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**How can the use of decentralized technologies help
communities increase the sustainability of the commons?**

Governing electricity through Blockchain Technology

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Introduction

Throughout the history of humans, sharing resources has been a well-known practice to ensure survival or comfort. Under resources, one understands fisheries, forests, food, etc. Sharing these resources in a closed group makes them common for everyone who is part of that respective community, which is why they are generally referred to as commons. (Financio, n.d., pp. 3–4)

However, it is also part of the human nature to abuse the commons. The abuse can be triggered by greed, scarcity, over-utilization, and many other reasons (Ostrom, 2002, pp. 6–7). Just like hunting prey doesn't make a lion evil, abusing commons doesn't make a human being a bad person either. The abuse of commons is a profound and very enduring challenge. Therefore, it is important to come up with a solution to prevent overexploitation and degradation of the commons through enforceable policies (Ostrom, 2002, pp. 6–7).

The author decided to view electricity as a common, since the whole world needs it to function and because it's not perceived as an infinite resource. For example, fresh air is viewed as an infinite resource. Individuals who use too much electricity prevent others from having the same privilege. (Ostrom, 2002, p. 1)

Electricity even creates a negative impact on the environment since energy is mostly not produced in an environmentally friendly manner. Disrupting the energy sector is very difficult because it is over one hundred years old and counts multiple established international enterprises. To make matters worse, the energy market in its nature, is a monopolistic market (Cramton, 2017, p. 590). This makes it very hard to create enforceable policies and governance.

But the world is constantly changing and evolving. The energy landscape is not an exception to this rule. Some stakeholders are continuously trying to reduce greenhouse gas emissions, improve the efficiency of existing systems, develop better gadgets, improve the resilience of the infrastructure, and become greener.

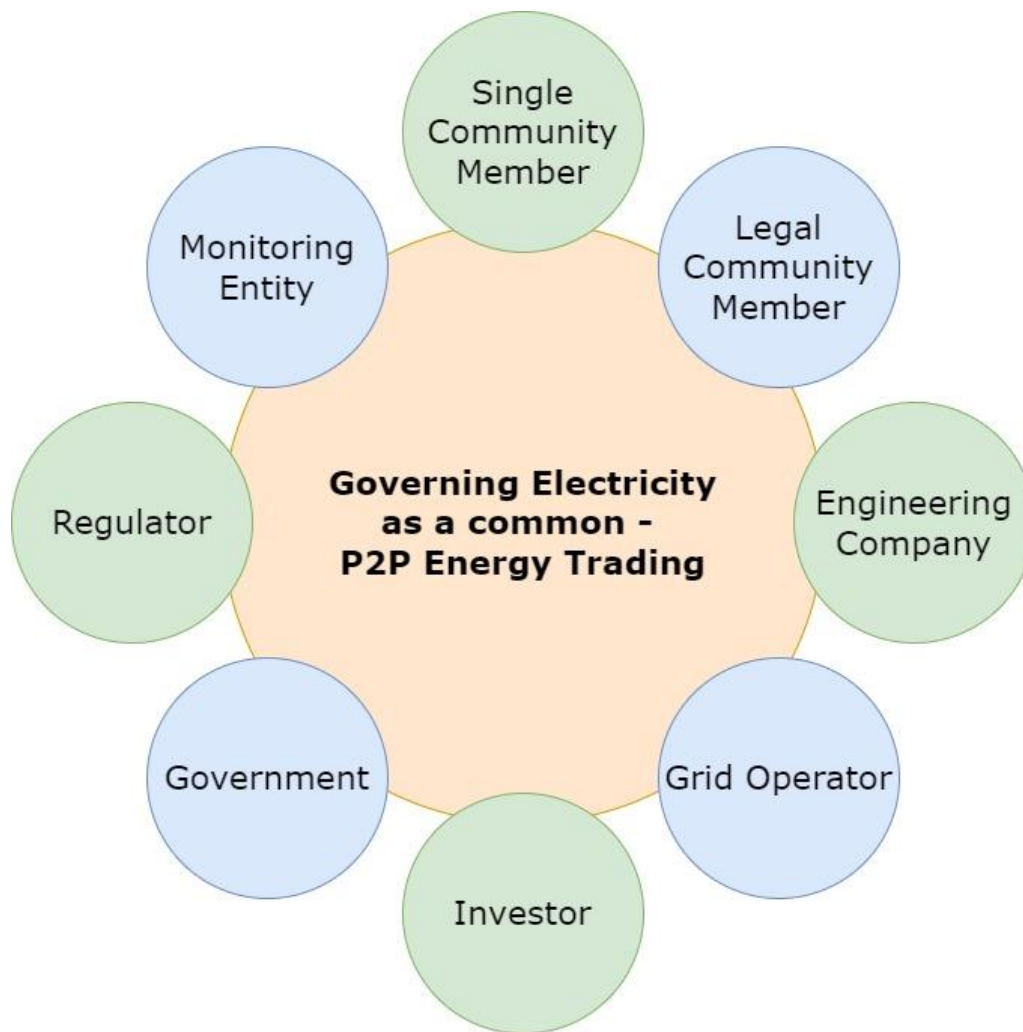


Figure 1: All stakeholders involved in P2P Energy Trading

In the past 25 years, renewable energy has contributed tremendously to the progress of the globe's emissions. Out of the renewable energy sources, solar energy is seen as the most promising technology. In the year 2050, solar power is expected to cover 40% of the world's energy supplies. (Krauter, 2006, pp. 10–12)

At the same time, blockchain first emerged as a futuristic tool with the potential to transform the energy sector into something nobody has seen before. But in the last ten years, it has manifested and proven that it is feasible and tangible. However, there is still a lot of room for improvement. (Swan, n.d., p. 8)

But why blockchain? Information has been crucial to humans since the beginning of time. It's so important, that the author can classify its preservation into three categories. Those are the following:

- Information must remain in its original form
- Information must be shared with the right people
- Loss of information must be prevented

Preservation of information has always been an issue that faces frequent challenges. People came up with multiple methods to prevent counterfeits, to implement confidentiality and to minimize the risk of the loss of information. The world has evolved and what was referred to as information,

turned into data in the digital age. Storing copies of the information in different locations was viewed as a great approach, but today that would be equivalent to distributing a copy of the data on different servers around the world. Finally, one might want to share the data with the correct people. This is done by authorising users and granting digital access. Distributing the same data among different systems in its original form, while granting access to only selected users is exactly what distributed ledger technology (DLT) was invented for.

DLTs are decentralized data storages with computational power, that are spread around different locations and synchronize the same data. One change to a file is reflected on every other instance of the system. All blockchains are distributed ledgers, but not all ledgers are blockchains. DLT is the umbrella term. There are multiple other DLTs such as Directed Acyclic Graph (DAG), Hashgraph, Holochain, Tangle, and many more. (Soltani et al., 2022)

Blockchain is far from perfect. Other DLTs, for example IOTA, tend to offer lower transaction fees than blockchain technology. As expected, this can vary depending on the chain in use. There are many more technical details, such as interoperability, where blockchain doesn't perform as well as other technologies. A big reason why other DLTs also might be interesting, is because many of them are faster than blockchain. However, this paper won't dive deeper into the difference between DLTs and blockchain, since the goal lies in a different direction. (Soltani et al., 2022)

In the author's opinion, Blockchain is interesting because it received not only a lot of media attention within the past 10 years, but because one can also find multiple research papers, which are constantly being published on its uses. Overall, it is a very fast-moving technology, which enjoys a lot of popularity and is therefore being adapted into many different fields.

Possible drivers for the growing interest in blockchain in the energy sector are due to its progress in efficiency and cost savings, renewable energy integration, community empowerment and many other aspects. Implementing blockchain however, can come with barriers. Those are technology adaptation challenges, regulatory uncertainty, initial setup costs, etc. Furthermore, antecedents should not be underestimated, as this is a technology that is not yet fully developed and implementable. Problems such as community readiness, policy support, education and awareness are other key points one must look out for.

With the progress of blockchain in mind, there are still multiple people who do not have electricity. According to Statista's data for the year 2021, Sub-Saharan Africa alone counts almost 600 million individuals without access to electricity (*Africa*, n.d.) with a population of 1.81 billion people (*Sub-Saharan Africa - Total Population 2011-2021*, n.d.). That's more than 30% of the population without access to electricity. These are mostly individuals, who live in rural areas, where no infrastructure exists yet. The literature states that extending the national grid in some countries costs between \$20,000 USD to \$50,000 USD per kilometer (engie.com, 2023). The duration of this extension is another topic, which raises further red flags.

While the existing energy market is pivoting towards green energy, the new markets that are to be established could be green from the beginning. A lot of research is being conducted on the use of blockchain and solar/wind energy in communities. The results are magnificent. Multiple pilot projects have been launched and are under continuous observation. Sadly, they all tend to focus on one community alone and don't cover other aspects such as:

- How communities can raise the funds to initially finance themselves
- How communities can govern the newly installed electronics
- How sustainability and longevity of the project can be guaranteed

- Integration of multiple communities

It is also important to understand when one can refer to a collective of people as a community. The literature refers to a group of people who form a community to develop a shared governance of resources in a specific domain with mutual interest as a community of practice (Wenger, 2011, pp. 1–2).

The author believes that governments will need a framework to ensure the self-sustainability of communities (mostly rural communities), Hence the research question: **How can the use of decentralized technologies help communities increase the sustainability of the commons? Governing electricity through Blockchain Technology.**

The Problem to be solved

As the introduction indicates, the energy sector is over a century old and therefore very established. On the other hand, the globe's population is constantly growing (Sadigov, 2022, p. 1), which means that new communities are being formed day by day. Some economists even speak about overpopulation. But here too, the author won't dive deeper into this aspect, since it is out of scope for this thesis.

While new communities are being formed, some others are even being left behind, due to lack of resources, finances, or even interest from their government. Furthermore, sometimes the historical structures in existence can't provide everyone with electricity, since they were not built for a consumption of the current size. However, the lack of electricity is not always due to poor infrastructure or incompetence of the government. There are various factors that one has to take into account, when analysing the energy situation of a country.

Apartheid South Africa is a great example of racial segregation. Johannesburg, a city based in South Africa, once had the best power station (Bathish & Löwstedt, n.d., p. 1) in the entire world. Predominantly white inhabited areas, urbans, have better access to electricity than rural areas (L. Clark & H. Worger, 2013, p. 71). Other locations face territorial challenges, such as isolated islands, dense forests, mountains and much more. From a technical perspective, energy production, transformation and transportation become very challenging when confronted with geographical factors. Inadequate regulatory frameworks combined with greed and corruption are also very important factors, especially when combined with population growth, political and social instability.

Cultural aspects could also play a major role in perspective to infrastructure and power consumption within the energy sector. However, one needs to always remember that developing countries still participate in the globalisation of technology, just at a slower pace (Archibugi & Pietrobelli, 2003, pp. 7–8). The literature points out that countries that invest a lot of money into education, stand out in R&D and therefore, adapt faster to technology. *“For example, Taiwan and South Korea inventors alone have registered more patents in the United States than all other developing countries of the world together.”* (Archibugi & Pietrobelli, 2003, p. 7) Society that adapts faster to technology could use more electrical gadgets, and therefore, require energy more often and in a more stable manner.

Another aspect could be the climate of the location. For example: cold locations require more heating, and therefore increase energy consumption. The overall lifestyle of a group of people also impacts the amount of energy that they require. One should also highlight that cultural awareness of environmental issues is not equally distributed around the globe and therefor, perceptions vary heavily (Omar & Hasanujzaman, 2023, p. 1768). Culture is a very versatile topic. It influences a broad

spectrum of life, such as working hours, leisure time, hobbies, education and much more. All this shifts the perception of the individuals within a culture.

With all the above being said, it becomes very evident that communities must find a way to produce and trade electricity with one another. But this should not be done without intervention or surveillance of the government, which is why regulation must be passed by governing bodies or entities affiliated with the government.

Given that the energy sector is a natural monopolistic market, the government needs to be involved because the lack of a standard and controlling body can lead to mass corruption, instability, and danger in the energy sector. Grids need to be dimensioned, prices for electricity need to be stabilized, social welfare should not be underestimated, etc.

The goal of the thesis is to draft a schema, which regulators can use to enforce sustainable behaviour to govern electricity as a common.

How communities trade energy:

Community members trade electricity directly with one another. This is also referred to as Peer-to-Peer (P2P) Energy trading. Participants who produce and consume energy, are called prosumers. Participants who only consume energy, are referred to as consumers. (Paudel et al., 2018, p. 2)

Blockchain will be the technology that guarantees transparency, honesty, and trust. The energy is mostly produced via solar panels on the roof of each community member. Trades occur on a remote platform while transactions are processed by smart grids. There are many more challenges in drafting a schema to govern P2P energy trading, which is derived from the literature reviews. Community members can monitor data on the trading platform.

The challenge that this thesis addresses, can also be summarised using the VUCA framework. VUCA stands for Volatility, Uncertainty, Complexity and Ambiguity. A very simplified VUCA framework implementation would classify the problem in the following way (Bennett & Lemoine, 2014):

Volatility	Uncertainty	Complexity	Ambiguity
Blockchain technology advances very quick into multiple different fields.	Acceptance of community members, feasibility of prototypes, Scalability, Adaptation, pricing and regulation.	Political interests, Game theory among participants, Conflict resolution and technological aspects.	Lack of understanding from the perspective of regulators, Conflict of interest for existing players who enjoy a monopolistic position in the market.

Table 1: VUCA Framework Implementation to classify the problem to be solved – Author’s table

Literature Review

After reading multiple articles, the author decided to divide the literature review into four sub-chapters.

There are multiple reasons why this occurred. The first reason is to create a logical flow of information. From the author’s perspective, blockchain technology is an enabler, not the central topic of this thesis. Regulation of the governance of electricity as a common in communities is the focus. Hence, why the author choses to evaluate human behaviour in connection to shared resources as the first step. The next reason is due to the theoretical framework that that the author selected. Elinor Ostrom, who crafted the “eight design principles”, is a Nobel Prize decorated

scientific economist. Her holistic analysis on how communities manage shared resources and govern stability builds on the challenge of the tragedy of commons, which itself is a very famous and respected framework. However, Ostrom conducted further research on its applicability to global issues, practical relevance, policy implications and especially the empirical evidence. Behavioural economics also reveals interconnected cultural differences in decision making, provides historical context, involves game theory that creates insight into the perspective of every participant and also highlights social interactions. All of these elements are important to draft a schema that should be accepted by communities. Because of the reasons mentioned above, behavioural economics is the first sub-chapter.

Next, one needs to understand the energy market. This is because the schema that will help communities govern electricity as a common, needs to be implemented into the existing energy market. Even though the energy market is over a hundred years old, one should not assume that it has not changed. The world is pivoting towards green energy, electricity is becoming more and more a basic need, and the efficiency of the gadgets is getting better year by year. However, the market is still victim to human manipulation, malicious intent, and bad interests. Even though the subchapter "*energy market*" is part of the literature review, it is important to note that the scope of this thesis is limited and therefore, undertaking a comprehensive exploration of all of facets of the energy markets it beyond the scope. This sub-chapter is meant to be treated as a high-level summary of where the energy market currently stands.

After gaining insight on how the energy market currently works, one needs to investigate where blockchain currently stands and what kind of research has been done so far. This is probably the most technical sub-chapter of the entire thesis. It investigates smart contracts, smart grids, the scalability of blockchain, the consensus mechanism of blockchain, security, technical limitations, and many other aspects.

Since the goal of this thesis is to draft a regulatory schema to govern electricity as a common, which will contain a list of rules, the three previous subchapters will then be analysed from a legal perspective in parallel to further deep literature review. For a more detailed literature review, please look at attachments.

Behavioural Economics

The literature points out human behaviour changes in situations that trigger scarcity and provides more depth into a human's greed (Ostrom, 1990). This is important, since the framework should limit the opportunity to be greedy, but also try to completely eradicate scarcity.

Furthermore, the literature pivots towards game theory. This is very important, as it is very easy to understand one human being. The difficulty lies in anticipating behaviour when multiple humans engage with one another. This will be the case when participants trade energy. (Hotz, n.d., p. 2)

Here, an interesting question would be for example: Should community members be able to set bid prices for the electricity that they wish to purchase or should the system issue automated bids?

The goal is to figure out what trading mechanism works best for a community while guaranteeing longevity. It should prevent people from trying to game the system by predicting their behaviour. So far, it is evident that community members are playing a cooperative game. This means that there's an incentive for members to cooperate with one another. The incentive is the energy that one now gets and the cheap energy prices.

In this sub-chapter, the author will investigate what the theory says about governing commons. This is also the sub-chapter, where the author will introduce Ostrom's design principles. The eight design principles are:

1. Clearly defined boundaries

This step covers the definition of boundaries and specifies who is authorized to use the common pool resource (CPR).

2. Congruence between appropriation and provision rules and local conditions

Appropriation rules like restricting technology, place, time, quantity and adding additional provision rules help to account for the perseverance of the CPR.

3. Collective-choice arrangements

Enables participants to modify operation rules. Enables all participants to be heard, even though not every voice should matter equally. Cooperation should be pushed.

4. Monitoring

Audits the CPR conditions and helps hold community members accountable.

5. Graduated sanctions

Adds a form of punishment to community members who abuse the CPR or don't act according to the rules.

6. Conflict-resolution mechanisms

Internal framework that applies to the community's culture, while helping to reduce or solve conflict.

7. Minimal recognition of rights to organize

Acquiring legitimacy confirmation for rules defined in the community.

8. Nested enterprises

Connection one's own community with other communities and working together in a bigger network.

(Ostrom, 1990, pp. 90–102)

The schema will use these design principles as the backbone. There are many other schemas to govern commons, but the author selected Ostrom's framework because of how close it is to communities. But keep in mind that Ostrom's design principles are far from perfect and get challenged or criticized from time to time. Stern for example challenged Ostrom's Design Principles on the scope of a global scale, since there are millions or billions of actors involved. The conclusion drawn by Stern is that even though Ostrom's design principles are great, they don't directly transfer to global resource commons and technological risks. (Stern, 2011, p. 229) The author partially agrees with this criticism, which is why these design principles were selected for governing electricity in communities. Technological risks however are a different topic. They are way more complex. Thus, further research is required in this area.

Another paper interrogated and critically reviewed Ostrom's design principles and drew the conclusion that the design principles could be fundamentally flawed, and that more studies are required to make them more generalizable. (Araral, 2013, p. 19) Here, the author has no opinion, since one would need to test the design principles for many different kinds of commons.

There are multiple other factors that one can bring up as criticism. Ostrom for example leaves out external factors. These are for example political instability and economic development. Another factor is for example the lack of guidance. She doesn't define KPIs on how one can track the implementation and evaluation, making it very difficult to measure the effectiveness of her

framework. The applicability of the Design Principles should also not be underestimated, especially in combination with evolving technology.

Electricity Markets

Next, the author will conduct research on existing electricity markets. This sub-chapter explains how traditional markets work. This includes the generation, transmission, distribution, and retailing of energy. This sub-chapter also explains the transition from the forward market into the day-ahead market, followed by the intraday market, where balancing occurs. (Cramton, 2017, pp. 594–598)

It also investigates the energy consumption of households and shows peak hours of electricity consumption. This is when it becomes evident, that P2P energy trading can not only be used for rural communities, but also for established communities in the first world. Using P2P energy trading can relieve the grid from stress, extend its lifetime, and reduce costs while creating more green energy at the same time. (Javed et al., 2022, p. 1)

The most important thing here is to understand that the energy sector is very different from other fields because energy should never be stored. That's always the least optimal approach. Unlike when selling merchandise like shoes, where shelf time itself doesn't diminish the product as rapidly as in the energy sector. Why? Because storing energy requires transformation, which leads to a loss. Converting the stored energy back to electricity also requires another transformation, which leads to further loss. The devices that are required to store and transform the energy also need to be maintained and monitored. **Therefore, supply and demand must always match.** The schema to be drafted must always take this into consideration. Energy offered by prosumers should be purchased as soon as possible by consumers. (Hogan, 2021, p. 10)

Technology & Blockchain

This sub-chapter consists of multiple real-life adaptations of blockchain projects and experiments. It will provide the author with knowledge on technical limitations, a status quo on where research currently stands, what to look out for in the future, point out difficulties that the industry is currently facing, and elaborate on pilot projects.

It is a very important sub-chapter, because there is a lot of fuzz going on about P2P energy trading, but most of the statements are based on rumours. The author will also classify every read paper using Ostrom's design principles, to figure out which design principle that it covers. This will help ensure, that all principles were taken into perspective during the literature review.

The author believes that the discoveries of this sub-chapter can be segmented as follows:

- Smart Grids
- Energy Trading Platforms
- Blockchain(s)

There are multiple discussions going on. Some involve the question of which trading mechanisms are technically the best. Other discussions focus on the reliability of smart grid grids. Then there's the issue of social acceptance, which goes back to behavioural economics (Borges et al., 2022). Just like in most discussions, reliability, scale, and security should now be underestimated too. There's also a debate on whether projects should use a private or public blockchain.

Legal implications

The previous sub-chapter's findings are connected to the legal aspects of P2P energy trading. The goal here is to figure out where legislation currently stands and what approach it takes to set constraints for P2P energy trading.

So far, the author has discovered that the most common approach is the sandbox model. This means that a pilot project is executed in an isolated environment and the results are documented (Schneiders et al., 2020). It's important to point out that the simulation is a real-life scenario.

The questions that arise are mostly over ownership of the devices and accountability. However, accountability is very versatile and sophisticated:

- If a system were to issue automated trades, who would be held accountable?
- Who owns the smart grids?
- Who owns the data on smart grids?
- Which data should smart grids monitor and what are the security requirements that must be met?
- Who is held accountable for smart contracts?

There are also political aspects. A research paper from the author Kim Joo Young indicates that the energy sector should always be fully under the control of the government since the goal of corporations is to maximize profits. This is a contradiction to the well-being and sustainability of a community. (Kim, 2015)

Conceptual Framework

This chapter connects the four sub-chapters of the literature review with one another and informs on how they are interrelated. The first relationship that is explained, is the relationship between behavioural economics and decentralized technology. The second relationship is the relationship between decentralized technology and legal. The last relationship established is between decentralized Technology and traditional energy markets. In this chapter, the author summarizes the gained knowledge from the literature review and suggests a first version of the schema based on the previous topics. The connections are visualized on the next page. It will be used to guide the research design and data analysis.

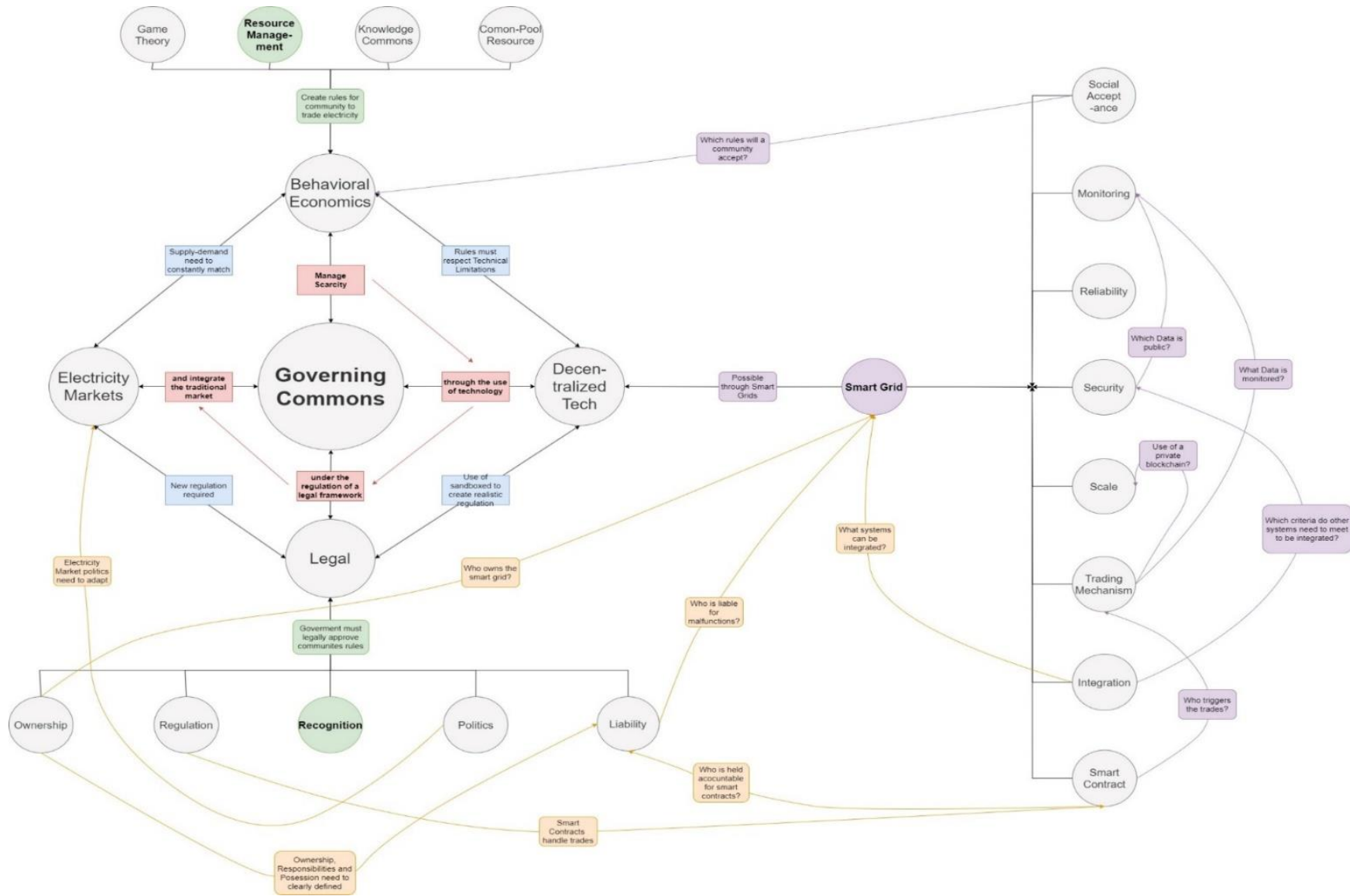


Figure 2: Conceptual Framework – (Author's diagram, 2024)

Methodology

After creating the conceptual framework, the next step is towards the methodology. Here, the author investigates real-life energy projects to extract valuable information to draft a feasible schema to govern electricity as a common use of blockchain within a community. This requires the investigation of existing projects, which can be used as a form of inspiration and as proof of concept. This approach also helps the author gain an understanding of the different approaches that companies are taking.

The data collected in this chapter derives partially from secondary data and primary data. The secondary data originates from the organization “Blockchain for Good” (Blockchain for Good, 2023). It lists multiple projects across a variety of fields such as food, manufacturing, finance, etc. Since the author focuses on the energy sector, the scope will be on the data from the energy sector. But since Blockchain for Good didn’t investigate the projects deep enough, but is known for listing ethical projects, it will be used as a reference list.

The author will evaluate every project within that list and rank it according to how well it delivers value towards the research question using Elinor Ostrom’s eight design principles as a framework. There are multiple research methods that can be used to rank projects.

Method	Pros for this thesis	Cons for this thesis
Weighted decision matrix	Allows author to disproportionately assign importance to criteria and the criteria can be further customized. However, all design principles are equal, so this method is not a fit too. (Kothari, 2004, p. 27)	Weight assigned to criteria must be explained in detail because if not, the result is completely useless. Ostrom clearly indicates that all design principles are equal. Weighing the importance of each design principle is also extremely difficult. This approach would also limit the consideration of uncertainty, as it must be included in the weighing of the criteria. Large projects when compared to small ones also become very hard to rank. They have way more aspects to them. This approach also assumes that the criteria are not interconnected. The scope of criteria would also need to be limited, since weighing them becomes too difficult. (Kothari, 2004, p. 27)
Expert judgement	The biggest benefit would possibly be the problem-solving skills of the expert and their approach to create a set of rules. Furthermore, the expert would have a holistic view seeing a broad range of factors.	Highly subjective, full of biases depending on the expert, very limited perspective and diversity (which is very bad for a project that focuses heavily on behavioural economics and drafting a regulatory schema),

	But this method is not fitted for this thesis. (Skjong et al., 2011)	nearly impossible in a fast passed technological field, which is constantly in development. (Skjong et al., 2011)
Scoring Model	Allows author to list criteria to create a scoring model. Ignores if criteria are interconnected. Works for big and small projects, since they have to all meet a certain threshold to achieve a high score. Scope of criteria doesn't have to be limited. Author can define criteria to reach the highest score based on a nominal ordinal scale, then use the results for quantitative & comparative analysis. (Kothari, 2004, p. 85)	Scoring models can be very subjective, but this is why the author will question his own rankings. The author also needs to re-rank projects, whenever new ranking criteria are discovered, since already ranked projects would be rated in an unfair manner. Kothari, 2004, p. 85)
Financial Methods (NBA, ROI, BCR, NPV, etc.)	Very objective and analytical results, however mostly used for profit-oriented purposes. Not a match for a thesis that focuses on delivering value.	Completely ignores the technological complexity and focuses solely on outcome, financially benchmarking each design principle, which makes no sense.

Table 2: Methodology Comparison – Source: Author's Creation

The author will conduct the ranking by using a scoring model to rank the projects. After the scoring model has been executed, the author will collect findings and document the results. The findings derived from reviewing the projects will be few in count, since the count of projects to be reviewed will be very few. Therefore, quantitative analysis will be difficult. Because of this, the author thinks that nonparametric statistical analysis is the right way to go next since it doesn't require a big sample size.

But this statistical approach will not be the only one in use. Other statistical methods will be used too. Descriptive statistics, such as measuring central tendencies through mean, median and mode calculations will provide further insight into the data. For example, the median will reveal how the average project ranks when using the design principles to rate it. Furthermore, frequency distribution is also interesting because it reveals how frequent certain scores are given to each design principle. Methods, that aren't a match to are for example bootstrapping, Bayesian methods, exacts tests and many others. For bootstrapping, it makes no sense to draw a repeated sample because the author used the scoring model to get the sample data and did the scoring himself. A repetition would lead to the exact same result. Bayesian methods are no fit, because when dealing with high dimensional models (the ranking criteria), they become very complex. Exacts tests are no match, because the Author has no null hypothesis and therefore, can't calculate a P-value. (J de Smith, 2021)

Since the rankings can be very subjective, the author wants to make them more generalizable. Here too, many methods exist. A meta-analysis would be interesting, since it provides a more unbiased assessment (Mishra & Alok, 2017). But the sample sizes derived from reviewing the projects will not be big enough. There are also many confounding variables since some aspects of the design principles are interlinked with one another. Because of this, the author's choice fell on the triple blind process. This is done so that the author can review the rankings of another individual, with whom the author will then have a discussion. The author will use this triple blind process to correct his previous rankings and then re-evaluate the projects that were reviewed. This synthesis will also challenge a few biases and misinterpretations of the author. The triple blind process is ideal to make the scoring model more objective.

The triple-blind process is part of the primary data collection. After the synthesis is complete, the author will use the newly gained knowledge to prepare qualitative interviews for further phenomenon (Mitev et al., 2019). The choice falls on quantitative interviews, because the reviewed projects already deliver quantitative data. The interviews will be created at a later stage.

The goal is to gain new insights on the topics from experts. The knowledge will be used in the next chapter to draft the schema.

Investigating secondary data

Disqualifying projects

Before the author investigates the projects from Blockchain for Good, the author must disqualify projects, that don't deliver value to the research. This can be done by creating a list of criteria, that the articles must meet. Once this list has been created, every project will be evaluated using this list as an instrument and the projects that don't meet the standards that have been set will be disqualified and ignored.

Some projects are not transparent enough to be reviewed in detail for a comparison to be drawn using the eight design principles. They don't provide any proof of concept, lack the existence of a backing community, their documentation often lacks technical depth and there are no respected partnering companies listed. Additionally, executing a project of this complexity alone without funding is almost impossible. As a researcher, it becomes very hard to take these kinds of projects serious. Many of them don't even have functioning websites or their sites have been taken down.

Summarized, this means that the author will collect data on the projects, while always taking Ostrom's design principles into perspective. If two or less design principles can be rated while the others would have to be ignored, the project will be removed. This is because focusing on two out of eight design principles will result in an overall very low score and makes it hard to put faith in a projects feasibility. If for example a project's description were to earn it the highest score for design principle *nested enterprise* (8) while all other design principles were ignored, this could be a fantasy project. The same applies for a project with the best score for design principal *monitoring* (4). Here too, a project could get the highest score by promoting a beautiful UI, but without any other design principle being measurable.

Coin dedicated projects

There are multiple projects, which allow participants to buy coins. In most projects, the coins are meant to represent a certain amount of energy that was produced. The problem, however, is that these projects don't provide further details, on how the energy can be used and what their respective coin, the token, really represents. The price increases or decreases solely based on supply

demand. This is physically not possible in a real-world adaption since electricity is prone to multiple environmental circumstances.

For example: If 1kW of energy were to be produced and 1kW would be assigned a value of 1 USD, then the demand would need to match immediately. If this is not the case, the energy must be stored. Converting the energy and storing it leads to a loss. So, the market price of a token would be impacted by this physical law. This doesn't seem to be a topic at all in any of the white papers of the coin dedicated projects. There are also no descriptions of the IOT devices in use, hence making it hard to estimate risk. The fancy white papers indicate that the goal is to increase popularity and blow up through an initial coin offering (ICO).

Another aspect, that must be taken into consideration, is that if coins represent a certain amount of energy that was produced, then one must make sure that no coins can be created in another way without being backed by existing energy. If this is possible, then the entire purpose was defeated.

Solely Profit oriented businesses (extreme projects)

The next criteria, which will be used to disqualify projects, takes the goal of the project owners into consideration. If the purpose of a company was to maximize profits, in most cases, the project will be disqualified. Again, exceptions will be made also here too. There will be some projects in the list, that are profit oriented, but they add tremendous insights during the investigation on how they operate. But those are the exceptions. All other projects of this nature will be removed.

Creating Ranking Criteria

Next, the author creates the ranking system. The ranking system will consist of an ordinal scale of five values:

- **1: Bad**
- **2: Minimalistic**
- **3: Good**
- **4: Very Good**
- **5: Perfect**

This means that one represents the worst possible score that a project can score, while five represents the best possible score. It's to be expected that one can view the ranking mentioned above as purely subjective. To avoid confusion, a standard must be set, which projects must reach to receive the highest possible score. The list below provides this information:

- 1. Clearly defined Boundaries**
 - Ownership of electricity must be clearly defined
 - Ownership of electrical units must be clearly defined
 - Requirements of participation must be precisely defined
- 2. Proportion equivalence**
 - Should focus on community members and give them power over their own energy supply and consumption
 - Participants need a certain degree of choice, but not full control over their energy consumption to eliminate discrimination or abuse
- 3. Participation**
 - System must include prosumers and consumers

4. **Monitoring**
 - Must contain (near) real-time data
 - Must contain bidding information and historical data
 - Must list historic trades in a decentralized ledger
 - Data is not allowed to belong to a company or organization
 - Must track energy consumption and provide carbon emissions saved through green energy
 - Must provide information on how much money consumers have saved
5. **Graduated Sanctions**
 - Sanctions should be applicable without individuals or companies protecting themselves through terms of use
6. **Conflict Resolution**
 - Conflict resolution must be possible by involving the community, not just two stakeholders.
 - Community must be able to track data to help resolve the conflict
7. **Recognition of Rights**
 - The system must include a legal framework, which can be used to hold community members accountable
8. **Nested Enterprise**
 - Smart Grids should belong to the government or individuals should own their own smart grid
 - Technology must be able to adapt to other technologies. Web services (REST-API) or real-time data ingestion are the best approach.

Project Summary

After the criteria of ranking have been created, the author can focus on reviewing the projects. Summarizing the projects makes it easier to reflect on the project soon and also helps the triple-blind participant to navigate through the thought process of the author. If the author leaves out an important detail about a project and therefore gives a project a bad ranking, the triple-blind process can easily point this out. The same applies to misinterpreted information on a project, which leads to a too-high ranking. Here is an example of how the summaries of two projects can look like:

1. *Power Ledger*

Power Ledger is an energy trading platform that enables participants to sell excess energy with their neighbours (Power Ledger, n.d.). The company operates using two layers on the Ethereum blockchain. (powerledger.io, 2023)

“OWR tokens are the frictionless blockchain tokens that allow Application Hosts and Participants access to and use of the Platform (like a limited software licensing permission). Sparkz tokens are issued against escrowed POWR tokens, via a Smart Bond, and used by the Application Host to onboard its customers. Application Hosts are entities and businesses that run an Application on the Platform. For example, a utility company using the Platform will be an Application Host, as is an EV-charging services business. A Decentralized Autonomous Organization can also become an Application Host.” (Power Ledger, 2019, p. 16)

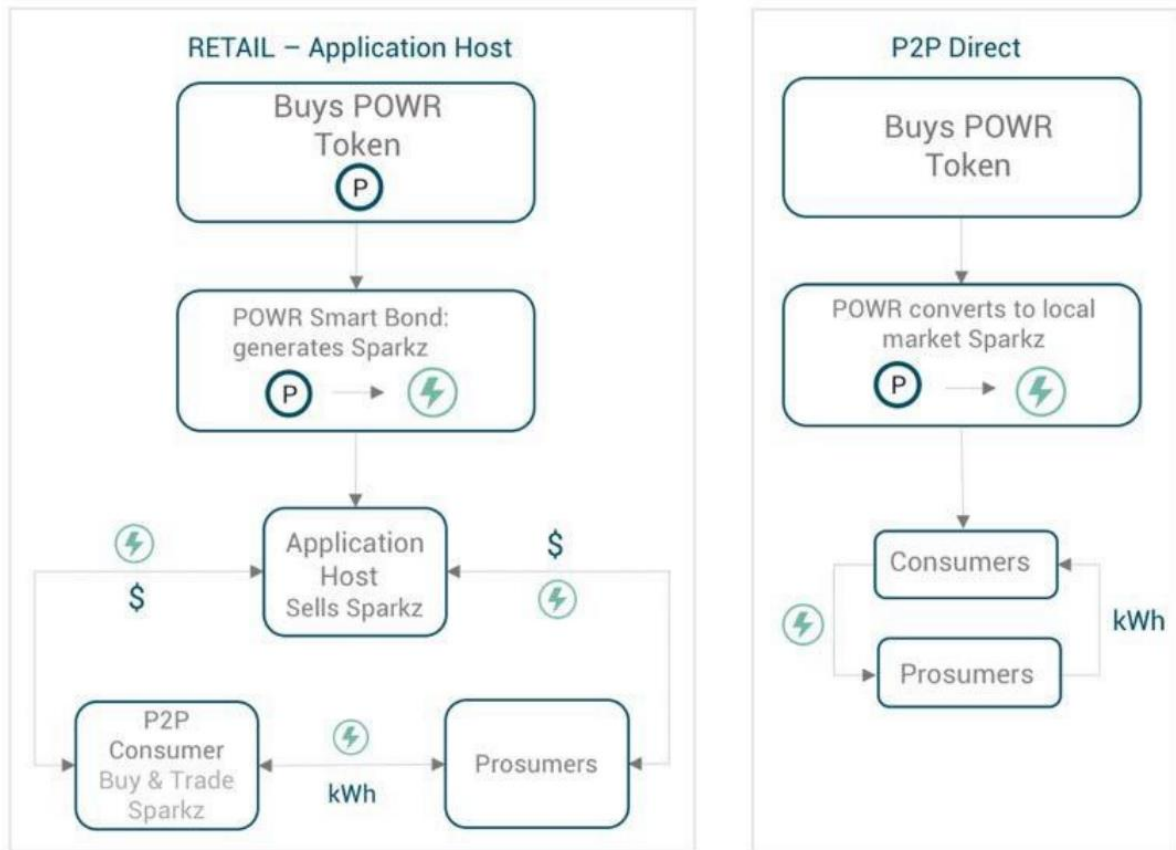


Figure 3: Power Ledger's Software (Power Ledger, 2019, p. 17)

The company claims to have had a successful trial from August to December 2016. The company doesn't only offer the software, but also hardware. (powerledger.io, 2023)

BCPG and Power Ledger now connected 6 buildings to their grid to further test P2P energy trading. The buildings consist of a shopping centre, a school, apartments, a condominium, a dental hospital and another building full of apartments. This P2P energy trading project is an attempt towards nested enterprises. One of the buildings contains an energy storage system, which gathers the overall excess production. (powerledger.io, 2023)

4. Blok-Z

Block-Z owns the product GreenLink, a renewable energy tracking software. It enables customers to trace the origin of their green energy. GreenLink tracks the data in real-time and provides in-depth energy and carbon emission avoidance information. The company can also issue certificates and create visualisations. The illustrations below reveals further details on how GreenLink works. (Blok-Z, 2023)



Traditional EACs are issued for the generation of assets. The retailer needs to buy the EACs beforehand.

GreenLink collects the Consumption & Production data from SCADA, local smart meters, IOTs, APIs provided by the market operator, etc. Greenlink creates wallets and defines unique tokens representing small fractions of the EACs.

Production and Consumption are matched on a 24/7 basis. Tokens are transferred to consumer wallets.

Figure 4: How Blok-Z Works - 1 (Blok-Z, 2023)

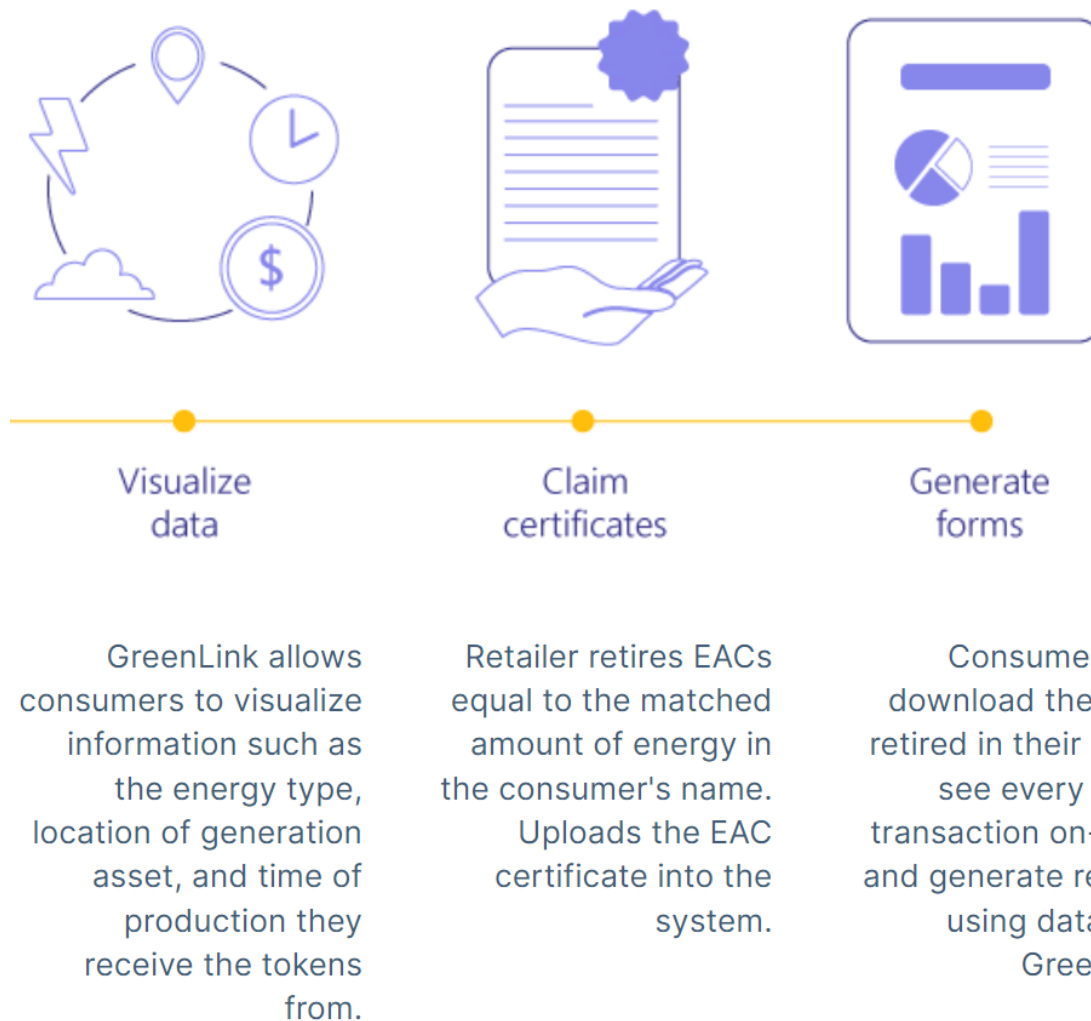


Figure 5: How Blok-Z Works - 2 (Blok-Z, 2023)

Ranking table

Lastly, the author ranks every project using Ostrom's eight design principles. For illustration purposes, the author will create a table. The table in this sub-chapter will contain ten columns. Column one contains the project's title and a short description, column two contains findings or conclusions drawn from ranking this project and columns three to ten each contain one design principle. Here is an example of a ranking:

Table 3: Ranking Electron Project – Source: Author's Creation

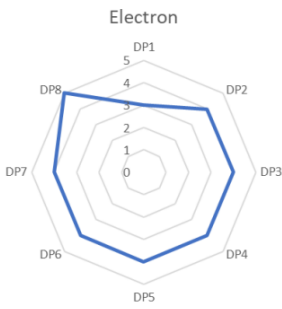
<p>9. Electron</p>  <p>Figure 29: Electron's radar chart of Ostrom's eight design principles – Author's creation</p> <p>Blockchain based platform for B2B prosumers with all kinds of devices.</p>	<p>Focuses on one hand on grid integration as a platform for all kinds of devices, on the other hand on trading (flexibility) for businesses (B2B).</p> <p>Interesting because P2P B2B can be combined with P2P B2C.</p>	<p>Boundaries are defined as the platform only enables integration and trading.</p>	<p>Financing is in the hand of participants. Therefore, hard to judge the proportion equivalence. Energy can even be produced via wind.</p>	<p>Once infrastructure is installed by a business, using the platform is very simple.</p>	<p>Monitoring provides all possible data including the setting of prices. Company uses near real time trading and work together with partners.</p>	<p>Tracks interaction and availability. Penalties are possible.</p>	<p>Since multiple grids are integrated, grid providers are held accountable for their hardware and security.</p>	<p>Integrated platforms scope the use and limitations of their project.</p>	<p>Main purpose is the connection of multiple devices into one platform and the current energy market.</p>
4.0	3	4	4	4	4	4	4	4	5

Table 4: Project ranking table - Source: Author's creation

Findings from secondary data

Statistical findings

In this sub-chapter, the author will investigate the rankings and draw conclusions. These conclusions occur by calculating the averages and modes of the data. Since the author can't expect to review thousands of projects, the distribution won't be nominal. Therefore, the author will use nonparametric statistical analysis to gain more insights into the ranking.

An initial draft of the schema to govern commons

The results will lead the author to create an initial draft of the schema. However, this schema is just a draft, which will be used for the primary data collection. The illustration in the chapter Conceptual Framework is the fundament of this initial draft, making this schema its continuation.

Investment - Government as an investor

Rural communities need investment. That said, the framework should contain characteristics that are lucrative for investors but limit their power in the decision-making process over the lifetime of the project. The control over the community must remain in the hands of community members. If investors were to make decisions on behalf of communities because they are the funders, then at some point they would pick individuals to represent their interests, who would add further experts and pay them for their expertise, which would turn the operations into a company. That's the opposite of the goal of this thesis. The goal is to make communities self-sufficient.

This means that investors shouldn't be profit oriented, but rather have interest in the communities' wellbeing and the environment. Better living circumstances create better economic balance for the country. The requirements set demand an investor who is not profit oriented but benefits indirectly through the overall improvement of the of the country's improvement. Because of the nature of these requirements, **only governmental organizations are eligible to be investors.**

The government is reimbursed thanks to better the conditions of communities since this will improve the overall situation in the country. This change could drive entrepreneurship, motivate individuals to pursuit further education, increase self-sufficiency and much more. The government's participation will also lead to mass investments in renewable energy and therefore, drop the production prices. The suggestion above covers the following design principles of Elinor Ostrom:

- Proportion Equivalence from the perspective of the government

Regulation (Core of the conceptual framework)

Another aspect, thanks to the government's involvement, is the progress of regulations. The government needs to draft an official term, which communities abide by. This term shouldn't be extremely detailed, but rather be viewed as a list of minimum requirements. It can also include do's/don'ts for the implementation of self-governing energy projects. There needs to be a national or international standard for this new approach, which is legally binding for adapters. Communities are then allowed to add further rules in the form of norms of agreements, but they must respect the of the basis that has been set. Involving the government puts the regulation in their interest.

Regulators must focus on two things when drafting the rules. One part consists of the technical requirements, while the other part focuses on liabilities.

Technical

Technical regulation includes all rules set for the technological implication and technological implementation throughout the lifetime of a project. This means that the mini hardware that stores data, the processors that do the calculations, the cables and wires that transport the energy and data, the smart grids that are used to monitor data and many more other devices need to meet the requirements set by regulators. This involves IT security, GDPR, and much more. The goal is not have the government manufacture or own the devices, but rather define clear requirements, which still feed a market's competitive nature to favor consumers.

This could be for example:

- Which protocols should smart grids support?
- Which data should smart devices log?
- In which interval should data be logged?
- How big should the logs be?
- Which encryption should smart devices use?
- Should data be encrypted and if yes, when and where?
- What's the maximum distance electricity is allowed to cover before it's deemed inefficient?
- Etc.

Liability and Duties

Since the end goal is to enable communities to work together or even sell energy to other participants, who might not be part of communities themselves, a lot of money will need to be invested into network infrastructure and other components. This will create a lot of complexity and probably also a lot of confusion on ownership, duties, and benefits. The rules to be created applied cover the following design principles of Elinor Ostrom:

- Proportion Equivalence from the perspective of participants
- Clearly defined boundaries
- Participation
- Monitoring

- Graduated sanctions
- Conflict resolution
- Recognition of rights
- Nested Enterprise

Interesting questions again would be for example:

- Who owns the smart grids?
- Who owns the produced energy?
- Should participants be able to set bids as they see fit? (Discrimination and abuse should be considered)
- Should there be ledger technology for each country or even a private blockchain?
- Who issues green energy certificates in P2P trading?
- How much energy are retailers allowed to sell to community members? (This should be limited by regulators)

It becomes evident that the conceptual framework will focus heavily on the regulator's aspects from a technical and behavioral economic perspective.

Collection of Primary Data

The collection of primary data occurs via the triple process with a participant, who will rank the same projects using the same ranking system. As soon as the ranking is finished, the author compares the rankings with his own rankings and engages in a discussion. The goal of this discussion is to agree on an appropriate score and gain a new understanding through the perspective of another individual. The discussion might make the author change his ranking and view on certain projects. This will lead to an update of the ranking table of the author, to other statistical findings, and perhaps even change the initial draft of the schema to govern commons.

The author now has reference data after reviewing projects, but certain aspects of the schema are still not yet defined. This gap is filled by conducting qualitative interviews with individuals who are experts in those fields. The author will prepare the questionnaires with his supervisor and engage in the interviews.

Findings from Primary Data

The conclusions drawn from the interviews and triple-blind process will generate a clear understanding of what needs to be done and which key points are very important in the schema. All gained knowledge will be documented in this sub-chapter.

Schema to govern commons

Here, the author drafts the schema to govern electricity as a common use of blockchain. The schema will contain illustrations and depictions, which should make it easier to comprehend.

Conclusion

It is not realistic to expect the drawn schema to be perfect. Therefore, there are certain dimensions that it won't cover well enough. Those will be highlighted in this chapter. Additionally, there could be multiple other domains that the author discovered when drafting the schema, which will make up part of the conclusion.

The author will also need to define a clear context and scope for the drafted schema to be used within. This happens in the conclusion too. If further research must be done, the author will clarify that here too.

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