ignoring its practical applications. Because of this lack of research, It is almost impossible to claim with certainty how blockchain might impact various aspects of humans lives, businesses, and the environment. Further study that explores the real-world applications and implications of blockchain technology is only in a number of areas.

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6.0 Appendix: Questionnaire

Motivations and Challenges:

1- Can you explain about the motivations and challenges that lead the fishing companies to implement blockchain technology?

- Cost efficiency
- Improved traceability
- Reduction of fraud
- Other (please specify)

Transparency in the Supply Chain:

2. How has blockchain technology increased transparency in your fishing supply chain?

- Real-time tracking
- Decentralized ledger
- Prevention of illegal fishing

Influence on Product Quality:

3- How blockchain positively influenced the quality of products?

- Traceability
- Identification of issues in real-time
- Improved authenticity

Cost Saving and Improved Efficiency:

4. How blockchain has contributed to cost saving and improved efficiency in supply chain?

- Reduction of intermediaries
- Automation through smart contracts
- Streamlining of processes

Customer and Partner Feedback:

5- Could you share any feedback or insights from customers or partners regarding the increased trust?

Waste Reduction:

6. How has blockchain technology contributed to the reduction of waste in your fishing operations?

- Optimized inventory management
- Sustainable resource use
- Prevention of overfishing

Challenges:

7. After implementing blockchain, what challenges or difficulties has your company faced?