BLOCKCHAIN TECHNOLOGY SUSTAINABILITY IN GOVERNMENTAL APPLICATION

STUDY CASE OF ESTONIA AND DENMARK

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Master's Thesis
Culture, Communication and Globalization
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Number of characters: 116.202

AALBORG UNIVERSITET

2022

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ABSTRACT

Blockchain technology is mainly known for its use in the cryptocurrency world. However, this technology can also be used in other contexts, such as the governmental one. This research investigates the sustainable potential of blockchain technology in governmental application, and more specifically, in the context of Estonia and Denmark, two digitalized countries.

In total, 8 semi-structured interviews of experts have been conducted, some via online meetings, others in writing. The collected primary data has been listed by categories of content and then, analyzed thanks to a qualitative content analysis. The contextualization and theoretical chapters of this research (which mainly relate to the concepts of sustainability and blockchain technology as well as the two countries' context) helped to understand, analyze and support the experts' statements.

It appears that the implementation of blockchain can indeed be a sustainable option for governments to consider. However, some conditions must be met in order for the technology to be more sustainable than the current systems. There already exist relatively sustainable blockchains, which a few are considered in this research. However, the technology is still a rather new one and the future might bring more sustainable options. Additional studies are also needed to dig into all existing blockchains and their potential sustainability.

1. Introduction

As part of my last internship, I have been in charge of the communication around a service related to tokenization, an online process that allows easy and fast assets and rights transactions via a type of blockchain. (Poulsen, 2021) It allowed me to gain new knowledge linked to blockchain technology. Being also in contact with it in my personal life, it has raised questions regarding my personal environmental-related beliefs and values.

This technology is becoming more and more used by lambda people as well as companies in diverse contexts and might become, for instance, a new way of online transactions (assets, rights, money, etc.). I was then wondering if it had ecological impacts and if it was possible to use blockchain in a sustainable way.

After doing some research online, I found that articles and research related to blockchain technology and its sustainability have been conducted and that it might be very interesting to dig into.

Blockchain technology is mainly known for its storage and tracking of cryptocurrency transactions, such as Bitcoin. (UN, 2021) However, it offers various other possibilities, which can be used by companies, for example, to reach some of the 17 Sustainable Development Goals (SDGs) set by the UN. But what if a government decided to implement blockchain technology?

Estonia is a country that has digitalized a lot of its governance based on blockchain technology (e-residence policy, e-voting, e-citizenship, Bitcoin-based ATMs, etc.). The country also plans to implement the technology "in governance, medical services, banking services". (Toshendra Kumar Sharma, 2021)

Even though data linking "blockchain technology" and "sustainability" can be found, when searching about Estonia and its use of the digital technology, the word "sustainability" is rarely mentioned.

I would like to know more about this technology and its sustainability in the context of the Estonian government. I also want to know if other digitalized countries, such as Denmark, can learn from the Estonian case. Indeed, the Scandinavian country has also digitalized a lot of its public sector. In 2016, it "ranked 9th among the world e-government leaders." (United Nations Department of Economic and Social Affairs, 2016)

2. Problem formulation

From this, I arrived at my problem formulation:

Can blockchain technology be a sustainable option in the context of a digitalized country such as Estonia? Would the technology also have a sustainable potential in Denmark?

The Estonian case will be taken as a point of departure. I will try to comprehend if blockchain technology can bring sustainable aspects to a government. Then, I would like to find out if it

is also applicable in the Danish context, and what the Scandinavian country could learn from such digital implementation in another digitalized government.

3. Theory

Sustainability

The main goal of the project is to figure out how sustainable blockchain technology can be in the context of governmental use. To be able to answer this question, we must understand what "sustainability" means and how to measure it. The chapter will help us to do so thanks to several sources' thoughts and definitions.

Over the years, the term "sustainability" has had several more or less similar definitions. (Kulman and Farrington, 2010, p.3437) Nowadays, it is known as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (WCED, 1987) The concept of sustainability has also had two major developments. The first one is its three-dimensional aspects, where the social, economic, and environmental dimensions must be in harmony. The second one is the distinction that can be made between "strong" and "weak" sustainability. (Kulman and Farrington, 2010, p.3438)

The idea of the three dimensions comes from the Triple Bottom Line concept created by Elkingtom (Elkington, 1994) which covers the people (social), the planet (environment), and the profit (economy). It is difficult to precisely measure those pillars, but here is how Elkington sees it. (Kulman and Farrington, 2010, p.3438)

The people pillar concerns people's happiness, well-being, and welfare. Happiness could be defined as a subjective state of mind depending partially on objective external conditions. This means that governments could improve this feeling of happiness. Those conditions could then be called "well-being" and "welfare", which could be defined as the capacities to accomplish one's potential and material needs (water, food, shelter, and health). (Kulman and Farrington, 2010, p.3440)

The profit pillar would be measured by the gross domestic product (GDP) of a country to see how much money it is making, as well as by the Human Development Index, in order to be more precise. (Kulman and Farrington, 2010, p.3439)

The two previous pillars must coexist with the last one, the planet pillar. However, as the people and profit pillars relate to the well-being of the present generation, it could go against the last pillar which is the one that cares about the future generations. This then raises questions concerning how to ally development and sustainability. (Kulman and Farrington, 2010, p.3439)

This leads us to the difference between the two types of sustainability. "Weak" sustainability could be defined as the fact that a loss of natural resources can be compensated by an increased capital. On the other hand, "strong" sustainability would mean that the planet pillar is the most important one. (Kulman and Farrington, 2010, p.3441)

Later in the history of the term, sustainability has been defined by Hedstrom thanks to four "buckets" (Hedstrom, 2019, p.5):

- Environmental Stewardship

This component could be associated to the previously defined planet pillar. Indeed, it refers to actions taken in order to protect the planet: "reducing waste; cutting carbon and other emissions; managing water quality and quantity"; etc. (Hedstrom, 2019, p.5)

- Social Responsibility

Here, "social responsibility" could be associated to the social pillar, as it refers to making sure everyone can have the life they want: "taking responsibility for the labor situation that your suppliers (and their suppliers) engage in; eliminating human rights abuses (e.g., child labor, forced labor, etc.); ensuring diversity and inclusion not only in your company but also throughout your value chain"; etc. (Hedstrom, 2019, p.5)

- Strategy and Execution

In this case, this could refer to the profit pillar. Indeed, it includes mentions of profit and value creation: "determining how our company can actually grow and be profitable while also reducing our full life-cycle (negative) impacts—and helping our customers do the same; creating value for society as well as for shareholders." (Hedstrom, 2019, p.5)

- Governance

This one stands out as it has no equivalence in the definition of the sustainability based on 3 pillars. The Governance refers to the way things are organized: "defined broadly as "how we run the place"—meaning the organization, structure, culture from the boardroom to the shop floor; the goals and metrics that incent behavior; engagement with internal and external stakeholders; disclosure and reporting." (Hedstrom, 2019, p.5)

Hedstrom refers to the Governance bucket as "the glue that holds everything together". (Hedstrom, 2019, p.23) In the context of a company, it would be the most important bucket, as without it, it would be "difficult to get anything else right" (Hedstrom, 2019, p.38).

- **The 17 Sustainable Development Goals**

The 17 Sustainable Development Goals (SDGs) are the heart of the 2030 Agenda for Sustainable Development, which was approved in 2015 by each of the United Nations Members States. (UN, 2015) The SDGs relate to several thematic issues. They are goals that those states are working on in order to reach a sustainable future (Lund et al., 2019). Here are some examples of those goals: the end of poverty, the improvement of health and education, the tackling of climate change, the preservation of the nature, etc. (UN, 2015)

These 17 SDGs will later be used in order to comprehend how sustainable blockchain technology can be.

On the UN website, each SDGs are developed into several targets. (United Nations, 2021) The first one elaborates the main goal, which most of the time has to be reached by 2030. The following ones get more in depth. Here are the 17 SDGs and a clarification of their targets.

1. No Poverty

The main target is to eliminate "extreme poverty for all people everywhere" (United Nations, goal 1, 2021), and such, by 2030. Extreme poverty is "measured as people living on less than $1.25 a day" (United Nations, goal 1, 2021).

The other targets mention: implementation of social protection systems; diminution of the poor's exposure to climate-related, social and economic disasters; implementation of significant mobilization of resources, programmes and policies to end poverty; etc. (United Nations, goal 1, 2021)

2. Zero Hunger

The core goal is to eradicate hunger by 2030, as well. It is also to make sure that everyone, especially the infant, poor and vulnerable people, has access to the necessary amount of nutritious and safe food, and such, all year long. (United Nations, goal 2, 2021)

The other targets mention: end of malnutrition; implementation of resilient agricultural practices and sustainable food production procedures; increase of the investment in agriculture research; etc. (United Nations, goal 2, 2021)

3. Good Health and Well-Being

The first target aims to reduce "the global maternal mortality ratio to less than 70 per 100,000 live births", by 2030. (United Nations, goal 3, 2021)

The other targets mention: end of avoidable newborns' deaths; end of diseases epidemics, such as AIDS, malaria, and tuberculosis; diminution of road traffic accidents leading to deaths or injuries; increase of the access to reproduction and sexual health-care aids; achievement of "universal health coverage"; reinforcement of the tobacco regulations; increase of health financing; etc. (United Nations, goal 3, 2021)

4. Quality Education

The main target is to make sure that, by 2030, every girl and boy completes "free, equitable and quality primary and secondary education", and such with significant and "effective learning outcomes". (United Nations, goal 4, 2021)

The other targets mention: guarantee of equal access to education; end of gender inequalities in education; insurance of access to education facilities which are safe and inclusive; increase of competent teachers; etc. (United Nations, goal 4, 2021)

5. Gender Equality

The “end all forms of discrimination against all women and girls everywhere” is the first target of this issue. (United Nations, goal 5, 2021)

The other targets mention: end of all kinds of violence against women; end of “child, early and forced marriage and female genital mutilation”; guarantee of equal opportunities for women in leadership; assurance of equal economic resources rights for women, such as ownership over land and other property; use of technology to empower women; adoption of policies to promote women rights; etc. (United Nations, goal 5, 2021)

6. Clean Water and Sanitation

By 2030, the core goal is for everyone to have widespread and fair “access to safe and affordable drinking water”. (United Nations, goal 6, 2021)

The other targets mention: access to sanitation for all; diminution of pollution to improve the water quality; expansion of international support in water-related programmes in developing countries; etc. (United Nations, goal 6, 2021)

7. Affordable and Clean Energy

The main target aims to “ensure universal access to affordable, reliable and modern energy services”, and such by 2030. (United Nations, goal 7, 2021)

The other targets mention: increase of “the share of renewable energy in the global energy mix”; increase of the energy efficiency; improvement of global collaboration to ease “access to clean energy research and technology”; enhancement of sustainable energy services supply in developing countries. (United Nations, goal 7, 2021)

8. Decent Work and Economic Growth

The core goal is to maintain the economic growth (per capita) in harmony with national contexts. (United Nations, goal 8, 2021)

The other targets mention: increase of the economic productivity level; promotion of entrepreneurship initiatives and development policies; achievement of decent employment for all; protection of labor rights, and promotion of safe working settings; expansion of the access to financial services; increase of “Aid for Trade support for developing countries”; etc. (United Nations, goal 8, 2021)

9. Industry, Innovation and Infrastructure

The first target relates to the need to develop transborder and regional infrastructure allowing human well-being and economic growth. (United Nations, goal 9, 2021)

The other targets mention: promotion of sustainable industrialization; increase of financial services for small-scale enterprises; improvement of research, and promotion of innovation; use of financial and technical support to enable sustainable development in developing countries; etc. (United Nations, goal 9, 2021)

10. Reduced Inequalities

The main goal is to reach and maintain “income growth of the bottom 40 per cent of the population at a rate higher than the national average”, and such by 2030. (United Nations, goal 10, 2021)

The other targets mention: promotion of inclusion for all, not matter the age, sex, race, etc.; adoption of policies in those regards; improvement and reinforcement of regulation of financial institutions; guarantee of representation for developing countries in international matters; facilitation of migration; etc. (United Nations, goal 10, 2021)

11. Sustainable Cities and Communities

Ensuring everyone access “to adequate, safe and affordable housing” is the first target of this issue. (United Nations, goal 11, 2021)

The other targets mention: insurance of access to sustainable and affordable transport systems; improvement of sustainable and inclusive urbanization; diminution of deaths and incidents due to global disasters; insurance of access to green, inclusive, and safe public spaces; etc. (United Nations, goal 11, 2021)

12. Responsible Consumption and Production

The main goal is to implement a 10-year agenda of sustainable production and consumption-related programmes where the developed countries would lead the developing ones depending on their capabilities. (United Nations, goal 12, 2021)

The other targets mention: diminution of worldwide food waste; sustainable management of chemicals and wastes; encouragement of companies to implement sustainable practices; reinforcement of awareness for sustainability for everyone; etc. (United Nations, goal 12, 2021)

13. Climate Action

The core goal is for all countries to reinforce their “resilience and adaptive capacity” to natural catastrophes and climate-related threats. (United Nations, goal 13, 2021)

The other targets mention: integration of “climate change measures into national policies, strategies and planning”; improvement of awareness about sustainability and adaptation through education. (United Nations, goal 13, 2021)

14. Life Below Water

The main target is to avoid all forms of marine pollution which are due to land-based actions, and such by 2025. (United Nations, goal 14, 2021)

The other targets mention: sustainable management and protection of coastal and marine ecosystems; end of overfishing, as well as unregulated, unreported and prohibited fishing;

prohibition of fisheries allowing the fishing mentioned previously; improvement of ocean health thanks to an increase of scientific knowledge and research development; authorization to access marine markets and resources for small-scale fishers; etc. (United Nations, goal 14, 2021)

15. Life On Land

The first target relates to ensuring "the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands", and such by 2020. (United Nations, goal 15, 2021)

The other targets mention: promotion of sustainable management and increase reforestation and afforestation; urgent action to avoid extinction of endangered species; end of trafficking and poaching of threatened species; creation of measures allowing to avoid "invasive alien species"; integration of biodiversity and ecosystem principles in local and national strategies; finance of "sustainable forest management"; etc. (United Nations, goal 15, 2021)

16. Peace, Justice and Strong Institutions

The significant diminution of all forms of violence in all countries is the main target of this issue. (United Nations, goal 16, 2021)

The other targets mention: end of any kinds of abuse against children; guarantee of "equal access to justice" for everyone and promotion of the rule of law nationally and internationally; diminution of arms flows, illicit financial and organized crime; diminution of all forms of bribery and corruption; development of "effective, accountable and transparent institutions"; assurance of "responsive, inclusive, participatory and representative decision-making"; reinforcement of the developing countries involvement in international governance; assurance of legal identity for everyone; assurance of access to fundamental freedoms and information. (United Nations, goal 16, 2021)

17. Partnerships for the Goals

The main target is the improvement of "domestic capacity for tax" thanks to the reinforcement of "domestic resource mobilization". (United Nations, goal 17, 2021)

The other targets mention: full commitment of developed countries; help for developing countries to reach "long-term debt sustainability"; promotion of an international equitable "trading system under the World Trade Organization"; improvement of "policy coherence for sustainable development"; respect of every country's leadership to determine sustainable policies; etc. (United Nations, goal 17, 2021)

- **In the context of countries**

As our research questions relate to how governments can act in order to be more sustainable (by potentially implementing blockchain technology, for example), it is important to understand how and why they should do so.

As we can read through the 17 SDGs targets, the actions must often be taken by regional, national, and international governance, as sustainable policies, practices, or measures must be implemented. It is then partially the responsibility of the United Nations Members States, which have approved the 17 goals, to act and try to reach those ambitions.

As explained previously, governance, one of the four main buckets of Hedstrom, is what makes everything else work. Hedstrom refers to companies when talking about governance, but we could also apply it to governments. This would mean that the way a government works (its structure and goals) is very important as it "holds everything together", as explained by Hedstrom (2019, p.23). What the government does has impacts on society, including the three pillars of sustainability.

By looking into the definition of blockchain and how sustainable it can be, let us see if, by implementing this technology, Estonia and potentially Denmark, members of the United Nations, could then take action to reach some of the 17 SDGs.

Blockchain technology

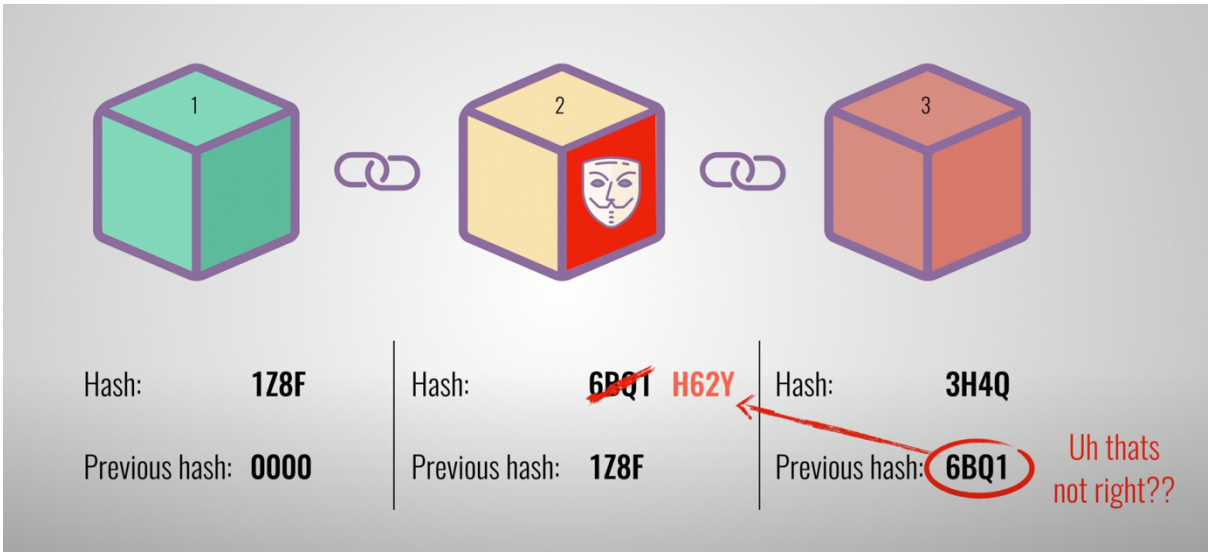
As the main subject of this project is blockchain technology, it is important to understand what it is and how it works, as people often lack overall knowledge about this rather young technology. (Alman & Hirsh, 2019, p.14-20)

Blockchain is a new technology that began as the essential system behind Bitcoin (Lund et al., 2019, p.16) which is a system of digital currency launched in 2009 that provides a secure way to earn and use electronic cash, and such, without enlisting the services of a bank or other financial entity. (Alman & Hirsh, 2019, p.14-20)

In practical terms, "a blockchain is a list of records organized in blocks" carrying information which are secured by strong coding and linked to each other. (Badreddin, 2018, p.317) The information contained in each block depends on the kind of blockchain. For example, the Bitcoin blockchain will store information such as the sender's and receiver's identity and the amount of money that is being transferred. (Simply Explained, 2017)

Blockchains are open, decentralized and based on a peer-to-peer network management, which means that every participant can upload new data. Thanks to a consensus protocol, each transaction is validated by the participants. (Asuquo et al., 2019, p.120) Once an information is programmed in a block, it cannot be altered without the approval of most of the peers involved in the network. (Badreddin, 2018, p.317) This feature makes it very difficult for information to be tempered. Blockchain allows transactions based on public-key cryptography which authenticate each message. (Asuquo et al., 2019, p.117)

Each block also has its own name, called a "hash", making it unique, similar to a fingerprint. When an information is added in the block, the hash also changes. Each block also has a hash of the previous block, preventing tempering. Indeed, if a block is tempered, its hash changes, but the following block still has the correct hash of this first block. The peer-to-peer consensus prevent this kind of tempering. (Simply Explained, 2017)



(Simply Explained, 2017)

As blockchains are always evolving, smart contracts have been created. They are stored in the blockchain, securing transactions. (Lawrenz et al., 2019, p.59)

According to several sources, including Alman & Hirsh (2019) and Badreddin (2018), blockchain technology has advantages. Thanks to this digital technology, each Bitcoin is unique and "cannot be copied and re-used in multiple locations". (Alman & Hirsh, 2019, p.14-15) It secures data and changes the current role of a third-party authority, making it unnecessary. It allows transactions to be immediate, cheaper, and still secure. (Alman & Hirsh, 2019, p.18)

"For example, when blockchain is adopted in real estate transactions, people will no longer need to go through a laborious process to officially record the purchase or sale of a real estate property, which involves the recorder's office of the city or county office and private title insurance." (Alman & Hirsh, 2019, p.18)

However, blockchain technology also bears some issues. For example, with the third-party authority gone, in the context of cryptocurrencies, there will be no institution to step in in case someone loses their own personal key to the blockchain ledger holding. Another issue, one that could be relevant for my research, is the amount of energy consumed by a blockchain in order to function. (Alman & Hirsh, 2019, p.19)

- **Blockchain technology and sustainability**

To understand how blockchain technology could bring to countries, such as Estonia and potentially Denmark, sustainable features, I will now elaborate on the technology's general sustainable aspects.

According to the UN, even though blockchain technology was primary used to manage cryptocurrency transactions, new uses have appeared in the past years which can help the execution and management of SDGs. (UN, 2018)

Indeed, in May 2021, the United Nations Commission on Science and Technology for Development (CSTD) examined the significance of blockchain technology in the economy and concluded that blockchain can contribute to sustainable development. (Banerjee, 2021)

Other sources, such as Lund et al. (2019, p.16) and Saberi et al. (2019, p.2131), are also positive about the fact that blockchain technology can be a valuable tool in sustainable growth.

However, the sources also emphasize the fact that such use of blockchain technology is still in early process, as the field is quite new, and needs more real-life implementations in order to prove the following statements. (Lund et al., 2019, p.16) Therefore, those must be taken as proposals, more than effective and proven answers to the issue. (Lund et al., 2019, p.19-22)

Here is a list of the SDGs that could be affected by blockchain technology and the reasons why.

Goal 2: Zero Hunger

Hunger affects mostly poor and vulnerable people, which refugees are part of. Blockchain technology could allow, in refugee camps, access to food coupons, and then reduce this particular issue. (Banerjee, 2021)

Goal 7: Affordable and Clean Energy

According to the 7th of the SDGs, pollution from fossil fuel must be reduced and replaced by green energy production. Blockchain technology could help make local and green energy production more common. (Lund et al., 2019, p.17)

However, some sources, such as Lund et al. (2019, p.17) and Sedlmeir et al. (2020), also call attention to the fact that blockchain can consume a lot of energy. Indeed, the technology has its disadvantages, as its Bitcoin and Ethereum networks, for instance, have massive footprints. (Lund et al., 2019, p.17)

It is challenging to imagine how a digital system can have such impacts.

The energy consumption of blockchains depends on their design, which must be considered while looking for IT solutions. For example, Proof-of-work (PoW) blockchains, used for most cryptocurrencies, use a lot of energy. However, according to Sedlmeir et al., they wouldn't be a big danger to climate, compared to the first generation of PoW blockchains, as the energy consumption doesn't increase considerably while more transactions are processed. (Sedlmeir et al., 2020, p.600) Non-PoW blockchains, on the other hand, applied mainly in enterprise and business context, use less energy than the PoW ones. (Sedlmeir et al., 2020, p.606)

Even though it is said that, because of their repetitive consensus, blockchain-based solutions require more energy than centralized non-blockchain-based systems, digitalization can also decrease energy consumption. Indeed, "for example, by enabling the digitization of supply-chain processes, blockchain can substantially reduce the amount of paperwork and transport, including air-freight (Jensen et al. 2019), or allow for more targeted recalls, leveraging many opportunities to reduce carbon emissions." (Sedlmeir et al., 2020, p.607)

More research on the subject is needed to properly realize how much energy this digital technology consumes.

Goal 8: Decent Work and Economic Growth

According to the article "How blockchain can power sustainable development" (Banerjee, 2021), blockchain technology could be an opportunity for developing countries to "diversify their economies" while generating revenue and increasing government income. (Banerjee, 2021)

Goal 10: Reduced Inequalities

This goal relates to, among other things, the facilitation of migration. Blockchain could help achieve this target as it could help refugees to identify themselves. Indeed, refugees often loose rights (the ability to vote or obtain a bank account, for example) as they may lack proof of identity. Blockchain and the use of biometric identity can then be used to solve this issue (Ledger Insights, 2020) and improve the access to national identification, as well as provide food coupons, as mentioned previously (goal 2, p.12).

Goal 12: Responsible Consumption and Production

Food items being damaged while being transported can result in food loss and waste which is an important target related to the 12th of the 17 SDGs (theory, p.8). This can be caused by inappropriate storage facilities. However, it is difficult to know the exact circumstances of when and where the damages occurred. (Lund et al., 2019, p.16)

Blockchain technology could improve supply chain management, allowing this type of damages to be avoided. (Lund et al., 2019, p.17) The quality of the received product would be improved and the replacement of a genuine item by a fake one would be more difficult. Indeed, the supply chain management would be visible for all parties concerned (Lund et al., 2019, p.21) which would have benefits concerning trust improvement "such as peer-to-peer data exchange, data security, data integrity, non-repudiation properties, an interoperable solution, and auditing" (Imeri et al., 2018). This trust would come from the two main factors of blockchain technology applications: public key cryptography and consensus protocol, which have been explained previously. (Imeri et al., 2018) Blockchain technology could, in this supply chain context, support the environmental and social dimension of sustainability. (Saberi et al., 2019, p.2131)

The UN confirms this, stating that blockchain technology could help reducing food waste by "supporting sustainable production by ensuring that products or production inputs are sustainably sourced, encouraging companies to adopt sustainable practices and integrate

sustainability information into their products, and ensuring consumers have relevant information for sustainable lifestyles (SDGs 12.6 and 12.7)". (UN, 2018)

Goal 13: Climate Action

Actions against global climate change, such as decreasing food waste and producing green energy, must be taken. (Lund et al., 2019, p.16)

As explained in the previous goals, blockchain technology has potential to make a difference and be a tool against climate change. However, the energy consumption of such technology must also be taken into consideration.

Goal 16: Peace, Justice and Strong Institutions

The digital technology could provide "legal identities and financial services to refugees and the very poor" which are particularly affected by hunger. (UN, 2018) It would be used as a tool against corruption (Ministry of Foreign Affairs, 2018, p.23), especially in refugee camps. Indeed, it would help refugees gain their identification and rights back, as explained previously (goal 10, p.8). (Banerjee, 2021) "The technology's feature of secure and transparent data recording could be used to ensure rights to aid, land, and money and prevent fraud" and restore public trust. (Ledger Insights, 2020)

However, data concerns have raised as anyone can request the "right to be forgotten" as a feature of Europe's General Data Protection Regulation (GDPR). However, this would be impossible when using the technology as data encrypted in blockchain cannot be erased.

Blockchain might also allow biases. Indeed, the technology prevent the falsification of data only after it has been added. This means that errors could actually be encoded and have negative impacts on people, as they would have been corrupted before getting to the blockchain. (Ledger Insights, 2020)

- **Blockchain and its potentially difficult implementation**

Some sources also point out the fact that blockchain technology cannot be implemented by any government or company.

First, any new technology would have to be easy to use in order for anyone to be willing to implement it. Indeed, if it is not easy, "the user experience will be negative" and they won't be eager to continue the experience. (Lund et al., 2019, p.21) In this case, the use of blockchain technology requires certain knowledge and familiarization. People often "lack of general understanding about blockchain", mistaking it for cryptocurrency. (Alman & Hirsh, 2019, p.14-20) As there are still no regulations, implementing this technology can also seem too risky. (Lund et al., 2019, p.22)

This could lead us to suppose that, for a government or a company to implement blockchain, the people involved must have the necessary familiarity and knowledge about the technology.

Second, the economic aspect of the implementation of such a technology is also significant. (Truby, 2018, p.408) According to Lund et al. (2019, p.20), some research focus on the economic viability of blockchain rather that its sustainability. Indeed, "technological innovation that costs more money than it saves will have a hard time becoming widespread". (Lund et al., 2019, p.20) This means that not every government or company would be able to operate with blockchain on the economic aspect.

4. Methodology

Ontological and epistemological approaches

The chosen ontological approach is constructivism (Bleiker et al., 2019) as, in the context of this paper, the knowledge is socially constructed. Indeed, it is the interviewees, experts in the field, that influence the issues around the sustainable potential of the blockchain governmental use. It is the people and their interactions that construct the reality, which is then subjective. I will try to answer "what" and "how" questions, such as: "What is the sustainable potential of the blockchain governmental use?", "How sustainable can the technology be?", etc.

As the reality is socially constructed and subjective, the epistemological approach will be an interpretivist one (Bleiker et al., 2019). The experts' beliefs and observations will be investigated based on their responds in order to understand the issues of my subject and answer my questions. (Bleiker et al., 2019, p.S5, S7) This means that the outcome of this research will be the individuals' perceptions. (Bleiker et al., 2019, p S4-S8) I will try to have the most objective approach of the reality, by admitting the subjectivity of the interviewees' answers.

Methods

- **Method of data collection**

My primary data will be collected thanks to interviews.

I will find the interviewees via online research, as well as via LinkedIn. I am going to post a publication mentioning the fact that I am looking for experts related to my thesis subject. This might lead to a snow-balling effect, as I will build a network of people helping me to find potential interviewees.

I will start by interviewing experts on the Estonian case, such as Axel Baudry (a business development manager at Guardtime, the company that has implemented KSI blockchain in the Estonian Government), as they could tell me more about how the implementation of blockchain has been possible in this Baltic country. As the Estonian case is my point of departure, I will then use this knowledge to ask questions to experts on the Danish case in order to see if such implementation would also be possible in Denmark.

For each interviewee, I will adapt my questions regarding their qualifications and knowledge on the subject. Thanks to the better understanding of the issues gained with the answers of

my first interviewees, I will be able to ask more precise questions during the following interviews. Some of the interviewees also asked me to receive the questions in advance, allowing them to be more prepared to answer them.

Depending on the interviewees' convenience, some of the interviews are conducted via online meetings, via Zoom or Google; others are done in writing, via emails or LinkedIn messages. The online meetings allow me to see the respondents' body-language. They are semi-structured interviews, as I prepared questions in advance, and then adapted them during the meeting, depending on the respondents' answers. This is more difficult to apply during the ones conducted in writing. However, an exchange of messages is still possible and allows me to deepen the interviewees' answers if necessary. In this case, the body-language is not visible, I might then miss a few information from the interviewees.

Combining those two methods seem to be the best option for me to collect the data I need in a quick and efficient way. Both also allow me to gain time, as neither of us, the respondent and myself, need to commute in order to meet face-to-face.

Here is a list of the interviewees with their background and profession. It will show us how relevant their knowledge is in relation to my thesis subject.

Experts interviewed via online meetings:

- Axel Baudry. He graduated with a master's degree in public administration at the university in the Netherlands. He is now a student at TalTech University and a business development manager at Guardtime, the company that has implemented KSI blockchain in the Estonian Government.
- Marco Schletz. He is a Postgraduate Associate at Data-Driven EnviroLab, an international group of researchers, scientists, programmers, and visual designers.
- Francesco Giacomello. He has a Master of science in Environment and Development Economics, is Product Manager at TripDoodler and a member of MasterZ Blockchain & Digital assets.
- Claus Skaaning. He has a PhD in Computer Science from Aalborg University and is the CEO of DigiShares, a company that focuses on tokenization.
- Andrej Kutliak. He is passionate about blockchain technology and worked as a developer at Behavee, a company offering technology services.

Experts interviewed in writing:

- Dimitris Kalamaras. He has a master's degree in Computational Mathematics and is a programmer working as web developer for Bitcoin Insider, a news website dedicated to cryptocurrencies.
- Marcel Tutor Ale. He has a PhD in Bioprocess Engineering and is a Process Engineer.
- Sergi Novohatski. He has a master's degree in International Business and Global business, finance and governance. He is also the founder and chairman of the Board of Node Expert Poland and has been a sustainability analyst at EcoVadis, a company provider of business sustainability ratings.

It was difficult to find interviewees directly related to the Estonian and Danish governmental blockchain implementation. As we can see, Axel Baudry, from Guardtime, is the only expert that allowed me to gain knowledge about the specific case of Estonia. Indeed, as it is Guardtime that has implemented the technology in Estonia and that it is the only company related to such application there, it is difficult to find other experts that would have deep knowledge on the Estonian case, other than people working for Guardtime. For the Danish case, I have contacted several companies and organizations that could have had knowledge about my subject, such as the Agency of Digitalization, but I haven't received any answer from any of them. Furthermore, blockchain technology hasn't been implemented yet in Denmark. Therefore, it is difficult to find experts on such application in the Danish context.

Most of my interviewees only have general knowledge on blockchain technology and sometimes also on its sustainable aspects. However, even though they don't have much knowledge directly related to the Estonian and Danish contexts, they will still be able to give me their expertise, thoughts and assumptions on the technology's sustainable aspects and its potential implementation in Denmark.

My secondary data will be collected online: articles, reports, web pages, etc. It will allow me to dig more into my interviewees' answers. Here are some examples of this secondary data: *Sustainability: What It Is and How to Measure It* (Hedstrom, 2019), *Understanding blockchain* (Alman & Hirsh, 2019) and *Blockchain and Sustainability: A Systematic Mapping Study* (Lund et al., 2019).

- **Ethical issues**

Even though a type of blockchain is already implemented and used in Estonia, it is still a rather new technology. Therefore, all declarations regarding its sustainable aspects, as well as its potential implementation in Denmark must be taken only as suppositions. Indeed, the technology is at the dawn of its history, and a lot has still to be proven.

Regarding the interviews, I might also be facing some ethical issues (Kvale & Brinkman, 2018, p. 61-79). As I will be directly communicating with people, I will have to be respectful in the way I approach them and ask my questions. I will tell them about the purpose of my project and how their answers will be used, in an academic context. When using their responses in the analysis, I will make sure to get their consent to record their answers and to cite them properly (if they agree not to be anonymous).

Furthermore, as some interviews will be done via online meetings and other via emails (or LinkedIn messages), there might be differences in the way the interviewees respond. Indeed, the ones answering in writing might give me shallower answers, as I won't be able to make follow-up questions as easily as I would do during online meetings. However, they would have more time to think, and potentially research, before answering my questions in writing, making their responses short and precise. This would be harder during online meetings, even though some respondents had received my questions in advance, allowing them to be more prepared. I think that the best option would have been to conduct only online meetings with my questions sent in advance. However, not all participants had the time to be present for a meeting, or to read and research the questions in advance.

- **Method of data analysis**

In order to analyze my collected data, I will be using a qualitative content analysis, a category-based method. (Schreier, 2013) Indeed, this type of thematic analysis is one of the typical approaches used in the context of interpretivism. (Bleiker et al., 2019, p S4-S8) It will allow me to generalize my interviewees' written (or transcribed) answers thanks to main ideas of content and themes. (Schreier, 2013) By reducing and structuring the interviews' content, I will be able to analyze them more easily. (Kvale, S., 2007, p.6)

As the categories will be shaped from the respondents' answers, I will use an inductive method, going from specific ideas to general ones. Even though I already have ideas of answers thanks to the theoretical chapter, this inductive method will allow me to discover themes that I might not have thought about before conducting the interviews.

After getting familiarized with the interviewees' answers, I will start by identifying the most relevant features of data (to my project). I will then create categories by detecting the global ideas, patterns of meaning. These categories will then be reviewed to make sure that they don't overlap one another and that they don't need to be modified, combined, or split. These categories will then be named and contextualized in the analysis.

With the help of my secondary sources (articles, reports, web pages, etc.), these interviewees' main ideas will allow me to answer my research questions: Can blockchain technology be a sustainable option in the context of a digitalized country such as Estonia? Could Denmark, another digitalized country, learn from the Baltic one, and also implement this technology?

- **Research method**

As I will be using a qualitative method, my primary data (the interviewees' responses) will allow me to answer my *what* and *how* questions (Aurini et al., 2016). I will try to do so by identifying, understanding, and interpreting this primary data. (Aurini et al., 2016, 34-77)

Thanks to the data collected in the theory and context chapters, I will have a better understanding of the issues. It will allow me to comprehend and contextualize the interviewees' answers and analyze them better.

This qualitative approach will allow me to explore a rather new issue that still needs more research and verification: the sustainable potential of blockchain technology in the context of governmental application.

5. Context

This chapter will help to set the context of this project. We will understand how digital Estonia and Denmark are, and how far they are in the implementation of blockchain technology. I will later use this knowledge in the analysis and discussion chapters.

Estonia and its digitalization

According to the Digital Economy and Society Index (DESI), Estonia and Denmark have some of "the highest scores for Digital public services" (European Commission, 2021, p.18).

The Baltic state is also one of the countries having "the most advanced digital economies in the EU", just behind Denmark (European Commission, 2021, p.19). Estonia is one of the best countries regarding "digital public services for citizens", scoring more than 90 points out of 100 in the indicator measuring what major Life Events can be done online (examples: new residence and birth of a child). (European Commission, 2021, p.68) It also scores more than 90 points when measuring the "digital public services for businesses" (European Commission, 2021, p.68).

These indicators show how digital Estonia is, whether it is through its businesses, its economy, or its public services.

In April 2007, the Baltic country was hit by a major cyberattack, leading to international cooperation being needed in order to minimize the rising threat, and Estonia becoming "one of the leading nations in cyber security" (e-Estonia, 2021).

Estonia has been building its digital society for years and has become very efficient, having a high level of transparency, as the Minister of internal Affairs of Estonia mentioned it during the Presentation of the Estonian Voluntary National Review (2016). In 2022, only two things need to be achieved physically: getting married and divorced. (e-Estonia, 2021)

On the website called "e-Estonia", the country is branded as "the world's most advanced digital society" (e-Estonia, 2021). This is also where we can find a timeline tracing Estonia's digital growth, starting in 1991 with the country's independence. (e-Estonia, 2021)

In 1994, a draft of a strategic plan for IT development, called "Principles of Estonian Information Policy", is created and ratified four years later by the Estonian parliament. (e-Estonia, 2021)

In 1996, the government starts its digitalization with: (e-Estonia, 2021)

- the "launch of the Tiger Leap Initiative, a country-wide IT infrastructure development program" (e-Estonia, 2021);
- the first e-banking services;
- and the "e-Cabinet meeting, [a] database and scheduler for streamlining governmental decision-making processes" (e-Estonia, 2021).

In the 00', here are some of the new additions to the soon-to-be e-government. (e-Estonia, 2021)

- e-Tax board: enabling declaration of taxes online.
- X-Road: the pillar of e-Estonia, "distributed data exchange layer for registers and information systems" (e-Estonia, 2021).
- e-ID and digital signature: enabling digital identification.

- i-Voting: increasing accessibility to elections.
- Cyber security: protecting online data.
- e-health: a system including data from Estonian healthcare providers.

In 2008, KSI blockchain is being developed. In 2012, it is implemented in Estonia to reduce potential other threats (following the 2007 cyberattacks), and back up several registries, making Estonia a pioneer of this technology. (e-Estonia, 2021)

In the following years, and up until 2021, here are some of the digital developments that followed the blockchain implementation. (e-Estonia, 2021)

- e-Prescription
- e-Residency: allowing anyone to join the Estonian society (e-Estonia, 2021) and providing benefits to entrepreneurs and citizens from states whose governments fail to have comparable digital developments and services (Tammpuu & Masso, 2019, p.622).
- Road administration's e-portal: a "one-stop online service for drivers and owners of vehicles" (e-Estonia, 2021).
- World's first data embassy: making Estonia "the first country in the cloud", an embassy outside the country's borders. (e-Estonia, 2021)
- Government AI strategy
- Proactive Child Care: enabling automatic benefits for parents of newborns.

- **Estonia and blockchain technology**

As explained previously, blockchain technology has been elaborated in Estonia in 2008 in order to prevent further cyberattacks. Indeed, in 2007, following the relocation of a Soviet-era monument, "Estonia became the target of a coordinated cyber-attack" (NATO STRATCOM COE, 2018, p.52) for more than 3 weeks. "Government and parliamentary portals, ministries, news outlets, internet service providers, major banks, and small businesses were all targeted". (NATO STRATCOM COE, 2018, p.52) The attacks affected the country's economy and demonstrated the influence of such cyber-attacks. "The vast majority of malicious network traffic was of Russian-language origin and had indications of political motivation" (NATO STRATCOM COE, 2018, p.52), but the Russian government refuted any involvement.

In 2016, the country "announced that Estonia's e-Residency platform will be facilitating a blockchain-based e-voting service to allow shareholders of companies listed on Nasdaq's Tallinn Stock Exchange, Estonia's only regulated securities market, to vote in shareholder meetings" (Dow Jones Institutional News, 2016). This technology allows the shareholders' participation to be more convenient and secure, as the e-votes are registered faster and in a more secure way, empowering the shareholders and improving their engagement. (Dow Jones Institutional News, 2016)

As mentioned previously, in Estonia, several registries are backed up and secured by blockchain technology: "Healthcare Registry, Property Registry, Business Registry, Succession Registry, Digital Court System, Surveillance/Tracking Information System, Official State Announcements, State Gazette". (e-Estonia, 2020)

The technology ensures that data is not misused. Indeed, it can do so by detecting who changes someone's personal health data and when it is done; seeing when some company's data in the e-Business Register was modified and why; ensuring that nobody has operated smart devices, such as war machines, that could be life-threatening; etc. (e-Estonia, 2020)

The technology used in Estonia is called KSI Blockchain (Keyless Signature Infrastructure) and was originally designed for the Estonian Government by Guardtime, a blockchain company (Guardtime, 2012). The use of blockchain technology allows data integrity and protection, as well as transparency (CoinEsper, 2021), replacing "human trust with digital truth" (e-Estonia, 2020)

Denmark and its digitalization

As mentioned above, according to the Digital Economy and Society Index (DESI), Denmark has some of "the highest scores for Digital public services", just like Estonia (European Commission, 2021, p.18), and it has also some of "the most advanced digital economies in the EU" (European Commission, 2021, p.19).

The Scandinavian country almost reaches, with 88%, the EU target concerning the integration of digital technology by businesses (European Commission, 2021, p.17). It also ranks one of the "highest in the integration of digital technologies" (European Commission, 2021, p.53) and in general connectivity (European Commission, 2021, p.26).

Regarding the e-Government users' indicator, which measures the percentage of persons using the internet to interact with public authorities, Denmark ranks quite high with 90% of users. (European Commission, 2021, p.67) The Scandinavian country also scores high with 90 points out of 100 regarding the digital public services for business indicator, which measures how interoperable those services are. (European Commission, 2021, p.69)

These numbers and statistics show how digital Denmark is, whether it is through its businesses, its economy, or its public services.

Indeed, Denmark has been transitioning from "paper-based public administration to Digital Government", also known as e-government, for several years now. (Motzfeldt & Næsborg-Andersen, 2018, p.136, 137)

The Danish Government explains Denmark's high digitalization by the fact that the Danish population has great trust in its public sector and confidence in each other. (Agency for Digitisation, 2016, p.6)

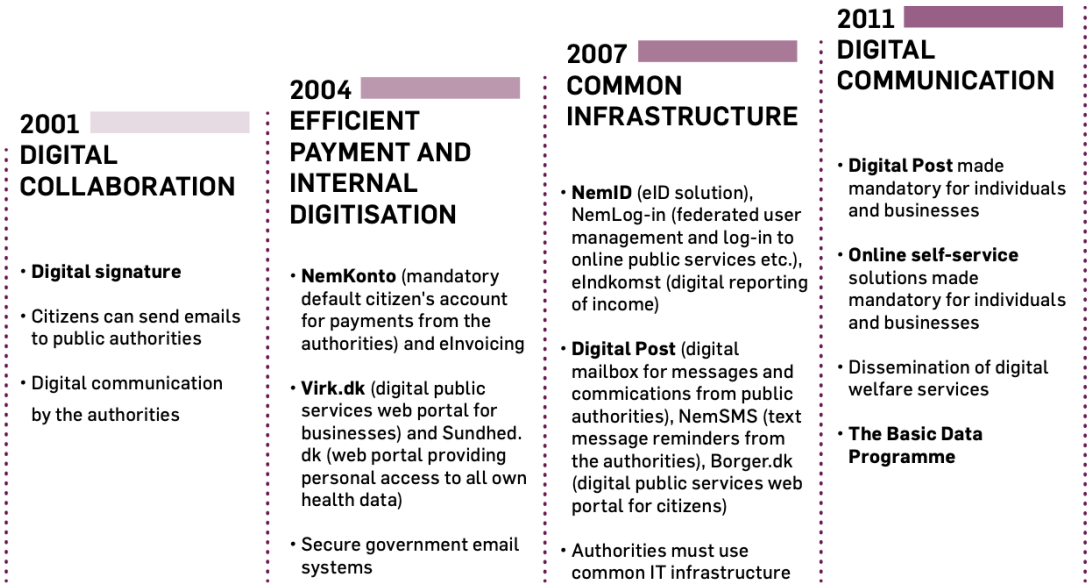
"There is a strong tradition of collaboration and finding new and practical solutions between public authorities, and across the public and private sectors." (Agency for Digitisation, 2016, p.6)

Everything started in 1968, with the introduction of CPR-register, a database of every resident in Denmark, used to identify each of them. This allowed the country's digitalization to begin in the 1970s, where the Danish public authorities begun to integrate computers and electronic records, replacing paper in its inner administration. (Motzfeldt & Næsborg-

Andersen, 2018, p.137) Then, from the 1990s, the development of the e-government become more advanced and complex, and concerned the external administrative activities. (Motzfeldt & Næsborg-Andersen, 2018, p.138)

In the '00s, the government started to use decision-support system, which would perform instead of human case officers in fields, such as the administration of environmental issues and taxation. Later decision-taking system would be implemented, initiating, processing, communicating, and making pertinent decisions. (Motzfeldt & Næsborg-Andersen, 2018, p.138)

Here is a timeline of the rest of Denmark's digital growth, found in *The Digital strategy 2016-2020*.



(Agency for Digitisation, 2016, p.13)

It shows 4 decisive years, where the Danish public services gradually became more digital, implementing, among other things, the digital signature, the NemKonto, the NemID, and the Digital Post. (Agency for Digitisation, 2016, p.13)

- **Denmark and blockchain technology**

According to Dinis Guarda in his article *How Governments Are Adopting Blockchain and AI In Advanced Economies Part 2*, Denmark would have for plan to implement blockchain "in digital identity, healthcare, business support and its welfare system", (Guarda, 2018) as well as in education. The Scandinavian country would be pushed by its population demographics to do so, as there are fewer young people available to work in the public sector. (Guarda, 2018)

However, when looking into the Danish *Digital Strategy 2016-2020* (Agency for Digitisation, 2016), there is no mention of such blockchain implementation. Only in *Strategy for Denmark's Digital Growth*, published in 2018, can we see the term "blockchain" appear. (The Danish Government, 2018)

Indeed, as part of the new initiatives regarding trade and industry growth, the use of blockchain is mentioned as a "solution for the Register of Shipping and certificates" (The Danish Government, 2018, p.45), making Denmark the first country to do so (The Danish Government, 2018, p.10). The technology would decrease the use of resources, lighten up the companies' burden, and allow them "to access data on registration type, quantity and application, which was not previously possible" (The Danish Government, 2018, p.46).

It is also stated in this document that DKK 32 million have been allocated for 2019-2023 for these matters. (The Danish Government, 2018, p.46)

The Ministry of Foreign Affairs of Denmark also states, in *Strategy for Denmark's Engagement with United Nations Children's Fund (UNICEF) 2018-2022* (2018, p.12), its common interest with UNICEF in technology such as blockchain, contributing to "the next generation of innovation fund models" (The Ministry of Foreign Affairs of Denmark, 2018, p.12).

These previous statements could lead us to understand that the Danish Government is planning on using blockchain technology and has created some economic support to do so. However, nothing is implemented yet, unlike it is in Estonia since 2008.

Reflection

The fact that those two countries are very digitalized might also bring inequalities. Indeed, the digital initiatives might end up helping privileged people with capitals and resources. Whereas these new solutions should be serving those in need of government services. (Tammpuu & Masso, 2019, p.622)

6. Analysis

From the interviews I have conducted, I have collected the most relevant features of data. After reviewing the content of the collected primary data, I have then created definitive categories by detecting the global ideas, patterns of meaning, and make sure they don't overlap one another or need to be modified, combined, or split. However, some of the respondents' quotes appear in two different categories as they relate to both and couldn't be cut in half. The categories have then been named and will be used in the analysis. In order not to be repetitive, this list will not be shared in this document as its content will appear and be analyzed here. However, the list can be found in the appendix, which also contents the complete interviews.

Here are the categories:

- Blockchain, its applications and protocols
- Estonian case and KSI blockchain
- Other options
- Sustainability
  - Energy consumption
  - Data security
  - Transparency and traceability

- Democratization of investment
- Balance between positive and negative sustainable aspects
- Danish and governmental contexts
- Potential threats to blockchain

I have decided to order the categories as such for different reasons. I have chosen to start the analysis with the category called "Blockchain, its applications and protocols" as it is important to know about the technology before going deeper into its sustainable aspects. Then, we have the category "Estonian case and KSI blockchain", as this is the point of departure of my research. Furthermore, just as the other types of blockchain, mentioned in the first category, KSI blockchain, as well as other ones in "Other options", have to be discussed and understood before exploring their sustainable features. The category "Sustainability" comes right after, including the sustainable aspects of the blockchains and protocols mentioned above. After this, comes the category "Danish and governmental contexts", which will be explored, thanks to the knowledge learned from the previous categories and other interviewees' comments. At the end, "Potential threats to blockchain" might put some of the acquired knowledge into perspective and lead to reflection.

Going through each category of content, I will now contextualize and analyze them in order to, later, answer my research questions. The two first categories will help contextualize and understand the following ones. My findings and reflections will then be further discussed in the next chapter, "Discussion". The last three categories ("Balance between positive and negative sustainable aspects", "Danish and governmental contexts" and "Potential threats to blockchain") will only be reviewed in the discussion chapter, as they will allow me to reflect on those subjects, as well as on my main questions.

Blockchain, its applications and protocols

First of all, it is important to understand blockchain and its variations, as it will help me later to answer my main questions.

The first comments of most interviewees on the subject are generally related to how new the technology is and how a lot still has to be researched and proven in the future.

"Blockchain is a new technology at its first steps. So, one could expect that problematic aspects will be addressed as the various blockchain protocols evolve." (Dimitris Kalamaras, appendix, p.43)

"Blockchain as a technology is still very young. A lot of questions need to be answered in the near future." (Marcel Tutor Ale, appendix, p.44)

Some respondents also mention that the technology is one that will shape our future.

"In my opinion, blockchain would be the future […] as a possibility to store in security a lot of information, and thanks for this security, you can make better services." (Francesco Giacomello, appendix, p.32)

"I would just add that the blockchain can be probably used for many applications that we have right now and make them more interconnected with lower fees and could make the economy more fluent and better for everyone […]" (Andrej Kutliak, appendix, p.42)

Even though I have already researched the subject in the theoretical chapter, the interviewees have brought more details and specificities to my attention. In the theory (p.10-11), I discuss the general properties of the technology without really taking into considerations the different applications it can have, as well as the different protocols it can be based on.

As explained in the theory related to blockchain and its sustainability (p.12), the technology is mainly known of its use in the cryptocurrency's context, but it has started to have other uses, some of them being tools to reach the SGDs set up by the UN. (UN, 2018) While most of blockchains related to cryptocurrencies are public (everyone has access to the data on the blockchain), those related to other contexts, such as governmental, for example, would be private, meaning that only some people would have access to the data.

"KSI blockchain is a blockchain, it is a distributed ledger, but it's not blockchain like Bitcoin or Ethereum. It's not a public blockchain, so it means that not everyone is actually able to validate the transactions." (Axel Baudry, appendix, p.13)

The interviewees gave me more insights into this perspective, letting me understand that, depending on the context in which the blockchain is implemented, its properties might be different.

I have learned from the respondents, such as Francesco Giacomello and Marcel Tutor Ale, that, in every case, blockchain has to be based on a specific protocol, also called consensus mechanism. The most common and known ones are the Proof-of-work and Proof-of-stake protocols (Francesco Giacomello, appendix, p.29). Depending on the needs of the blockchain application, a protocol might be a better fit than another one. Each protocol works differently. Therefore, their sustainability is different. Indeed, there is currently a debate in the field related to the energy consumption of the two main protocols.

"The current debate between the efficiency of Proof-of-work (PoW) vs. the Proof-of-stake (PoS) in relation to energy related issues." (Marcel Tutor Ale, appendix, p.44)

"[…] there are other different protocols, but the most famous are Proof-of-stake and Proof-of-work. The other ones are very similar to the Proof-of-stake, but diverse in different things." (Francesco Giacomello, appendix, p.30)

This will have to be taken into consideration while answering my main questions.

Estonian case and KSI blockchain

As explained in the contextualization chapter (p.20), Estonia is a digitalized country that has implemented blockchain in order to secure registries and protect itself from potential threats. (e-Estonia, 2021) This has been done thanks to the support of Guardtime, "a deep tech company specialized in cryptography and data management" (Axel Baudry, appendix, p.12).

Axel Baudry, business development manager at Guardtime, has given me more insights into the properties of the specific blockchain implemented in Estonia and the context of this implementation.

Axel Baudry explained that the fall of the USSR and the independence of Estonia had a role to play in the digitalization of the country. “In 1991, Estonia was a poor country, everything needed to be done” (Axel Baudry, appendix, p.13) and that is when the digitalization started. Then, following a cyberattack in 2007, as explained in the contextualization chapter (p.20), the country decided that the security of its data was essential.

“Estonia understood that we actually need to do something for cyber security. It was really important.” (Axel Baudry, appendix, p.14)

As the government didn’t have much money, “a win-win situation” (Axel Baudry, appendix, p.15) was created between Estonia and private companies, such as Guardtime, willing “to contribute to the gross of the country” (Axel Baudry, appendix, p.15). In 2008, Guardtime was founded and KSI blockchain created, and in 2012, it was implemented and used in Estonia, providing “integrity to the data […] used be the Estonian government” (Axel Baudry, appendix, p.13).

Keyless Signature Infrastructure (KSI) blockchain is a blockchain that doesn’t relate to cryptocurrencies, it is different from the one used for Bitcoin, for example. Its application relates to data management and digital assets. It is a private permissioned blockchain working “with a distributed consensus which is an agreement between different compute-nodes over what is a true or what is a false record” (Axel Baudry, appendix, p.19). This also means that you need to require the access to be part of it.

KSI blockchain doesn’t hold the data, which is stored on external servers, but only the hashes of those.

“[…] since KSI blockchain doesn't store the data, it stores only the hashes of the documents, it's very scalable, the hashes are very light data, it's not heavy at all, it's like couples of bytes.” (Axel Baudry, appendix, p.14)

As explained in the theory (p.10), the hashes are the identity of the blocks, making each block unique and recognizable by its name. If the data is altered, the hash will change, and the infraction will be noticed automatically. (Simply Explained, 2017) Axel Baudry elaborates on the fact the any kind of modification, as well as when it has been and by whom, will be revealed. Without this technology, this kind of violation of the data would probably not be detected.

“You can change the data because the data is stored in some servers, but KSI blockchain will guarantee that the data wasn’t modified, destroyed or stolen. So, it creates trust with the government data. […] Whereas before, without the KSI blockchain, we could not tell, we could just see that there is some data, maybe it was modified, maybe it was not.” (Axel Baudry, appendix, p.15)

Axel Baudry also explains that it is the Estonian government that holds the power over the data, while Guardtime handles the nodes of the blockchain (appendix, p.19). The nodes are the computers validating all transactions on the system.

"KSI Blockchain has 5 nodes spread over different continents, the locations remain hidden even for the employees." (Axel Baudry, appendix, p.19)

Other options

There exist other blockchains, using different protocols and having their own qualities and potentials.

Sergi Novohatski mentioned Baseledger blockchain (appendix, p.46), a blockchain for corporations that he is working with. It is a cheap and fast "public-permissioned, council-governed blockchain". (Baseledger, 2022) However, Sergi Novohatski couldn't tell me anything about the sustainability of this blockchain and I didn't find anything relevant on the website dedicated to it.

Andrej Kutliak told me about NEAR (appendix, p.43), a decentralized blockchain claiming to be climate neutral thanks to green projects. This protocol "has been awarded the Climate Neutral Product Label from South Pole" (Yessin Schiegg, 2021).

Those blockchains, as well as many others not mentioned here, could be worth exploring and could have the potential to be used for governmental application, possibly making a government more sustainable. However, I won't do it in this paper, as I don't have the time. Indeed, it would be difficult to find and analyze all blockchains existing at the moment.

Sustainability

During the interviews I have conducted for this research, I have asked the respondents about the sustainability of blockchain technology. Two main matters were mentioned by most of them: energy consumption and data security. The other sustainable topics discussed relate to the transparency and traceability of data, and the democratization of investments which won't be much developed in the context of this research, as I focus on the governmental application of the technology.

Some of the interviewees, such as Dimitris Kalamaras and Axel Baudry, also mentioned the SDGs, elaborating on the fact that blockchain could help, or not, reach some of them: goal 7 (Affordable and Clean Energy), goal 9 (Industry, Innovation and Infrastructure), goal 11 (Sustainable Cities and Communities), goal 13 (Climate Action), goal 16 (Peace, Justice and Strong Institutions), and goal 17 (Partnerships for the Goals).

"I suppose Blockchain could help in meeting some parts of Goal 9 and perhaps Goal 16." (Dimitris Kalamaras, appendix, p.43)

"So, the goals 16, 17 and 11 are related to governance, the KSI blockchain actually helps to increase the trust in the governmental data, since the KSI blockchain actually stores the

hashes of the documents, we will see that the data isn't modified, destroyed or stolen." (Axel Baudry, appendix, p.15)

"At the same time, the blockchain technology and particularly the Proof-of-work consensus mechanism used by some networks works against Goal 13 as long as it does not use 100% renewable energy." (Dimitris Kalamaras, appendix, p.43)

I will now elaborate on each sustainable aspects mentioned by the interviewees, linking them to the theoretical parts related to blockchain technology and sustainability, as well as to my main questions.

- **Energy consumption**

In the theoretical chapter called "Blockchain technology and sustainability" (p.11), I have mentioned the fact that blockchain consumes a lot of energy. (Alman & Hirsh, 2019, p.19) Therefore, it might be an issue in the context of the goal 7 (Affordable and Clean Energy), as well as the goal 13 (Climate Action). However, still according to the theory, and supported by the respondents, the impact of the technology might not be that strong. (Sedlmeir et al., 2020, p.600)

According to the interviewees, the issues related to the energy consumption of blockchain technology depends on different factors, mainly: the protocol used and the source of energy.

As explained before, the two main protocols on which blockchains are based are Proof-of-work (PoW) and Proof-of-stake (PoS). What differentiates them is the way the consensus between all network participants is achieved. In the case of PoW, as Marco Schletz explained to me, "the so-called miners, the network validators, are competing with each other by providing as much computational power to the network as possible. […] [And the] miners have an ever-increasing incentive of creating more computational power which is equal to a higher energy consumption" (appendix, p.21). Whereas PoS "doesn't compete through computational power" (Marco Schletz, appendix, p.22), making it less energy intensive than PoW, as it was also mentioned in the theory (p.12). (Sedlmeir et al., 2020, p.606)

Even though a lot of cryptocurrency blockchains are based on PoW, some of them, such as Ethereum, are shifting to PoS, as a few respondents mentioned.

"Ethereum is a Proof-of-work technology, and it is younger than the Bitcoin technology. Right now, the developers of Ethereum are shifting from Proof-of-work technology to Proof-of-stake technology." (Francesco Giacomello, appendix, p.29)

Most interviewees, such as Claus Skaaning, Andrej Kutliak, Francesco Giacomello and Dimitris Kalamaras, also mentioned that a lot of blockchains based on PoW are not as much energy-consuming as often portrayed. Indeed, many are using renewable energy, reducing their environmental impact.

"[…] also, those blockchains, like Bitcoin, that cannot move over to another consensus mechanism are increasingly using renewable energy, right. Renewable and trapped energy, so energy that is lost if it's not used for anything locally. It is increasingly used also for

Bitcoin. So, even though it could be viewed as quite a large problem right now, it's decreasing all the time." (Claus Skaaning, appendix, p.35)

"And, for example, I also noticed that the blockchain that are still using Proof-of-work, they are starting to use green renewable energy. Like, for example, in Canada, there is a company that is focusing just on mining Bitcoin through waterfalls that they have there and through putting their stations in the areas where the energy that is naturally in there wouldn't be used otherwise." (Andrej Kutliak, appendix, p.39)

"[…] This means that a lot of mining companies, mining industries, are located near some renewable sources of energy. This is never considered when talking against Bitcoin, but this is very important to understand how this energy consumption is composed. It is true that Bitcoin has a very high energy consumption, but this energy consumption is mostly produced by renewable energy because the renewable energy is cheaper than not renewable energy and the mining companies can have a better return when using renewable energies." (Francesco Giacomello, appendix, p.29)

According to Dimitris Kalamaras, Bitcoin's use of renewables range would already reach 75 percent. (appendix, p.43) However, I haven't found any source supporting this statement.

Nevertheless, in the context of this research, the use of PoW isn't relevant as it relates mainly to cryptocurrencies, unlike PoS, which could then be a potential option to explore.

Francesco Giacomello and Claus Skaaning have also compared blockchain with other industries related to finance. The banking and gold industries would consume more than the Bitcoin industry.

"[…] compared to other industries, like the banking industries, the consumption of the energy is like 50% of the banking industries which consume like 263 terawatt-hours per year. The gold itself, the industry of the gold, consumes like more than half more than the mining Bitcoin. I'm speaking about gold is considered like a reserve of value for hundreds of years, and Bitcoin it is considered the same, I mean, almost everyone right now accept that Bitcoin could be defined as a store of value." (Francesco Giacomello, appendix, p.29)

This is confirmed by Giungato et al., in the article *Current Trends in Sustainability of Bitcoins and Related Blockchain Technology* (2017), stating that "the environmental costs of bitcoin mining are less than paper money, gold and banking systems" (p.4).

Looking at the currency itself, bank notes and coins would soon be totally replaced by digital currencies, making it more efficient. This would lead to less consumption of paper and metals, saving cost and energy (Claus Skaaning, appendix, p.35).

"[…] you also have to compare the use of energy that you see with blockchain with the use of energy that you see with existing systems, right. Existing financial systems, for instance, also spend a lot of energy. If you look at the one other area, maybe, it could be the currency itself. So, right now, we use paper money and coins, but this will transition to be a digital currency in the future, there's no doubt about that. It will be much less expensive, there would be much less printing of paper notes and much less use of metals to make the coins,

and the entire system for processing all these currencies will be made much more efficient." (Claus Skaaning, appendix, p.35)

To some extent, the digitalization would then allow the system to reduce their carbon emissions, as it was explained in the theory (p.13). (Sedlmeir et al., 2020, p.607)

Axel Baudry also mentioned the fact that using blockchain on top of existing digital systems, without actually replacing them, would obviously add extra energy consumption.

"Usually, blockchain is used as an extra layer for data integrity which adds up on top of already existing digital systems, thus, it usually consumes an extra amount of energy." (Axel Baudry, appendix, p.19)

According to Francesco Giacomello, in the case of smart cities, the technology would actually consume less energy than "normal cities", "because they are more efficient" (Francesco Giacomello, appendix, p.31).

However, we could argue that moving towards smart cities could bring inequalities, as elaborated in the contextualization chapter (p.23). (Tammpuu & Masso, 2019, p.622) Indeed, the digitalization in governmental settings already excludes part of the society, such as homeless people or the elderly, which might have more difficulties accessing digital tools. Smart cities could bring this disparity to another level, leading to new forms of exclusion.

According to Marco Schletz, blockchains used in governmental context, which are generally permissioned blockchains, usually don't consume much energy.

"Bitcoin is basically the only blockchain that has this energy thematic. It depends on like how they achieve consensus, but I would be quite certain that they [KSI blockchain] don't consume much energy and especially in the government setting, it's basically mainly permissioned blockchains." (Marco Schletz, appendix, p.22)

This confirms the words of Axel Baudry explaining that, in the case of KSI blockchain, a permissioned blockchain, as only the hashes (which are very light data) are stored on the blockchain, it consumes very little energy (appendix, p.14). However, we could again argue that the external servers, which actually store the data, could increase to total energy consumption of such implementation, as it is being done in Estonia.

From the respondents' answers discussed here along with the theory, we could then conclude that, for a most sustainable governmental application, permissioned blockchains, protocols such as Proof-of-stake and the use of green energy would be the best options, in relation to energy consumption. However, the existing system would have to be totally replaced by those solutions, as both of them working together would just be add to the energy consumption rate. Furthermore, the choice of going towards smart cities could bring inequalities, which have to be considered in the context of this research, as they could affect other sustainable dimensions of the technology.

- **Data security**

In general, according to interviewees, such as Sergi Novohatski and Marco Schletz, blockchain technology is a very secure system, more secure than "normal" centralized data sharing system, as it is distributed.

"So, in general, if to follow the rule your keys your coins or your data then blockchain is much safer than the centralized databases." (Sergi Novohatski, appendix, p.45)

"[…] generally blockchain is a lot more secure than a normal data sharing system because you have it distributed and you have it immutable, which means that you can't change it overtime. It is decentralized and you use a cryptography in order to secure also that data privacy." (Marco Schletz, appendix, p.23)

When data is encoded in the system, it can only be altered with a consensus (Dimitris Kalamaras, appendix, p.43), as also explained in the theory (p.10). (Asuquo et al., 2019, p.120) As it is a decentralized system, it is very hard to attack it. The only way for anyone to do so is called the "51% attack", meaning that the attacker would have to own 51% of the system's nodes (Francesco Giacomello, appendix, p.30).

Furthermore, the debate between PoW and PoS continues here in the context of data security. Indeed, it is said that PoW, especially blockchains such as Bitcoin, could be more secure as it would not be vulnerable to the 51% attack, as it is very decentralized.

"Bitcoin is not vulnerable to the 51% attack, because in order to have success in hacking. […] if someone wants to have hack the Bitcoin technology, he has to own the 51% of all nodes. That means that he has to own the 51% of all Bitcoins in circulation, but the total market count of the Bitcoin is, at the moment, 740 billion of dollars. So, if someone wants to attack and do a 51% attack, he should own at least 51% of this 740 billion which is a very big amount, no country can spend all this money. This is why Bitcoin is considered so secure." (Francesco Giacomello, appendix, p.30)

Another issue, mentioned in the theory related to blockchain technology (p.11), is the fact that "with the third-party authority gone, in the context of cryptocurrencies, there will be no institution to step in in case someone loses their own personal key to the blockchain ledger holding" (Alman & Hirsh, 2019, p.19). This is confirmed by Axel Baudry, "if you lose your personal key to your wallet, it is lost forever" (appendix, p.17). However, this only relates to blockchains linked to cryptocurrencies, which I will not focus on in the context of this research. This also applies for PoW, as explained in the previous category, and such because of its context of application (cryptocurrencies), as well as its energy consumption issues.

In the case of governmental application of blockchain, usually permissioned blockchains, according to Marco Schletz, "the government blockchains are a lot more secure than what they currently have in terms of data management" (appendix, p.23). They could even be more secure than public blockchains, such as Bitcoin and Ethereum. Indeed, with permissioned blockchains, used in governmental context, the identity of the invader would be known, as you need to require the access to be part of the network.

"[…] they might be more secure, because Bitcoin and Ethereum, they can get attacked from external actors. So, there are attacked actors. Whereas with these more permissioned sustainability blockchains, you have to be a known actor, so you know who would attack the network." (Marco Schletz, appendix, p.23)

This also refers to the reason why Estonia had decided to implement the technology in its government, preventing further cyberattacks. (context, p.20)

From the respondents' answers discussed here along with the theory, we could then conclude that, for a most sustainable governmental application, the substitution of the existing system by permissioned blockchains would be the best option, in relation to data security.

Those data security matters relate closely to the next sustainable aspect of the technology: transparency and traceability.

- **Transparency and traceability**

In the theoretical chapter called "Blockchain technology and sustainability" (p.14), I have mentioned the fact that blockchain might allow biases, as "the technology prevent the falsification of data only after it has been added" (Ledger Insights, 2020). Errors, voluntary or not, might then be encoded in the system. However, still according to the theory, and supported by the respondents, blockchain can also be used as a tool against data corruption. (Ministry of Foreign Affairs, 2018, p.23). Indeed, this kind of errors can be avoided thanks to smart contracts audits and artificial intelligence and organizations called "oracles" verifying the data before it is being encoded.

"Errors can actually be encoded in a blockchain. You need to write a new smart contract, or you need to be extremely careful before implementing the smart contract on the blockchain. So, a lot of effort is made to create smart contracts audits and things like that, but it's really costly. […] there are also artificial intelligence verifying smart contracts, but they are really systemic, and sometimes they miss some mistakes. People are better, but slower, and it costs a lot." (Axel Baudry, appendix, p.17)

"There are solutions that are proposed by so-called "oracles" in the space, and for example, these guys, the company, is ensuring that, first of all, the correct data and verified data only get in blockchain and they act as a third party that is verifying and making sure that all the institutions, all the collaborated party, are up to standards. […] They are ensuring that such corruptions don't happen." (Andrej Kutliak, appendix, p.39)

Therefore, the technology might actually be a tool used to reach the goal 16 (Peace, Justice and Strong Institutions), which relates to the "diminution of all forms of violence in all countries" (theory, p.9), including corruption.

This also applies to the transparency of blockchain, which was also mentioned by most of the interviews, such as Andrej Kutliak, Claus Skaaning and Axel Baudry, when asked about sustainable features of the technology. Indeed, in the context of public blockchains, mainly used in the context of cryptocurrencies, the transactions can be seen by all people involved

in the system. This could be useful in the context of corrupted countries, as individuals could secure their funds.

"Because of the blockchain, it is very transparent and it's very secure in the nature of the transactions and the amounts of people that can see what's happening on it, we thought it would be a good solution, for example, to strip the people, like for example in Nigeria, from the inflation of the corruption in the government and give them possibility to receive the funds securely, and without getting their bank accounts frozen." (Andrej Kutliak, appendix, p.38)

In the context of governmental application, people would be sure about the safety and veracity of their data, which would create trust in the digitalization and the government.

"[…] the KSI blockchain actually helps to increase the trust in the governmental data, since the KSI blockchain actually stores the hashes of the documents, we will see that the data isn't modified, destroyed or stolen. So, it helps to trust the digitalization, it helps to trust that my data is not used by outsiders or people that I didn't grant the right to access my data." (Axel Baudry, appendix, p.15)

Blockchain could also be used in order to prove the veracity of people ID, while voting, for instance. (Andrej Kutliak, appendix, p.38)

"I'm also thinking about a voting system through blockchain, it would be something very interesting to do, as there are applications like, for example, Cardano foundation that are making an ID for citizens that would be used in order to make sure that all the people that are participating in the voting are the actual citizens through cryptography. The cryptography that is, for example, now being used is called "zero-knowledge proofs" which helps the two sides: to prover and validator, to make sure that both sides are who they are, without revealing any information along the way." (Andrej Kutliak, appendix, p.38)

This would confirm that the technology could help reach the goal 10 (Reduced Inequalities), improving the access to national identification for refugees, for example, as explained in the theory (p.13). (Ledger Insights, 2020)

According to Francesco Giacomello, the technology also allows the traceability of different kinds of data (supply chains, energy consumption, etc.). The data would be stored more efficiently in order to build smart cities. (appendix, p.31) This feature of the technology could also help to reach the goal 16 (Peace, Justice and Strong Institutions).

From the respondents' answers discussed here along with the theory, we could then conclude that, for a most sustainable governmental application, the use of blockchain technology would be a good option, in relation to the system's transparency and traceability, even though, as explained before, this step further into the digitalization of the government could increase inequalities.

- **Democratization of investment**

This aspect of blockchain technology doesn't directly relate to the governmental context, so it will not be much elaborated in this research. However, I thought it was still interesting to include it in the analysis, as it shows another progressive feature of the technology.

According to Claus Skaaning, with the help of its company DigiShares, blockchain allows a democratization of investments, making "it possible for ordinary people investors to get access to types of investments that they don't normally have access to" (appendix, p.34). The company aims to open the financial system, not only "in Europe, but also potentially in Africa where there's no access even to banking" (appendix, p.34). It would be beneficial for governments, especially in undeveloped countries, as it would develop the financial ecosystem. (Claus Skaaning, appendix, p.34)

Indeed, in the theoretical chapter called "Blockchain technology and sustainability" (p.13), I have mentioned the fact that blockchain "could be an opportunity for developing countries to "diversify their economies" […] and increasing government income" (Banerjee, 2021). Therefore, it might help reach the goal 8 (Decent Work and Economic Growth), as well as the goal 9 (Industry, Innovation and Infrastructure), which also aims for economic growth. (Dimitris Kalamaras, appendix, p.43)

7. Discussion

When looking at the analysis chapter, we can notice that I don't refer to some of the sustainable aspects of blockchain technologies stated in the "Blockchain technology and sustainability" chapter. (theory, p.12-14) Indeed, I have mentioned that blockchain could help reach:

- goal 2 (Zero Hunger), allowing, in refugee camps, access to food coupons (Banerjee, 2021)
- and goal 12 (Responsible Consumption and Production), improving supply chain management (Lund et al., 2019) and reducing food waste. (UN, 2018)

I have decided not to elaborate or focus on those features, as they were not mentioned or confirmed by the interviewees, as well as they don't directly relate to the context of this research: the governmental application of blockchain.

I am now going to discuss what have been elaborated and analyzed in the previous chapter. I will do so mainly thanks to the last three categories of content created from the interviewees' answers.

Balance between positive and negative sustainable features

When we look at the assumptions made in the analysis, we can see how blockchain technology can bear both positive and negative sustainable aspects in the context of a governmental application.

Indeed, the implementation of blockchain could be a sustainable decision, but only under some conditions. Such implementation would increase the energy consumption of governments if the existing system were not totally replaced by the technology. This substitution would also be beneficial in relation to data security, as well as the data's transparency and traceability. Furthermore, to minimize its energy consumption, the blockchain would have to be a permissioned one, using a protocol similar to Proof-of-stake (energy efficient) as well as renewable energy.

However, when digitalization is already creating inequalities for certain categories of people, implementing the technology in governments would cultivate these discriminations. It would make the technology less sustainable regarding its social pillar, which "concerns people's happiness, well-being, and welfare" (theory, p.4). (Kulman and Farrington, 2010, p.3440) This could also impact some of the 17 SDGs, such as the goal 3 (Good Health and Well-Being) (theory, p.6), or the goal 10 (Reduced Inequalities) (theory, p.8). Measures would then have to be implemented by the governments in order for these social issues to decrease. On the other hand, as explained in the analysis (p.33), the technology itself could also lead to reduced inequalities, as it would guarantee the data safety and veracity, and work against data corruption.

In the context of the Triple Bottom Line concept (Elkington, 1994) describing the notion of sustainability (theory, p.4), for any system to be sustainable, the three pillars must coexist in harmony. In the context of this research, here is how the sustainable features of blockchain relate to those pillars:

- The energy consumption issues relate to the "planet pillar", as it refers to the protection of the environment. (theory, p.4)
- The data security, as well as transparency and traceability matters, relate to the "people pillar", as it refers to people's data and their security. This pillar concerns people's happiness, which governments can have influence on thanks to external conditions, such as the implementation of blockchain technology making their data secure. (theory, p.4)
- The economic matters (related to cryptocurrencies) relate to the last pillar, the "profit pillar", as it refers to the economic growth of individuals and countries. (theory, p.4) However, it will not be taken into consideration in the context of this research, as I only focus on the governmental application of blockchain.

As explained in the theory (p.4), the people pillar must coexist with the planet pillar. (Kulman and Farrington, 2010, p.3439) However, this could be difficult as the first one relates "to the well-being of the present generation" (theory, p.4), and the second one, to the one of the future generations. This would then raise the question: "How can we ally development and sustainability?". (Kulman and Farrington, 2010, p.3439) How can we care both about the security of the citizens' data and the energy consumption of blockchain?

I have asked the interviewees if they thought that the positive features of the technology could balance the negative ones, and still make it a sustainable option for governments.

According to Axel Baudry, the compromise between data integrity and energy consumption would "depend on the use-case and the sensitiveness of the data" (appendix, p.19). It would then depend on the context in which you will use the technology, and how secure you want the data to be.

As explained in the analysis, in the use-case of cryptocurrencies, the most secure blockchain would be Bitcoin, which is also the one that consumes the most energy. (analysis, p.31) However, I also mentioned that, in the context of governmental application (the application we care the most about in the context of this research), permissioned blockchains consume very little energy and are way more secure that the existing systems in place in governments. (analysis, p.31) Those permissioned blockchains could then be the best solution, compared to other types of blockchain, in order to help the people and planet pillars coexist and make governments more sustainable. Thanks to the Estonian case studied in this research, I have learned about KSI blockchain, which could be a potential option for governments to investigate. Indeed, the technology is a permissioned blockchain which is secure and doesn't consume much energy. (analysis, p.26) However, we could also argue that, in the context of KSI blockchain, as the data is stored on external servers, this adds up to the total energy consumption of the system.

When asked about those matters, in the context of a potential implementation in the Danish government, Francesco Giacomello explained that, in his opinion, the negative sustainable features of blockchain (mainly, its energy consumption issues) could be balanced by the positive ones (its security, transparency and traceability). (appendix, p.32) He also mentioned the fact that new, more efficient, and more sustainable protocols would probably be released in the future, solving those issues.

> "Probably, in the future, will be released new protocols, more efficient than the existing ones. […] I'm sure that, in the future, there will be released more sustainable protocols."
> (Francesco Giacomello, appendix, p.32)

Claus Skaaning agrees with Francesco Giacomello, explaining how strong blockchain is on both social and profit pillars. (appendix, p.34) He also mentioned the fact that, even though the technology might have energy consumption issues, making it weaker on the planet pillar, it also has to be compared with the one of the existing systems, which might be superior. (appendix, p.35)

If the profit pillar was also taken into consideration, we could then have to choose between "weak" and "strong" sustainability (Kulman and Farrington, 2010, p.3441), preferring the profit or the planet pillar as most important one. Indeed, exploiting cryptocurrencies blockchains, which of are very energy consuming technologies, would benefit the profit pillar at the cost of the planet one. This would be considered as "weak sustainability". However, as some of those blockchains are switching to less consuming protocols or to renewable sources of energy, this could be considered as "strong sustainability", making the planet pillar the most important one. (theory, p.4)

Danish and governmental contexts

When asked about the potential implementation of blockchain the context of the Danish government, some interviewees insisted on the fact that it is important to know how useful this would be for the government, before implementing it.

"What's the point to use it in Denmark? Why would Denmark actually use blockchain?" (Axel Baudry, appendix, p.16)

"How can it help the government?" (Marco Schletz, appendix, p.20)

Marco Schletz elaborated on two different options. The first one would be to use the technology in order to coordinate the inside of the government, and across different actors. The second one would be more international, helping several countries to communicate and collaborate in order to achieve certain goals, which could be linked to climate action. (appendix, p.20) It is the first option that interests me, as it is the one used in the Estonian case, the point of departure of this research.

Regarding the Danish willingness to implement such technology and according to Claus Skaaning, the "government itself is not really concerned with the blockchain" (appendix, p.36). This could also mean that the implementation of such technology would be difficult, as the government is not familiar with it, as explained in the theory (p.14). (Alman & Hirsh, 2019, p.14-20)

The economic situation of the Danish government also has to be taken into consideration, as such implementation might have its costs. (theory, p.15) (Truby, 2018, p.408) However, as explained in the contextualizing chapter (p.23), Denmark would actually have a budget of DKK 32 million allocated to initiatives related to blockchain. (The Danish Government, 2018, p.46) Nevertheless, blockchain implementation could also be done without this kind of financial support, as it has been done in Estonia, with a "win-win situation" between the government and several companies. (analysis, p.26) Furthermore, the technology is mentioned in some strategical documents for future implementations, such as *How Governments Are Adopting Blockchain and AI In Advanced Economies Part 2*, *Strategy for Denmark's Digital Growth* and *Strategy for Denmark's Engagement with United Nations Children's Fund (UNICEF) 2018-2022*. (context, p.23)

Claus Skaaning also added that The Danish Financial Supervisory Authority (FSA) might be active in this field (appendix, p.35).

"I know the regulators, the FSA, also here in Denmark, knows a lot about it and is very active in the area and that's a part of the government." (Claus Skaaning, appendix, p.36)

I have tried to contact them in order to investigate this possibility, but I haven't received any answer from them.

Marcel Tutor Ale supports Claus Skaaning's words, as he explained that the subject would be under discussion among the Danish government, arguing whether they would allow a "decentralized protocol to be coupled to their current system" (appendix, p.44).

However, I cannot confirm those words as I have not been able to get in touch with any organizations or individuals directly working with the Danish government.

We could also argue that, unlike Estonia which implemented blockchain as it needed more data security and trust after being cyberattacked, Denmark might not need such implementation. Indeed, the Scandinavian population might not be in demand of such reassurance in its government and regarding its data security. As explained in the contextualization chapter (p.21), "the Danish population has great trust in its public sector". (Agency for Digitisation, 2016, p.6) The purposes of blockchain implementation might then come from somewhere else. It might come from the need of more sustainable governmental tools, or even the willingness to become a more technological, digitalized and connected country. Answers from the concerned Danish parties are needed in order to look deeper into this issue.

In the case of blockchain implementation, we have to remember that each context of use requires a certain kind of blockchain. (analysis, p.25) Therefore, we have to answer this question: which types of blockchain and protocol would be the best suited to the Danish government?

According to earlier discussions in this research, a permissioned blockchain, using a protocol similar to Proof-of-stake (energy efficient) as well as renewable energy, would be the best sustainable blockchain option for governmental, in relation to energy consumption and data security issues. Marco Schletz confirms this, saying that a permissioned system makes the blockchain less public and open, which would be suitable for governmental application.

"So, for example, for government systems, you want to have not necessarily a total public blockchain, but you want to have like a more permissioned system. […] for like the government part, the permissioned system is a lot more suitable than building it on a totally open and free blockchain." (Marco Schletz, appendix, p.22)

Axel Baudry also explained that KSI blockchain, the one used by the Estonian government, is the best option possible. (appendix, p.16) Indeed, it combines important features needed in governmental context. It is less public than other blockchains as it is a private permissioned one (allowing only selected people to be part of it. Furthermore, the governmental data can be modified, as they are stored on external servers, making it also less energy consuming. However, the blockchain still guarantees the data's integrity as it used "to timestamp every modification to make the system more trustable". (Axel Baudry, appendix, p.16)

Thanks to KSI blockchain, the data would then be secure, but the governments would still have a hold on them. Indeed, as explained earlier in the analysis, "it is the Estonian government that holds the power over the data, while Guardtime handles the nodes of the blockchain" (p.27).

As governments might not want to decentralize their data, some interviewees, such as Marcel Tutor Ale, worry about the decentralization of blockchain technology, which is one of the main features of the technology.

"Does the government want to enter decentralization? Are they willing to hand over their power to the digital ledger for transparency?" (Marcel Tutor Ale, appendix, p.44)

According to Claus Skaaning, for governmental application, "it has to be centralized to some degree" (appendix, p.34). KSI blockchain could then be a good option for the Danish government, for instance, as the actual data wouldn't be stored in the blockchain, but on external severs managed by the government. Then, the decentralization feature of blockchain technology wouldn't be a concern.

Nevertheless, Andrej Kutliak argues on the fact that governments shouldn't have total power over the people's data, and that the centralization of this data would bring security issues in the future, as they could still be attacked.

"I don't believe that it's a good solution to give the government total power over this, but only to delegate the systems that are maintaining such mechanisms, if that makes sense." (Andrej Kutliak, appendix, p.41)

However, the blockchain world is still very new, the future might then bring those solutions.

Axel Baudry also explained that other technologies could also be considered, such as decentralized clouds. (appendix, p.16) As mentioned in the analysis, there also exist many other blockchains than KSI blockchain, such as Baseledger blockchain and NEAR. (analysis, p.27) However, the interviewees haven't mentioned a lot of those potential options that could be used in a governmental context. This is understandable as many existing blockchains aren't known from the public yet. Just as KSI blockchain was unknown to all interviewees (except Axel Baudry, of course), even though they all either work in relation to the blockchain world or are very passionate about it. Nobody knew about KSI blockchain, even though it is being used by the Estonian government and could be one of the best options for governmental application. We could then think that there might already exist a blockchain which would be an even better fit than KSI blockchain, but nobody knows about it yet.

Potential threats to blockchain

During the interview, Francesco Giacomello also mentioned the fact that the blockchain might face a threat from Quantum computers. Indeed, those algorithms, which are still being developed, would be able to simulate the 51% attack, calculating "an amount of data that was not measurable before" (Francesco Giacomello, appendix, p.32). However, not all blockchains would be vulnerable to Quantum computers. Indeed, KSI blockchain is one of them, as mentioned in a document called "The Facts of KSI", sent to me by Axel Baudry. (appendix, p.20) This is confirmed by Guardtime, "KSI is quantum immune, meaning it's security is not vulnerable to quantum algorithms run in existing or upcoming quantum computers" (Ivo Lõhmus, 2016).

However, as mentioned several times, blockchain technology is still a rather new one. This means that other threats, unknown for now, might arrive in the future, and jeopardize its application in governmental and other contexts.

8. Conclusion

After getting familiarized with my primary data (the interviewees' answers), I have created categories. I have then analyzed their content, which allowed me to understand the specificities of such technology and investigate my research questions: Can blockchain technology be a sustainable option in the context of a digitalized country such as Estonia? Would the technology also have a sustainable potential in Denmark?

The knowledge collected in the analysis and discussion, thanks to the theory and the 8 conducted interviews, will now be summarized in order to answer my questions.

Regarding the first question of this research, "can blockchain technology be a sustainable option in the context of a digitalized country such as Estonia?", I would answer: "yes, but under some conditions."

Indeed, in order for the technology to be at its maximum sustainable potential in governmental application (decreasing the energy consumption of the system and improving its data security, transparency and traceability), different features have to be fulfilled:

- The existing system must be completely replaced by blockchain technology.
- A permissioned blockchain must be used.
- A protocol similar to Proof-of-stake must be used.
- Renewable energy must be used.

In the context of the Triple Bottom Line concept describing the notion of sustainability (theory, p.4), these characteristics would then be beneficial for both the social and planet pillars and would help to reach some of the SDGs: goal 7 (Affordable and Clean Energy), goal 10 (Reduced Inequalities), goal 13 (Climate Action), and goal 16 (Peace, Justice and Strong Institutions). According to the interviewees' answers, both pillars could coexist thanks to such permissioned blockchains, as they are both energy efficient and very secure. The third pillar, profit, isn't taken into consideration here as it has only been discussed by the interviewees in the context of blockchain linked to cryptocurrencies, which don't relate to the context of this research.

However, here are the disadvantages of such implementation:

- Digitalization increases social inequalities.
- Some solutions, such as KSI blockchain, coexist with other systems (such as external servers), increasing their total energy consumption.

Both social and planet pillars could then be impacted by such features, working against some of the SDGs: goal 3 (Good Health and Well-Being), goal 7 (Affordable and Clean Energy), goal 10 (Reduced Inequalities), and goal 13 (Climate Action).

To counter these issues, the chosen blockchain would then have to completely replace the existing system, as mentioned above. Furthermore, governmental initiatives and measures

would have to be implemented to assure that all people concerned have the same access to the digital tools.

If countries such as Estonia and Denmark are able to fulfil all these conditions and implement those measures, making the implementation of blockchain as sustainable as possible, they would then be taking action to reach some of the 17 SDGs. As explained in the theory (p.10) and proven here, this would mean that, thanks to their governance, those countries are able to make real changes and have impacts on their sustainability.

Regarding the second main question of this research, "could the technology also have a sustainable potential in Denmark?", I would answer that it depends on the government's willingness to do so.

It is difficult to be sure about Denmark's position on the matters. Indeed, such implementation is mentioned in several official strategical documents and a budget would have been allocated to it. However, nothing has been executed yet and I didn't receive any confirmation from the concerned parties.

The main feature of blockchain technology is its decentralization. However, governments, such as the Danish one, rely mostly on centralized data systems. Such technological implementation would then have to be done with a blockchain which would not rely on decentralization. This is the case of KSI blockchain, implemented in the Estonian government, as the data is stored on external servers, which are controlled by the government.

This would mean that, in order for blockchain to be used by the Danish government, it would have to rely on an external system, controlled by the government, in addition to the blockchain. However, this would increase the whole system's energy consumption, making it less sustainable. This then leads us again to the balance between different pillars of sustainability.

Should we prioritize data integrity by implementing blockchains, such as KSI blockchain, which wouldn't be the best sustainable option regarding the energy consumption issues?

Or should we prioritize those energy consumption matters by deciding not to implement such technology, but then neglect the data integrity?

However, existing systems might consume as much as blockchain, or maybe even more. Implementing blockchain might then turn out to be the best one, in the context of governmental application.

To answer this dilemma, we might have to work on a case-by-case basis, examining the energy consumption of the existing system, and comparing it to the chosen blockchain. In case blockchain implementation becomes a potential option for the Danish government, this is what the government might have to do, in order to make its decision the most sustainable one.

As mentioned above, the blockchain used for governmental application in Estonia, KSI blockchain, isn't the best sustainable option, as its energy consumption could still be

decreased. There exist other blockchain options which could be explored. However, they might also not be completely sustainable. Nevertheless, we don't know what the future is made of, as blockchain is still a rather new technology. One day, the future might bring us more potential threats to the technology. It might as well bring us the perfect solution, combining all pillars of sustainability and helping reach all SDGs related to those matters. Who knows? The solution might already exist in the mind of an unknown blockchain passionate.

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