Title: Using Serious Gaming to Understand and Discover Distributed Ledger Technology in Distributed Energy Systems

Design Project
Final Report

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INTRODUCTION

In 1965, Gordon Moore wrote [16] about the falling cost of computer chips with the number of components per circuit rising. With the technological developments in computer circuits (see appendix), the future of electronics looked very promising as to all the new applications that computers chips could be used for. To find new applications, a thorough understanding of the technology is crucial. History is full of examples of applications of new technologies for which the technologies were initially not intended for. The steam engine was originally designed to pump water, but a creative mind brought the steam engine into transportation and initiated an enormous transformation for the transportation market. Another example is the world wide web, where the technology was originally intended for military intelligence only. Nowadays, this technology has an enormous influence on modern society. To think of new creative applications for technologies, sessions can be organized to first understand and subsequently think of new applications.

Serious gaming lets participants experience a simulated world and can be used for three purposes: skills improvement, changing behavior and knowledge creation. It can provide a way to let employees of a company understand and discover applications of new technologies in complex ecosystems. The aim of this study is to build upon the knowledge of how serious gaming can be used to stimulate understanding on new technologies (by using DLT as a case study). A game is designed and used to create an environment to let participants experience a technology and have a better understanding of what the technology does in practice. Distributed Ledger Technology (DLT) is used as a case for which serious gaming is tested. This subject is chosen because of two reasons: (1) the hype [6] that exists around the technology blockchain and (2) companies are eager to learn what the applications of this technology are and how they can create value with the technology in their business. An application that is interesting to discover is the use of blockchain in distributed energy systems. This is a system where households with solar panels can exchange their produced electricity, supported by blockchain and without the need for an intermediary (utility).

The serious game in this project is designed in an internship at Accenture in Amsterdam. The main business of this company is to implement information technology systems in companies in order to help improve their business. DLT is a software technology which is a novel technology and a serious game has the potential to help Accenture let employees experience new technologies and create knowledge about how a new technology such as DLT can be applied at one of the clients of Accenture.

The report is organized as follows: chapter 2 establishes the background of the subject in this project. Chapter 3 describes the methodology of the project as to how the research is conducted. Chapter 4 depicts the overall picture of where in society this project is relevant. Chapter 5 goes deeper into how the game is designed. Chapter 6 provides the results of the gaming sessions and how these can be interpreted. Chapter 7 concludes the project and chapter 8 provides a discussion about the research.

2

BACKGROUND

This chapter establishes the background for this project where it seeks to show how the project is relevant for the academic world and what has done in this subject before this project.

2.1 SERIOUS GAMING

This section discusses multiple serious gaming used in varying themes and with varying goals.

2.1.1 *Architectural planning and design*

At the Technical University in Delft, Ekim Tan [24] researched serious gaming in the field of architectural planning. In architectural planning, hierarchy was deciding who made the decisions and the citizens (who had to live in the designed areas) had no to very little input. This caused a mismatch between what the major architects would see fit and what the citizens needed. The game "City Gaming" is a serious game used as a method for collaborative decision making, the themes that are handled in the game are affordable housing, circular economy, migration, inner city transformation, urban expansion and participatory design. The game resulted in greater decision making and a company "Play the City" which continues to make serious games.

2.1.2 *Samsø*

In Denmark the government decides that the island Samsø100% fossil fuel free. Initially, the government imposed this idea on the citizens of that island. They soon realized that this way of forcing the citizens, brought a resistance among them. To solve this, serious gaming was used [11] to bring together the citizens in order to align interests and motivate people to talk about the subject. As soon as the story and picture around putting wind mills all over the island was told, people were more cooperative and willing to put energy in to the shift to a fossil-free island.

2.1.3 *Co-designing in the 'Energy Safari'*

In Groningen, Gugerell and Zuidema [8] argue that experimenting and learning are increasingly considered as means to innovate governance approaches for pursuing a more sustainable society. They create a serious game by using a collaborative co-designing process in which the 'Energy Safari' was created. They find that using prototypes while co-designing games offer a promising strategy to ensure regional embeddedness and create recognizable and meaningful narratives. The games evoke focused discussions and reflect on real world models and abstractions but also leave sufficient room to explore and experiment. The examples in these sections show that serious gaming has been used before for educational and discovery purposes and has been yielding interesting insights and learning experiences.

2.1.4 *Designing ecosystems of the future*

During this project a visit was given to 'De Ceuvel' [1], where a community was established where some members of the community have solar panels (producers of electricity) and some were only consumers of electricity. The system there was enabled by blockchain to let the members exchange electricity in the community. To design this system, serious gaming was used[1] to explore the possibilities and discover how this system could be implemented in the real world.

2.2 EXPLORING DISTRIBUTED LEDGER TECHNOLOGY

As was seen in the previous section, serious games can be used for different purposes. In this project, the combination of the technology of blockchain and serious gaming is researched. During 2017, the terms blockchain and Bitcoin have been hyped, which can be seen in the extreme volatility (and increase) of the price of a Bitcoin [6]. The cryptocurrency Bitcoin is enabled by a distributed ledger technology (DLT) called blockchain. DLT is a technology that entails a record of information (a database), that is shared across a network. The best-known form of DLT is blockchain, where all transaction data is stored in blocks that are attached to each other to form a chain. The transactions in the system are reviewed by a fixed number of independent members, which makes centrally organized intermediaries obsolete [15]. This technology has the potential to offer an alternative technical solution for storing data in a decentralized way. Clients of Accenture and Accenture itself want to know what this can mean for their business and how they can be the first to implement the technology to have a competitive advantage. In various industries, companies are exploring the application possibilities for DLT in their business. The European Central Bank [19] brought out an exploratory paper about possible use cases in security markets with several scenarios and recognizes that DLT holds potential for the financial industry. Pilkington [18] describes multiple industries where blockchain can be applied: government, science, energy industry, finance and logistics.

2.2.1 *DLT applications in energy industries*

An promising use case for DLT is in the energy industry [17]. This is because the popularity of distributed energy resources (DERs) is rising [30]. This is enforced by the fact that solar and storage technology is decreasing in price and becoming more affordable for households (The price of solar has dropped from 350 dollars per MWh in 2009 to below 100 dollars per MWh in 2018 [2]). Blockchain, a DLT where systems can be organized more decentral, fits this decentralized organization of the energy infrastructure. Examples can be found in the energy industry where its infrastructure is organized in a decentralized manner, supported by blockchain technology. In Brooklyn, NY, an initiative [14] is present where a community

1 Information retrieved from conversations at a tour at De Ceuvel
2 https://www.bloomberg.com/quicktake/solar-energy

is formed where electricity is exchanged. In this community, households owning solar panels are able to sell electricity to members of the community, so they can keep trading profits within the community. This incentivizes investments in solar panels, because the community members no longer have to pay for the service of an intermediary. The transaction system is based upon blockchain technology, where the participants pay each other with cryptocurrency. They show that (private) blockchains are suitable information systems that can facilitate localized energy markets. Another example where incentives, facilitated by DLT, are provided for solar powered energy is Solarcoin. SolarCoin [12] [7] is a cryptocurrency that is distributed amongst owners of solar panels. The goal of the creators of the coin is to incentivize generating renewable energy and to that end, they give 1 SolarCoin to people for every MWh that they produce with their solar panels. In Amsterdam, a pilot project [1] was initiated by a collaboration between De Ceuvel, Alliander and Spectral. In this project, locally produced renewable energy is distributed in a community supported by blockchain technology. Participants of the system can trade energy from peer to peer and handle transactions via a cryptocurrency. These examples show that companies are actively searching for blockchain technology applications in redesigning energy infrastructures. To make potential participants in such a complex system more aware of the benefits of DLT, an interactive simulation tool could educate them. Moreover, together with the participants, new use cases could be discovered in a interactive, engaging manner. In this way, within a company (such as Accenture), knowledge can be created about how a new technology (such as blockchain) can be in complex existing ecosystems.

2.3 STAKEHOLDERS

Employees at Accenture Employees in Accenture see value in a tool where blockchain technology is understood and discovered to be able to have fruitful discussions about new applications at clients of Accenture. The participants that use the tool are only learning something if the tool is realistic and has a good balance between complexity and simplicity [23]. Blockchain focus groups are present in the company but do not have a tool to explore the full potential of blockchain technology, which entails communicating and educating about blockchain technology. They are missing an interactive simulation tool to discover future potential scenarios with new technologies. Currently, a business-as-usual way of acquiring new business is to look at the market together with the client and see how new systems can be designed by Accenture and implemented at the company. But a tool to explore new technologies and how they can be applied in businesses is missing. With the current body of academic literature, a tool can be designed to educate employees and potential clients about DLT. Insights will be created and new designs of complex systems will be discovered during the session. With this tool, Accenture can show competencies in its ability to think of new complex systems, implementing technologies and leading innovation.

Potential clients The clients of Accenture that are operating in energy industries are eager to know what blockchain technology can add to their business. Decentralized organization of technology is gaining popularity and businesses need to react to this development. With the tool, they can learn how DLT can be adding value to their business and learn how Accenture can facilitate the implementation of the project. This group of potential clients can consist of grid operators that want to discover how blockchain technology can disrupt their business. These groups of potential clients must play the game and must be willing to play the game. Their feedback on the game is valuable for the project to improve the overall output of the project. The desires of the participants of the game will have to be collected prior to the design of the game. Companies such as Alliander and Enexis have to think of strategies to incorporate DERs into their infrastructure systems, so playing a serious game about the subject of increasing DERs can help them think about strategies.

2.4 PROBLEM OWNER

The problem owner in this project is Accenture, their mission is as stated in their "Code of Business Ethics": Our mission is to help our clients become high-performance business and governments. We seek to understand our clients expectations and strive to meet or exceed them. We collaborate with our clients to shape exceptional opportunities of value that can be predicted, measured and repeated.

Accenture is a company that strives to bring out the best in technological capabilities and innovation within their clients. To that end they create solutions that make companies better performing entities with the newest technology. To be able to accomplish these goals, Accenture needs to be able to communicate the competencies they have in their business. A presentation or a pitch can be a way of communicating this information but it is only information going one way.

Within the company there are multiple initiatives that aim to incorporate blockchain into the competencies of the company. These initiatives organize informational sessions where DLT is explained, but not further elaborated upon to discover new use cases.

2.5 PROBLEM STATEMENT

As was said in the background section, the technology blockchain is hyped and companies want to know what they can do with the technology. As Gartner states [6]: *Blockchain concepts are extremely hyped given their embryonic status, but ignorance is dangerous. Maturity will usher in dramatic and sudden changes, radically reshaping economic systems, institutions and societal models that have existed for hundreds of years. Scenario planning is essential.* To be able to see what applications are suitable for a company's industry, awareness and understanding of DLT is crucial. Blockchain technology has potential is many industries as can be seen in the previous section, but to understand the technology is something that few companies have mastered.

In the preamble of this project, blockchain technology was being hyped [6] and companies were eager to learn what blockchain technology could mean for their business. However, *companies are lacking a tool that facilitates an educational session where they can discover and understand a new technology, such as blockchain*. This is why the following problem statement was formulated:

Companies are lacking a tool that facilitates an educational session where they can discover and understand a new technology, such as blockchain

3

METHODOLOGY

In this chapter the methodology that is used in this project will be discussed. An artifact is designed in this project and thus to well-quoted books an design science will be used as a reference to establish a methodology.

3.1 DESIGN SCIENCE

Hevner [10] argues that design science research is motivated by the desire to improve the environment by the introduction of new and innovative artifacts and processes for building these artifacts. When looking at another design science book by Wieringa [29], the motivation stated is: "design science research is curiosity-driven and fun-driven research". The motivation of this project is to increase awareness and understanding of DLT in distributed energy systems. In literature DLT systems are described where a more sustainable electricity supply is realized, which improves the environment by introducing a new artifact. In the article of Hevner design science is embodied as three closely related cycles of activities which are shown in figure 1. These cycles interact with each other and provide inputs to each other.

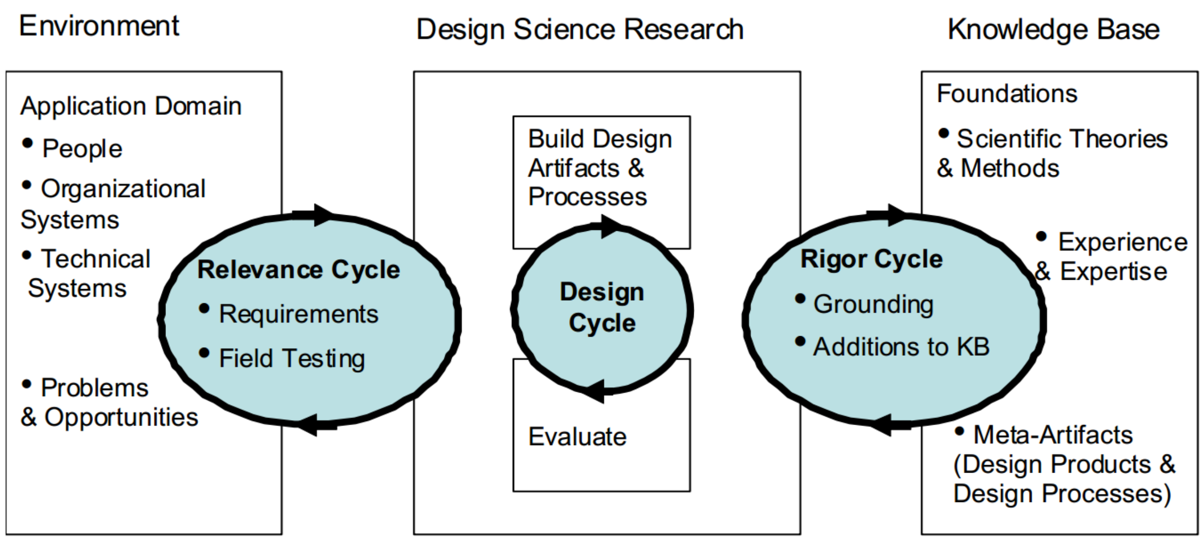

Figure 1.: Design Science Research Cycles by Hevner

In figure 1 the three cycles from the article by Hevner are shown. The relevance cycle provides the requirements and field testing from the environment, where the technical systems and the users of that system are located. The rigor cycles provide the grounding and frameworks from the knowledge base. In the design cycle the artifact is created that must provide a relevant solution to the environment whilst being academically grounded by the knowledge base. In a design project for Industrial Engineering and Management it is the goal to create a project-based design case, which is executed at a company.

3.1.1 *Goal of the project*

To fill the gap of a lacking tool as stated in the problem statement, the goal in this project will be to design a serious game as a tool to facilitate an educational session where participants can discover and understand a new technology, such as blockchain. To be relevant for the academic database, frameworks are used to make it a valid artifact. The frameworks and methods used are described further on in this chapter. Following the background and problem statement, the following goal of the project is formulated:

Design a serious game to increase awareness and understanding of applications of DLT in decentralized energy systems

3.2 RESEARCH QUESTIONS AND SUB-QUESTIONS

The research questions in this project are established to ensure the academic validity of the project. In the sections after the research questions, the frameworks are presented to answer the research questions.

- How to design a serious game that increases awareness and understanding of DLT in distributed energy systems with clients of Accenture?
  - Which concepts of DLT are most critical to show in the game?
  - How to ensure realism in the game, such that the players will be engaged in the game?
  - What kind of rules make the game playable and competitive?
  - How to make the decisions and outputs of the game quantifiable?
  - On what kind of themes can serious gaming provide insights?
  - How to ensure that the results from the simulation are transferable to reality?
  - How to evaluate and validate the game?
- What is the balance between simplicity and complexity in the game to ensure increased awareness and understanding?

With these research questions, a design for a serious game is made and the artifact is created. In the following section the requirements are presented.

3.2.1 *Requirements*

The frameworks that are used are used to pursue three different goals and these are also the criteria by which the design is validated.

- The game must enable understanding and discovery of a new technology in a complex context and increase awareness of the system at hand.

- Organizing the game such that it pursues the goal of knowledge creation.
- Bringing structure in the game design such that the game is balanced in terms of complexity and simplicity. The game should not be too simple, but also not too complex.
- The game should be realistic enough to let the participant of the game to be educational.

At the end of the game, questionnaires are filled in by the participants to check whether the design criteria and learning goals are met. Next to the answers to the questionnaires, the game master obtained encompassing insights that are included in the report. These two sources of information validate the tool that is designed in this project.

3.3 PROPOSED SOLUTION

In this project the goal is to create an artifact, namely: an interactive tool that can be used to communicate, educate and discover new applications of DLT in distributed energy systems. To learn about a new technologies and what kind of applications it could have in an industry or in a certain company, there are various ways to handle such an orientating process. One could give a presentation, promoting the benefits of the application of a technology. However, when in such a presentation jargon is used of which the listening party has no understanding, the presentation loses its value. A way to solve this is to make the presentation interactive and let the participants work with the material that is being discussed. Being engaged enhances the retention of the material and lets the participants understand it better. If you also add a competitive element, so transforming the interactive session into a game, then learning becomes effortless. The artifact that is designed in this project is a serious game that shows an application of DLT in a distributed energy system. The game is designed to let players experience the technology in a practical application so that they understand what the abstract term blockchain can do. Through the game, it is possible to engage the participants of the game and show that Accenture has the competencies and knowledge to implement a technological future with blockchain technology. In the game, the most important aspects of DLT will be shown, to let the participants get familiar with and understand the most important aspects. The complex technological system needs to be mapped entirely, which requires skill and knowledge about the system to be.

3.4 EXISTING LITERATURE

3.4.1 *Serious gaming*

A form of an interactive simulation is serious gaming, where the participants are engaged in the problem at hand and future potential scenarios can be discovered. In serious gaming perspectives of the different participants are shared and together future potential scenarios are discovered.

A serious game can be used for three purposes: knowledge creation, skills improvement or changing behavior (Wenzler, personal communication). In the game that is designed in this project the main goal is to create knowledge about DLT in a distributed energy system. This knowledge might lead to change in behavior as they learn more about the benefits of the technology and improvement in skills as they learn what impacts of the technology to keep in mind while designing a DLT system. The goal here is to create knowledge amongst the players and let them experience and understand the technology applied in a certain environment.

Guided by theory of Csikszentmihalyi [4] about optimal learning when the edge of the comfort zone is continuously sought after, Hamari et al. argue and finds that players of the game learn more when they are more engaged. In designing a serious game, the balance needs to be found between making it too complex and making it too easy. This corresponds to theory of Csikszentmihalyi, that argues that learning is done at a tension level that is between being stressed and being in your comfort zone. To find this balance requires testing and redesign. At a more meta level, Ross et al. [22] review the use of games as educational tools with the specific goal to describe the advantages of game-based media over traditional methods for the purpose of systems engineering education. To design a serious game, one should bring an overview to a complex system to be able to see where the challenge lie that can be tackled by serious gaming. The ultimate challenge in serious gaming is to simplify concepts, while still being able to educate the players and let them think about the complex technological concepts in a thorough manner. To help businesses understand what the potential is of DLT for their business, a serious game can provide insights into possible future scenarios. When a company like Accenture organizes such a gaming session, possible future collaborations can also be established to bring new clients into the firm. New technologies have the potential to disrupt ecosystems that have been in place for decades. However, to persuade decision makers to invest in new technologies is a problem when a technology has not yet been established and matured. When the internet was just being established as a public resource, ideas were brought forth about e-commerce, buying and selling via the internet. At first managers would not believe this and shut down the ideas. But now, e-commerce is estimated to be a $2 trillion-dollar business. To convince management and (potential) users of the new technology, a one-way communication method like a presentation can be insufficient. To engage management and force them to think about and interact with the future system, a serious game is suitable as a way to communicate but also discover new scenarios with the technology.

3.4.2 *Frameworks*

In the academic body of literature frameworks are present that will be used in the design of the serious game.

In the paper by Mayer et al. [13], they establish a methodology for the research and evaluation of serious games. The first step that they describe is to frame the game as to what kind of context of research it has. A game can be a design artifact, a socio-technical design. But also, a research method comparable with simulation or experimentation. The game designed in this project will be a socio-technical design that runs a simulation to educate players and discover new future potential scenarios, so it contains elements of both. Hayes [9] describes a gap in literature in the fact that serious games are mainly assessed in terms of quality of their content and not in terms of their intention-based design. In her paper, elements of a holistic approach for development and evaluation of serious games are described. They include learning objectives, learning outcomes, usability, user experience, motivation, ludus, aesthetics, cost and sustainability. Wenzler provides in a paper [27] a useful framework in the form of dimensions on which a game designer has to make choices. Dr. Wenzler is a professor at the TU Delft and works as a strategy manager at Accenture. He has developed numerous games and extracted generic elements to add to the academic body. The combination of being a professor at a university and an employee at Accenture makes that Ivo Wenzler can help in the process of designing the serious game. Another paper [28] authored by Wenzler is about how to translate the results from the simulation into real-life performance. This will also facilitate designing the game in such a way that the simulated environment is realistic and valuable (e.g. in the form of insights) for the players. Van der Spek [25] describes determinants of a successful serious game and how to assess the learning that has taken place in the game. Von Mammen et al. [26] describe a methodology that can be used in the design of serious games that facilitates creating a structure. Pitt et al. [20] describe twelve tips for maximizing the effectiveness of game-based learning. From these frameworks, the described components of games will be used to design the game in the most complete way. In the design cycle the artifact will be designed and built using established academic knowledge from the rigor cycle as input. The before mentioned frameworks are input to the design process. The output of the design cycle to the rigor cycle is generalized content that can be added to the knowledge base. On the other hand, the relevance cycle, is used as input in the form of requirements from the environment. The output from the design cycle will be testing the game with people that will learn from playing the game.

3.4.3 *Designing a serious game in a company*

After the literature scan and research design are completed, the game design commenced. The first version of the game is a prototype, which is tested by fellow interns at Accenture. Afterwards, the feedback is collected to improve the game. This is an iterative process, as the game is played and improved multiple times. The learning goals are tested to which extent they are achieved. The tool should serve two goals. On the one hand, it improves the understanding of complex systems and technologies. On the other hand, with their obtained understanding of the system, the participants can discover new applications of the complex system at hand. With serious gaming both goals are facilitated. A serious game can be used to educate the participants of the game in an engaging learning experience. The game forces the participants to think about the system at hand and make decisions according to their personal goals. When decisions are made in the game, future potential scenarios emerge from the interactions. These scenarios can be used to design complex systems.

An important aspect that is important to keep in mind while designing the game is to keep the goals of Accenture in mind to also be able to achieve a valuable artifact for their business.

3.4.4 *System description*

In figure 2 the visualization of the system description is shown. The serious game is the artifact in this system that is designed with the aim to solve the problem that is presented in the problem statement. The awareness about DLT applications in industry is aimed to be increased and during the game the players will experience DLT, which increases understanding.

3.4.5 *Inputs*

Accenture Accenture provides the environment where competencies and knowledge are available. These competencies and knowledge are used to design a game that is able to show the workings of distributed ledger technology and let the players understand the technology.
Participants Once the game is designed, the participants in the game will learn about the DLT

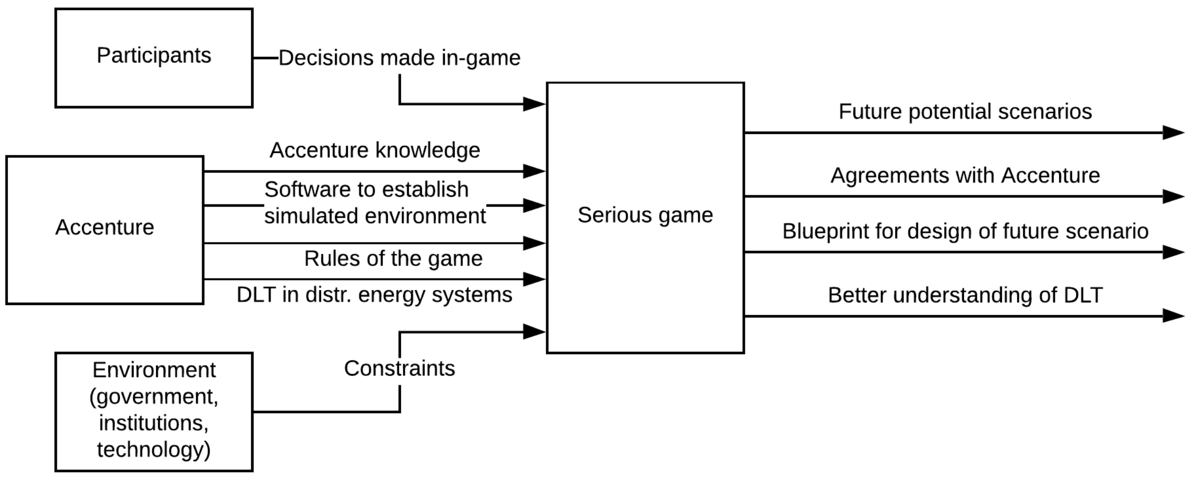

Figure 2.: Visualization of system description

in distributed energy systems that is simulated in the game. During game they will be engaged in the inner workings of the technology. Because of this engagement with the material, they can think of new solutions with the new technology that is presented.
Environment The current environment provides the constraints that are put upon the players in the game. The game will simulate a future environment, where certain constraints (like the cost of solar panels or storage) might be changed. It is important to keep these constraints realistic, to ensure that the players take the game serious.

3.4.6 *Serious game*

The described inputs will be used as input into a interactive simulation tool with a competitive element (serious game). Designing the game will be supported by frameworks from literature described in this chapter. This tool will simulate a gaming environment where the players must make decisions in order to compete with their fellow players. The game will provide a safe environment where decisions can be made with no (real-life) consequences, this enables the discovery of future potential scenarios and understanding of the potential of the new technology that is presented. The goal of the game will be to educate the participants of the game about DLT in a distributed energy system. Next to that with the obtained knowledge the participants can think about wide applications of the new technology in industry.

3.4.7 *Outputs*

Outputs of the game will be:

- Future potential scenarios: the decisions made in the game can be translated into real-life implementations of the new technology.
- Agreements with Accenture: during the game, Accenture shows her competencies and knowledge in the new technology. The potential client that plays the game can make agreements with Accenture to implement a system with the new technology.

- Blueprint for design: the simulated system should be as realistic as possible to provide a simulated environment where decisions seem realistic to implement. The decisions can then be used as a blueprint to implement the scenario that has been played out in the game.
- Better understanding: the participants will better understand the system and the perspectives of the other participants.

Research-oriented games

To design the game, the frameworks described in the section 'Frameworks' will be used to ensure that validated structure are used. The framework described by Mayer et al. [13] will be used, where useful steps are described when it comes to designing the game. Critical questions can be asked during the design of the and afterwards via questionnaires to the participants of the game. The elements of the frameworks will be implemented into the game and in the questionnaire afterwards, the participants of the game will be asked whether they have experienced these elements are present and where improvement is needed. This feedback will be then be used to improve the game and that what makes this method an iterative process where the game is continuously improved.

To design the game, the steps described by Mayer et al. are used:

- Framing; what am I going to use the game for?
- Foundations and requirements; how to evaluate whether the game is successful?
- Conceptual framework; how to evaluate whether learning has been done?
- Quasi-experimental research design; what kind of questions are asked post-game.
- Contextualization; how to gather data from the game, quantify decisions
- Defining questions and hypotheses; what is the goal of the game?
- Operationalization; how to organize the game?
- Data reduction and analysis; how to collect and process the collected data?

Designing the game with a goal

Wenzler [27] provides a list (figure 3) of components that define the characteristics of the game. The list of components lets the designer of a game critically think about aspects like what kind of problem is being solved, what is the goal of the game, is the game played in rounds and does the game take place in multiple locations? In appendix A.2 a general elaboration on each dimension can be found. In chapter 5 each of the ranges of the characteristics will be defined for the game that is designed in this project.

When frameworks like the ones by Mayer et al. and Wenzler are used to design a game, the questionnaires afterwards check whether the frameworks have been implemented correctly.

Simulation components	Simulation dimensions	Range of characteristics (mutations) for each dimension	
A. Context	Problem	understood	ambiguous
	Objective	knowledge transfer	knowledge creation
	Model	qualitative	quantitative
	Story	reality based	metaphor based
B. Players	Target	single individual	multiple groups
	Level	operational	executive
	Roles	own (real-life)	somebody else's (assumed)
	Culture	homogeneous	heterogeneous
C. Process	Sequence	real time	concentrated
	Interaction	directive	self organizing
	Steps	sequential	iterative
	Indicators	qualitative	quantitative
D. Environment	Location	single	multiple
	Place	physical	virtual (IT-based)
	Material	static	evolving (transformable)
	Representation	realistic	symbolic

Figure 3.: Wenzer (2008): components of a game and the dimensions therein

Balancing the game

Another source that is used to be able to ask critical questions about the game, is the book 'The Art of Game Design' [23] by Jesse Schell. This author has designed hundreds of games and knows how to make a solid game experience. The book described the 'elemental tetrad' that allows a game designer to categorize and bring balance to the components of a game.

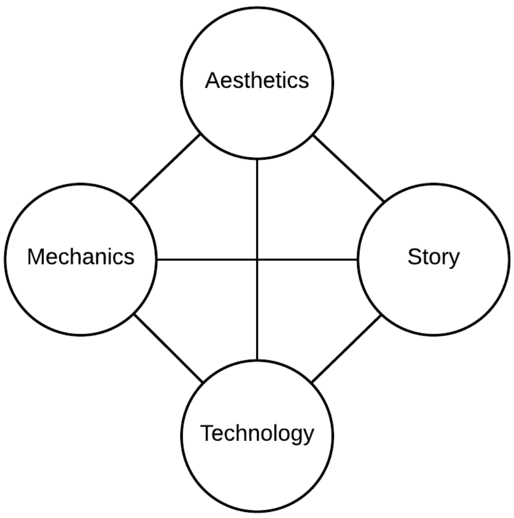

Figure 4.: Elemental tetrad by Jesse Schell

In figure 4 the tetrad by Jesse Schell is shown with its categorization of components. The aesthetics involve how the game looks, sounds, smells, tastes, and feels. Aesthetics are of great importance because they have the most direct relationship to a player's experience. Mechanics are about the procedures and the rules of the game. They describe the goal of the game, how players can and cannot try to achieve it, and what happens if they try. Story involves the sequence of events that unfolds in your game. It can be linear and pre-scripted, or it may be branching and emergent. The technology is what facilitates the game play. It involves the material and interactions that make your game possible. The technology enables certain possibilities in the game and limits other. These categories of components amplify and supplement each other. In the chapter about the game design, first the frameworks of Mayer et al. and Wenzler will be described. After that, the categories of components of Schell will be used to bring more structure to the report.

3.5 PLANNING

Planned activities

- Analyze current situation, what is the knowledge level of the companies currently about DLT in distributed energy systems?
- Study the distributed energy system case, where can DLT be of most value?
- Design the game, the artifact that is designed is the most important output of the project.
  - Use framework by Wenzler [27] to identify characteristics of the game.
  - Use framework by Mayer et al. [13] for designing the game.
    - framing
    - foundations and requirements
    - conceptual framework
    - quasi-experimental research design
    - contextualization
    - research questions and hypothesis
    - operationalization
    - data reduction and analysis
  - Use the book by Jesse Schell [23], asking critical and iterative questions about the design of the game.
  - Do a test run with the game to receive early feedback. A gaming session with interns is organized to see how the game performs in educating the participants. Collect feedback and answers to questionnaires.
  - Improve the game, keeping in mind the used frameworks
  - Second test run with Accenture employees. Collect feedback and answers to questionnaires.
  - Improve the game.
  - Final test run of the game. Collect feedback and answers to questionnaires.
- Write report (also done during rest of project)

Milestones:

- Research Design and Project Planning due: 22-03-2018
- Mid-term Report due: 01-05-2018
- Draft final report due: 18-06-2018
- Final Report due: 01-07-2018
- Final presentation: t.b.d.

3.6 GANTT CHART

In the Gantt chart a visualization is shown where the planning of the different activities are planned. The planning shows is that the game is played three times and thus improved twice.

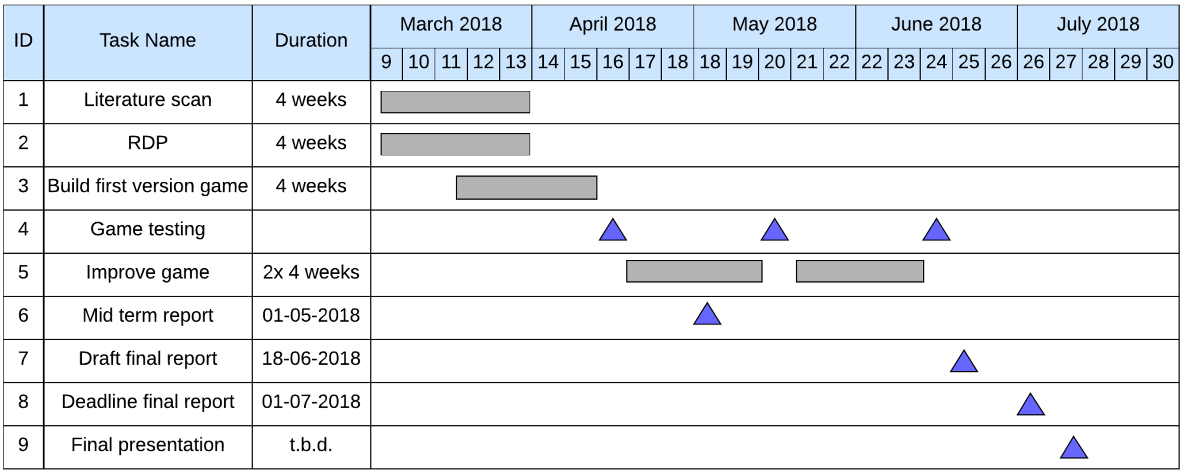

Figure 5.: Project planning visualized in a Gantt chart

4

SOCIETAL RELEVANCE

In this chapter the social and technological context of the project will be described.

4.1 ENERGY TRANSITION

In the industrialized world we live in today, 86.7% of the global energy supply is fueled by fossil sources [2]. These sources are not available until infinity and the need to change to renewable energy is becoming clearer because of climate change [5]. The government is setting goals [1] to obtain higher shares of renewable energy in the energy mix of the Netherlands. The goal in the nearest future is to have a renewable energy share of 14% in the energy mix in 2020. Next, in 2023 the share should be 16%. Lastly, in 2050, the energy supply should be completely renewable.

4.1.1 *Measures from government*

Examples of measures that are taken by the government to promote renewable energy resources are 'Garantie van Oorsprong'[2] (guarantee of origin) and net-metering[3]. The first measure gives out certificates of origin where the energy is produced, such that an entity can show that there is green energy consumption. However, these certificates can also be decoupled, such that the green energy is consumed in one place and the certificate is sold to another party to indirectly stimulate renewable energy. This is when i.e. a municipality wants to greenify its energy consumption, which indirectly stimulates renewable electricity production. These guarantees can even be bought outside the country where the energy is consumed, which causes even more decoupling. In Norway, there are many pumped-hydro-storage installations, which produce large amounts of renewable energy. Because of the large supply of renewable energy, the prices of the certificates are low. Companies in the Netherlands can buy these certificates to be able to say that they use green energy, while in fact they do not actually use green energy. Next to that, there is net-metering for households, which entails that solar generated electricity is put back on the grid, the same price is received for which consumption is paid. However, this regulation is only until 2023, when the energy price [4] received is lowered from € 0.22 to around € 0.04 per kWh. With or without net metering, when a solar panel owner produces more solar electricity with the solar panels, the selling price of that surplus electricity is already drastically lower than the price that is paid for consumed electricity. When the selling price of produced electricity with solar panels is so low, the in-

1 https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/meer-duurzame-energie-in-de-toekomst
2 https://wisenederland.nl/groene-stroom/faqs-garanties-van-oorsprong-gvos
3 https://www.consuwijzer.nl/energie/duurzame-energie/teruglevering/wat-is-salderen
4 https://www.zonnepanelen.net/salderen/

vestment in extra solar panels to provide more renewable electricity, becomes economically less attractive. This attractiveness is an element that is researched in the game, with which set of rules is investing in solar attractive for households and how can the government anticipate on this. The share of renewable energy has increased from 12,5% in 2016 to 13,6% in 2017 [5].

4.1.2 *Flexibility*

With rising popularity of renewable energy resources, the intermittent nature of those energy sources becomes more challenging. Because the sun does not shine constantly and the wind does not blow constantly, renewable electricity from these sources cannot be called upon on demand. These renewable sources are not flexible in when they can be started and shut down, while flexibility is something that is quite valuable to utility companies. To guarantee a stable electricity supply, one should have a reliable energy source that is available when needed. However, in renewable energy sources, there is a dependency on i.e. the wind or the sun. Thus, to solely power a country with these sources is an enormous challenge. A solution could be to store electricity that is produced, to use it at a later time.

In general, electricity storage systems in the electricity sectors are currently used in three main segments according to an IRENA report [21]: First, grid services, where electricity storage systems offer solutions with their fast response, quick deployment time and unmatched scalability for system services (e.g. frequency control) that are needed to cope with increasing intermittency caused by distributed energy sources. Second, behind-the-meter applications are used for local self-consumption of decentralized generation. With this solution the amount of power obtained from the grid can be lowered. Thirdly, off-grid applications offer access to electricity to people that normally would not have access in rural areas. The second segment is the most relevant in this project (because of the decentralized nature of production), but the IRENA report states that in this segment storage is not economically profitable (yet). With storage and solar technology improving and the investment costs decreasing, this combination of producing solar power and storing it can thus become increasingly interesting economically.

4.1.3 *Legal aspects*

On August 1st, 2007, a law was put into practice about the parting of the businesses of grid operators and producers of energy[6]. This law states that management and ownership of the grid and delivery of energy (electricity and gas) should be accommodated by separate enterprises. This law prevents grid operators to take on the business of producing or trading energy. Between the announcement of this law and the implementation, the government experienced resistance from the companies that disagreed with the law. Utility companies like Eneco and Essent even sued the state against this announced law and the judgment was in their favor initially. But the state appealed and there was cassation. This gave energy companies until January 2011 to part business in grid management and delivery of energy.

Now that distributed energy resources are gaining in popularity, also the stability of the grid is being challenged[3]. A solution suggested by Basak et al. is to work with microgrids to provide higher dependability of service, better quality of power supply, and better efficiency of energy use. But to enable the implementation of a microgrid, the grid operator should agree

5 https://www.cbs.nl/nl-nl/nieuws/2018/09/meer-stroom-uit-wind-en-zon
6 https://www.nrc.nl/nieuws/2004/04/27/splitsen-energiebedrijven-is-gezond-7683847-a1132017

with your plans. However, this is not allowed and a grid operator would rather implement such a system themselves, but as soon as they extract energy from a battery, they are a producer and that is now allowed. Another party that could have influence in this situation and that is allowed to be a producer is the utility company, but they would rather keep production centrally organized because of economies of scale. This is how the progression of microgrids is decelerated.

A solution to this problem is to have a group of consumers and producers behind one meter, such that legally it would be considered as one household. In this community the electricity can be exchanged among the community members, but the utility and grid operator would only register the net inflow/outflow of energy from the community. This is how the legal problem is solved in 'De Ceuvel', which was introduced in the background chapter. This way of organizing the electricity infrastructure incentivizes sharing electricity and investing in renewable electricity and is thus used in this project.

4.2 SERIOUS GAMING AS A TOOL TO DISCOVER AND UNDERSTAND

These themes that are presented in this chapter are subjects that are valuable to explore in a serious game. During a game, the players can experience varying regimes under which they have to operate and see how it affects their business. A game allows for though experiments about to for example accelerate the energy transition with certain combinations of technologies, but also how the government should adapt legislation to provide an environment that stimulates renewable energy production and consumption.

5

GAME DESIGN

5.1 BUILDING UPON GIANTS

The first step into designing a serious game is to look at frameworks in literature, which are discussed in chapter 3. In this section, two frameworks will be used to design the serious game. Via Accenture, conversations were held with dr. Ivo Wenzler from the TU Delft, which provided me with insights and frameworks to structure the designing of the game. Next to that, another framework by Mayer et al. (where Wenzler is co-author) is used.

5.1.1 *Doing research with a serious game with the framework of Mayer et al.*

In the framework by Mayer et al. eight steps are described that are used when designing a game with the purpose of a research method.

Step 1: Framing; what am I going to use the game for?

As mentioned in the methodology chapter, a serious game can be uses for three purposes. The intention of this game is to create knowledge about an application of DLT in distributed energy systems. Thus, the goal is to bring people together to gain knowledge, but also to start a discussion about other (future or new) applications of the technology.

Step 2: Foundations and requirements; how to evaluate whether the game is successful?

After the game is finished, questionnaires are distributed to collect feedback from the players about the game. The aspects that are questioned are based on evaluation criteria that are described by the framework that are studied. Questionnaires when the game is finished

Requirements (Mayer): broad scope, comparative, standardized, specific, flexible, triangulated, multi-leveled, validated, expandable, unobtrusive, fast and non-time consuming, multi-purposed

Step 3: Conceptual framework; how to apply the frameworks that constitute a successful serious game

In the frameworks that are discussed, critical questions are asked concerning the game design. This helps making the game as complete and educational as possible. The frameworks help bring structure and consistency to the game that is designed.

Step 4: Quasi-experimental research design; what kind of questions are asked post-game

This step is about how the research is organized. The gaming sessions will be used to create knowledge and is evaluated by the players afterwards.

Step 5: Contextualization; how to gather data from the game, quantify decisions

The game is played in an Excel spreadsheet, which records all the decisions that are made in the game. Furthermore, the discussion and insights gained are collected afterwards, but also during the game by the game master.

Step 6: Defining questions and hypotheses; what is the goal of the game?
The goal of the game is to increase awareness and understanding of an application of DLT in a distributed energy system.
Step 7: Operationalization; how to organize the game?
The organization of the game will be described in the sections after the research-oriented frameworks.
Step 8: Data reduction and analysis; how to collect and process the collected data?
Throughout the sessions, generalizations can be drawn from the separate gaming sessions. These generalizations are insights gathered from playing the game that are experienced multiple times during the different sessions.

5.1.2 *Defining the components of the game with a framework by Wenzler*

In this section the framework by Wenzler about the characteristics of the components of a serious game are shown in table 1. In the methodology this framework has been discussed as to what it entails. In this section, the table will show how the different components are filled in. The first three columns show the framework, which components are there, which dimensions do these components have and in what kind of range they are expressed. For example, looking at the first dimension; a problem can be understood by the players of the game, where the game is used to solve or deal with the problem. Next to that the problem can be ambiguous, where the game is used to explore the problem to let the problem be understood trough the game. For an explanation on each of the dimension the reader is kindly referred to the methodology. In table 1 an extra column is added with an elaboration on each of the range of characteristics, how it is applied in the game. The choices are made considering the learning goals of the game, the context in which the game is played and by conversing with mr. Wenzler at Accenture.

Table 1.: Components by Wenzler elaborated upon

Simulation components	Simulation dimensions	Range of characteristics for each dimension	Elaboration
A. Context	Problem	Understood - Ambiguous	The problem is low awareness of applications of DLT in distrbuted energy systems
	Objective	Knowledge transfer - Knowledge creation	Knowledge is created about an application of DLT in a distributed energy system
	Model	Qualitative - Quantitative	The game will have qualitative aspects such a investing in DERs and storage and will be supported by quantitative aspects in feedback
	Story	Reality based - Metaphor based	The story in the game will be realistic in the assumptions that are made to support the game
B. Players	Target	Single individual - Multiple groups	There will be two teams competing in the game to reach certain goals that are given to the teams
	Level	Operational - Executive	The roles that are played are households that are responsible for their energy distribution
	Roles	Own (real-life) - Somebody else's (assumed)	Every player will assume their own role (household) with the option to make certain investments
	Culture	Homogeneous - Heterogeneous	The culture of the players will be homogeneous

Table 1.: Continued

Simulation components	Simulation dimensions	Range of characteristics for each dimension	Elaboration
C. Process	Sequence	Real time - Concentrated	Rounds will simulate 6 months of time passing by, which will enable the players to see the long-term consequences of their decisions
	Interaction	Directive - Self organizing	The set of options that each player has is limited.
	Steps	Sequential - Iterative	Rounds will have a pattern in which they are played.
	Indicators	Qualitative - Quantitative	Players will receive quantitative feedback in how their financial situation has improved or deteriorated
D. Environment	Location	Single - Multiple	The emulated environment will be in one place and remain there
	Place	Physical - Virtual (IT-based)	The teams will be situated in a room in which they play on their laptop, but they discuss in person.
	Material	Static - Evolving (transformable)	The artifacts required in the game will not transform, only the price of a certain investment might change.
	Representation	Realistic - Symbolic	The playing pieces will be as realistic as possible and resemble the entity that they represent.

5.2 ELEMENTAL TETRAD: STORY

For every component of the elemental tetrad, the details will be discussed in the following sections.

5.2.1 *Setting the scene*

The game simulates an energy exchanging community that consists out of several households of which some own solar panels. The owners of solar panels produce solar powered electricity which they consume themselves but when they have a surplus, they want to sell it to the grid. The price they get for their produced electricity is not very attractive and does not incentivize investment in extra solar panels. The grid operator has the responsibility to maintain grid stability and provide a reliable power supply. Traditionally, the electricity supply was a one-way stream, but nowadays, distributed energy resources are gaining popularity and solar produced electricity puts power back on the grid. This creates instability on the grid and is a challenge for grid operators.

The game is played with varying legislation regimes: the first regime is the current real-world situation with limited selling prices for produced electricity to the grid and increasing instability of the grid due to DERs. In the second regime blockchain is introduced which enables an energy exchanging community. Peer-to-peer trading, smart contracts and transparency are introduced. In both regimes, households have the option to invest in solar panels and electricity storage units. In the first regime, the households with solar panels consume their own produced electricity and they want to sell their surplus to the utility company. However, they receive a very low fee for every kWh they want to sell. Thus, investing in a collection of solar panels that has a capacity that is higher than your own consumption is not attractive in this way. The attractiveness of (extra) storage is linked to the consumption of the households and to the capacity of the solar panels. The higher the consumption of the household, the higher the capacity needed to provide this demand. On the other hand, if there is a higher capacity of solar panels, the storage capacity needed to store this energy is also higher.

When the second regime kicks in, the ability to sell energy to neighbors is given to the households that own solar panels. A solar panel owner can then sell its surplus to neighbors and realize a better price than selling it to the grid. This incentivizes investment in extra solar panels in the energy exchanging community. The equilibrium of such a community would be when there are enough solar panels to be self-sufficient within the community. If more solar panels are bought, the surplus would be sold to the normal grid and only low a fee per kWh will be realized. In this case storage can increase attractiveness of investing in solar again by providing capacity to store the surplus that was otherwise sold to the grid.

The instability that arises with the increasing popularity of DERs will also be diminished by establishing such a community. Within the community the frequency and load of the network will be managed separately from the normal grid. This enables further an increasing number of DERs, while maintaining stability. When the self-sufficiency of the community increases, the distance that power has to travel before it can be consumed also decreases significantly.

The game thus shows the possibilities of DLT in distributed energy systems and increases awareness of the benefits of the applications. The game is designed to show the difference of the situation ex-ante and ex-post blockchain implementation. Players will notice that the price they are able to sell their energy for is much higher than before. The payback period of the investment in solar panels decreases significantly and investing in more solar power capacity is there for incentivized.

There is a difference in how this is organized between versions of the game. The first version of the game has two phases, where the first phase has net-metering enabled and the second phase of the game has blockchain enabled. From the second version of the game onwards, there are three phases. In phase one, net-metering is enabled and producers of electricity get the same price for their production (up to a certain amount) as for their consumed electricity. In the second phase, both net-metering and blockchain are disabled. The participants of the game will then see what kind of influence the regimes have when they are both disabled. Finally, in the third phase, blockchain is enabled and they can exchange electricity among the members of the community.

5.3 ELEMENTAL TETRAD: MECHANICS

5.3.1 *Roles*

The roles in the game are categorized as minimally needed to make the game meaningful and as automated players. The last category means that during the game these entities will appear to make decisions, but are not made by a player of the game, hence the categorization 'automated'.

Human players:

- Households

Automated players:

- Government
- Utility

5.3.2 *Physical game elements*

The game will take place in a room where every player has a laptop to interact with the simulated environment. They each have a separate table with their laptop to make computations about the decisions they want to make. The game will also include a geographical location where all players can see what kind of physical assets are in the simulated environment. This can be a physical game board but also a digital interface where people can return to and see how they are doing.

5.3.3 *Goals*

- Households
  - Realize the lowest payback period possible for your investments
  - Be as self-sufficient with electricity as possible

5.3.4 *Main activities players*

First phase (without blockchain):

- Households selling electricity to utility for a low price.
- Households buying solar panels to meet renewable energy goal, but having trouble with payback time of investment.

Second phase: In this phase the players are presented with more options to choose from.

- Smart contracts
  - Decide whether your preference is to sell energy when electricity price is high or sell it as soon as it is produced. The player is given a choice to give a preference to 'help the community' or to 'maximize profits'. The consequence of this choice is a lower or higher electricity selling price, respectively.
- Peer-to-peer trading
  - Selling your produced electricity to your neighbors for a higher price than you could realize in the first phase.
- Transparency in transactions of currency and energy

5.3.5 *Decisions per player*

- Invest in solar panels
- Preference for selling electricity to maximize profits or in favor of the community
- Invest in storage

5.3.6 *Costs*

Electricity price

In table 2 the costs for electricity selling and purchasing are shown. The prices are based on sources from utility companies and other sources that involve the selling or installation of solar panels. The sources are shown under the table.

Investment costs

In table 2 the costs of various products in the game are shown. The energy price varies for the different situations. In the initial situation without exchange within a community, the price that a household pays per kWh is €0,22. When a households produces less than it consumes, it will turn back the meter, so in effect the households receives €0,22 for its produced electricity. However, once the household produces more than it consumes, it wants to sell the surplus to the utility (which is the only possibility in the initial situation) and it will receive €0,03 per kWh.

When the community is enabled, each household has the choice to help the community (i.e. other households pay less for electricity) or to maximize profits (sell electricity for the highest price possible, where the price are €0,15 and €0,19, respectively.

It is impossible to predict how the costs of the investments exactly will change in the future. That is why each round, after decisions are made, the player that has made the most money in the previous round can draw a card, which will state a percentage drop in investment costs.

Table 2.: Costs of products in-game

	Product	Initial Price	Quantity	Capacity
Investments	Solar panel	€ 247,20[1]	1 unit installed	350 kWh[1]*
	Tesla Powerwall	€ 7.060,00[2]	1 unit installed	14 kWh[2]
Energy price	Normal consumption price	€ 0,22[3]	1 kWh	n/a
	Selling surplus to utility	€ 0,03[3]	1 kWh	n/a
	Helping community	€ 0,15[3]	1 kWh	n/a
	Maximize profits	€ 0,19[3]	1 kWh	n/a

*solar panels are assumed to produce 350 kWh per round (6 months)

The percentage drops can be either 15%,25% or 40%, which has a significant impact on how attractive the technologies are to invest in the setting of an energy exchanging community.

This will simulate technological advances in solar[1] and electrical storage[2] technologies, which are expected to decrease in the coming 2-6 years. The electricity prices[3] are assumed to remain around these prices (not decrease or increase as the investments) during the game.

5.3.7 *Learning objectives*

- Understanding how blockchain technology can be applied in distributed energy systems and what kind of features it has and how it can work for your personal situation.
- Discover how blockchain technology can be applied in industries.
- Increase awareness of a sustainable ecosystem with distributed ledger technology.
- Discover solutions for issues that are discovered during the gaming session (such as Bitcoin calculations consume large amounts of electricity).
  - Smart contracts: Issue payments between producers/consumers, decentralizing energy sector. Opening the market for competition
  - Peer-to-peer trading: disintermediating
  - Transparency in transactions
  - Realization of micro grid
  - Renewable certificates
- Benefits decentralized electricity infrastructure.

5.3.8 *Self-consumption*

In the game, some households own solar panels and other solely consume. The households have a electricity consumption that is not constant and a solar electricity supply that is also not constant. The amount of electricity that can be consumed which is produced by solar panels of a certain household is low. This is because when the sun shines, it is not said that

1 https://www.zonnepanelen-weetjes.be/zonnepanelen-prijs/
2 https://www.tesla.com/powerwall
3 https://www.energieleveranciers.nl/zonnepanelen/terugleververgoeding-zonnepanelen

the household also has a demand for electricity. This is why the percentage that a household can consume of its own production is set to 60%. To increase this percentage, one would have to align their demand to their supply with demand-response. An example of demand response is where appliances are turned on once there is a supply of solar electricity. However, this function is not embedded into the game, but players can invest in a Tesla Powerwall. This electricity storage device can store the solar electricity to consume later. With the first Powerwall, the self-consumption percentage is increased from 60% to 84% and if one were to buy another Powerwall, the percentage would increase to 94%[4 5].

5.3.9 *Initial situation of game*

The players are assigned to teams of 4, where every team resembles a community which has 4 households. Some of these households will already own solar panels (prosumers), but some will also be consumption-only households (consumers). Each team represents a neighborhood and contains at least one household that owns solar panels. In the next section, the two phases will be described in how they differ.

Phase 1: The households that own solar panels produce electricity that they consume themselves when they need it. When they produce more electricity than they need for consumption they can sell it back to the grid, but the price they get is not high. This does not incentivize the investment in more solar panels because more production means more electricity sold for a low price. It can also occur that subsidies are removed from buying solar panels, which further lowers the incentive to invest in solar panels.

Phase 2: When blockchain technology is enabled in the community, the households can now exchange energy with their neighbors. With the technology set in place, the community can operate their energy exchange independently from the grid. They might draw from the normal grid when they have a shortage or sell electricity when they have a surplus, but the goal is to be self-sufficient. The participants can make investments in more solar panels and/or electrical storage to further build the green energy supply within the community.

5.3.10 *Rounds*

In a round the simulated environment is paused and participants can make decisions. After a certain time limit, they cannot make any moves anymore and then a period of 6 months elapses. The participants can see what the consequences of their decisions in the game are.

5.4 ELEMENTAL TETRAD: AESTHETICS

The gaming session must provide clear feedback to the players that provide enough information to make decisions in the game.

5.4.1 *Software in session 1*

In figure 16 and 17 the main display and the individual player display are shown. The main display is shown on a big central display during the gaming session. On this main display,

4 http://euanmearns.com/will-solar-panels-and-tesla-powerwalls-meet-your-homes-energy-needs/
5 https://www.tesla.com/powerwall

visual feedback is given on how each community is doing. Figure 16 shows the main display with consumption, production, surplus, number of solar panels bought, number of Powerwalls bought, how much money was made and what the average electricity price was in each community. On this display both communities could see how they are doing in the competition to be as self-sustainable and make as much profits as possible.

Figure 6.: Central display for all players to see in session 1

The individual display (shown in figure 17) for each players shows more detailed information about their individual production, consumption, money made per round, payback period and how much assets they own. On this display they can make their decisions as to which investments they want to make.

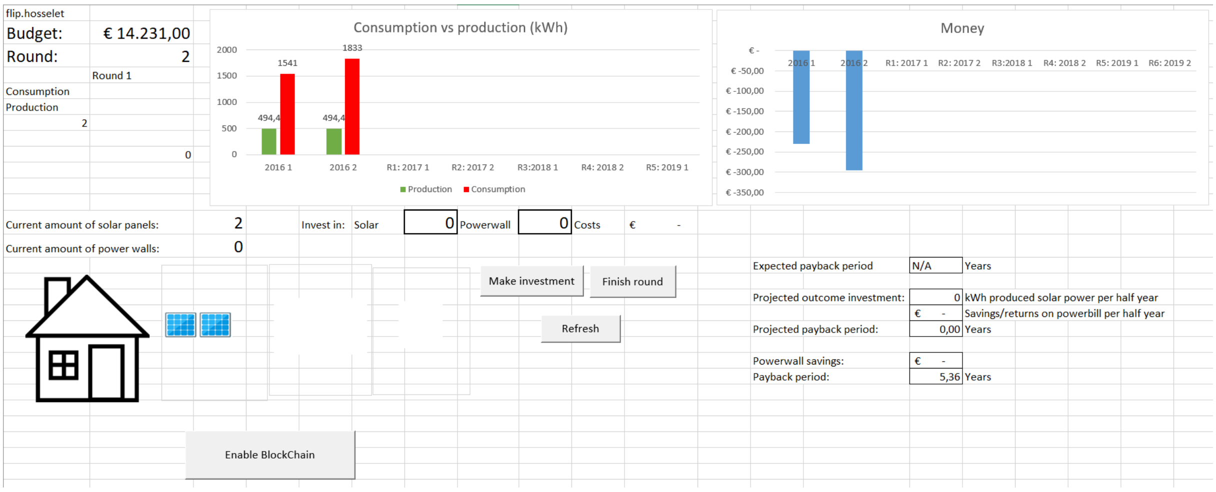

Figure 7.: Display for individual players in session 1

5.4.2 *Software in session 2*

To be able to add features and improvements to the game, the spreadsheet files were built from scratch. This contributed to a more efficient spreadsheet with more functionality. The main display (in figure 8) now shows what the distribution is in the chosen preferences by the players. It also displays what the current investment cost is of the investments. This is relevant because the costs change per round according to the random percentage price drop. Next to that, the choice was made to change the regimes (net-metering and blockchain) during one game, instead of resetting the game and replaying with or without net-metering or blockchain. The main display shows whether net-metering and blockchain is enabled or disabled. Also, another important metric is added: the payback period. In the second version of the game, the emphasis was more on having the payback period as low as possible, as this is also a competing metric between the communities.

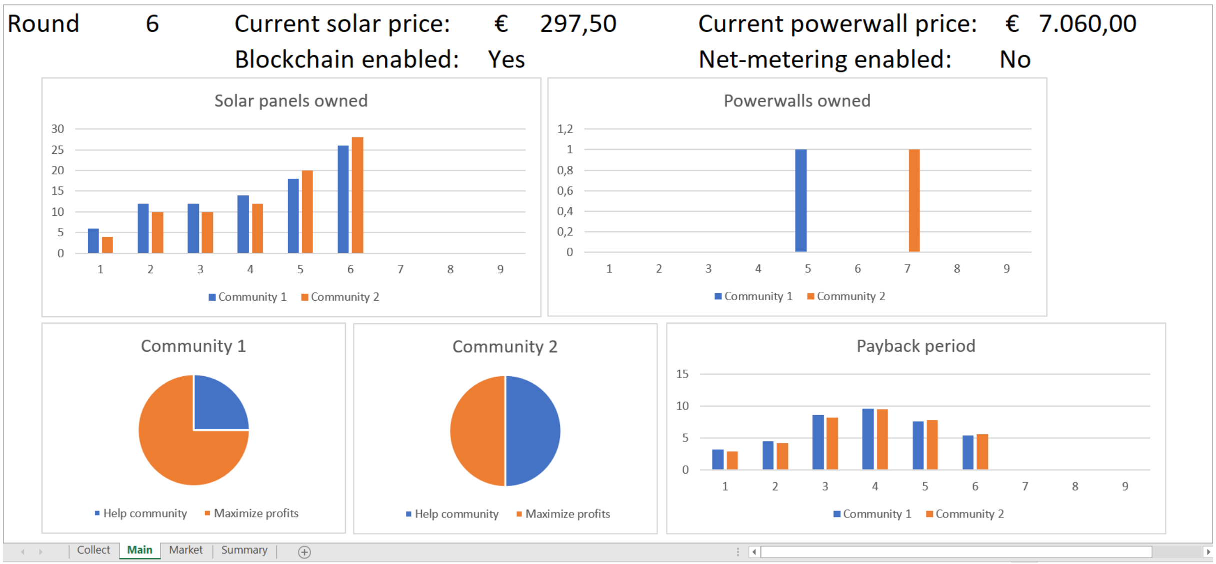

Figure 8.: Central display for all players to see in session 2

In the display for the individual player, a clearer distinction was made between making money with electricity bill savings and selling electricity. Next to that visual information was added to show how much of the production was used for self-consumption and how much electricity was sold to the grid. Another addition that was made was the ability to buy community storage. In this feature the player could together with the community invest in a storage unit of which they could all benefit. In their spreadsheet the payback period was also added in a graph to let players keep track of how their payback period is affected by doing investments and by the changes in rules.

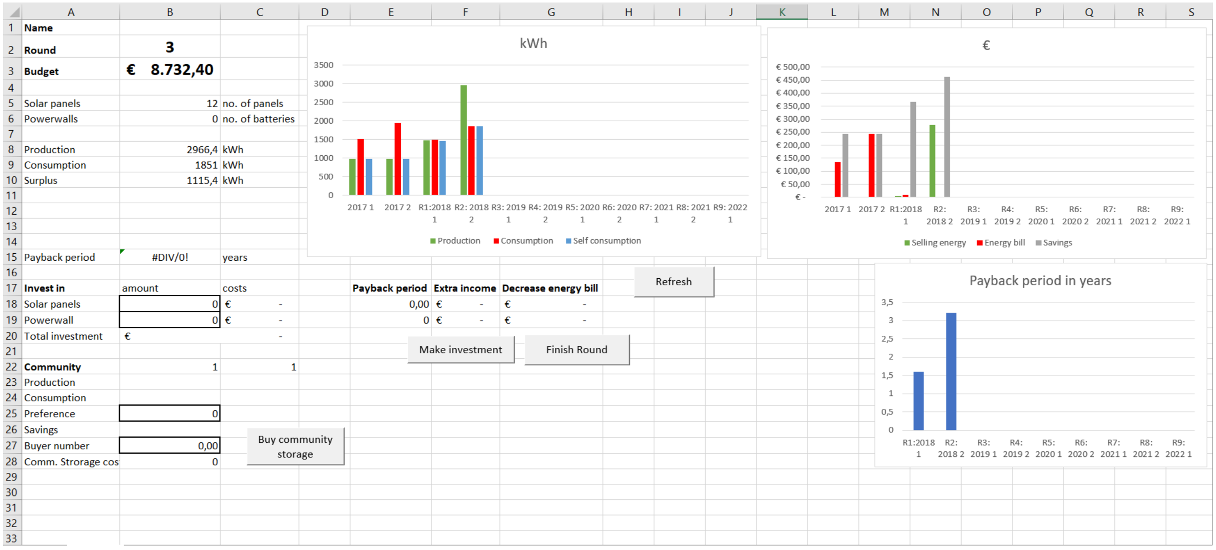

Figure 9.: Display for individual players in session 2

5.5 ELEMENTAL TETRAD: TECHNOLOGY

5.5.1 *Designing the game in versions*

As can be seen in figure 5 of chapter 3, the game will be tested on three occasions. In these occasions, the game is tested for playability, realism, learning goals and overall experience. The participants of the game are asked to fill in questionnaires and through that medium feedback is gathered to improve the game. Moreover, the game session itself provides the game designer of insights about the game by experiencing how the game is played. With these two sources of information the game is improved after every session and additions or alterations to the design of the game are done accordingly.

5.5.2 *Means facilitate the game*

To facilitate the gaming session, software is a useful way to simulate an environment where the game takes place. In the initial versions, the choice is made to use Excel in the combination with Visual Basic for Applications (VBA). This choice of software has aesthetic limitations, but this choice was made in order to have a working prototype fast. Having a prototype fast allows for testing the workings and learning goals of the game. In this project the focus is more on adding academic value (creating knowledge with the game and making the game comprehensive) than making it aesthetically pleasing.

The game will take place in a room with tables and the participants are asked to bring their Accenture laptops to be able to communicate with each other. The players will be placed around the table and asked to open the spreadsheets on their laptop. Before and during the game, presentations will be given about the workings of the game and what the goal is of the game. When there is a change in rules (net-metering or blockchain is enabled or disabled), a presentation will give an explanation about what the consequences are, but playing the game will let the players experience and understand the changes in rules.

The game is facilitated by Excel, which brings forth the need to make simplifications. In the game, a world is simulated, but not the complete world can be simulated. A goal of the game is to show blockchain, but also that is not a holy grail. Blockchain is not a technology that can be a solution for everything, which is also shown in the game. The game shows an application of blockchain in distributed energy systems but also shows that it is nothing more than a shared database and that the consensus mechanism is not the blockchain, but a means to achieve a shared database. The Excel spreadsheet lets the players experience the simulated economic benefits of an energy exchanging community.

In between phases (before and after enabling blockchain) the concepts of blockchain are explained and the players sees how it works and what will change for them. The choice is made to not let the players experience on a deep technical level how a consensus mechanism works and to let the players visually experience how the shared database works. This was considered in the early stages of the game, but in reality, when such an electricity-exchanging community were to be implemented, the users of the system would just want reliable electricity as cheap as possible. Thus, they just want a system that works and they do not want to be bother with the technicalities of the system.

When the game is played, questions can be asked to ask the players whether they can think of new ways to reach a shared database with for example, a new kind of consensus mechanism.

5.5.3 *Software*

The excel file will serve as a interactive tool for the player to make decisions in and see how their decisions impact their economic situation.

Another purpose of the excel file is to capture the decisions that are made and put them in another excel file to be able to analyze the results afterwards. The VBA is programmed in such a way that during the game, each excel file of each player communicated with a central excel file that collect all player data. In this way, the data is centrally stored and enables the ability to analyze the results faster and provide visual feedback to the players as the game is playing out. Also, because the excel files can communicate with each other via the central main file, interaction within the community is possible.

To create a competitive element in the game, visual feedback as to how players are doing is crucial.

5.6 Changes after sessions

So far, the basis of the design of the game has been described in the previous sections. Over time, the game has been adapted to add new features and implement the feedback received after sessions.

5.6.1 *Enabling the new technology*

In the versions after the first version of the game, the change will be made to not reset the whole game after enabling the DLT. The choice in the new versions is made to continue with the same investments that the players have made. Now they will see, once DLT is enabled, the payback period of their investments has dropped significantly.

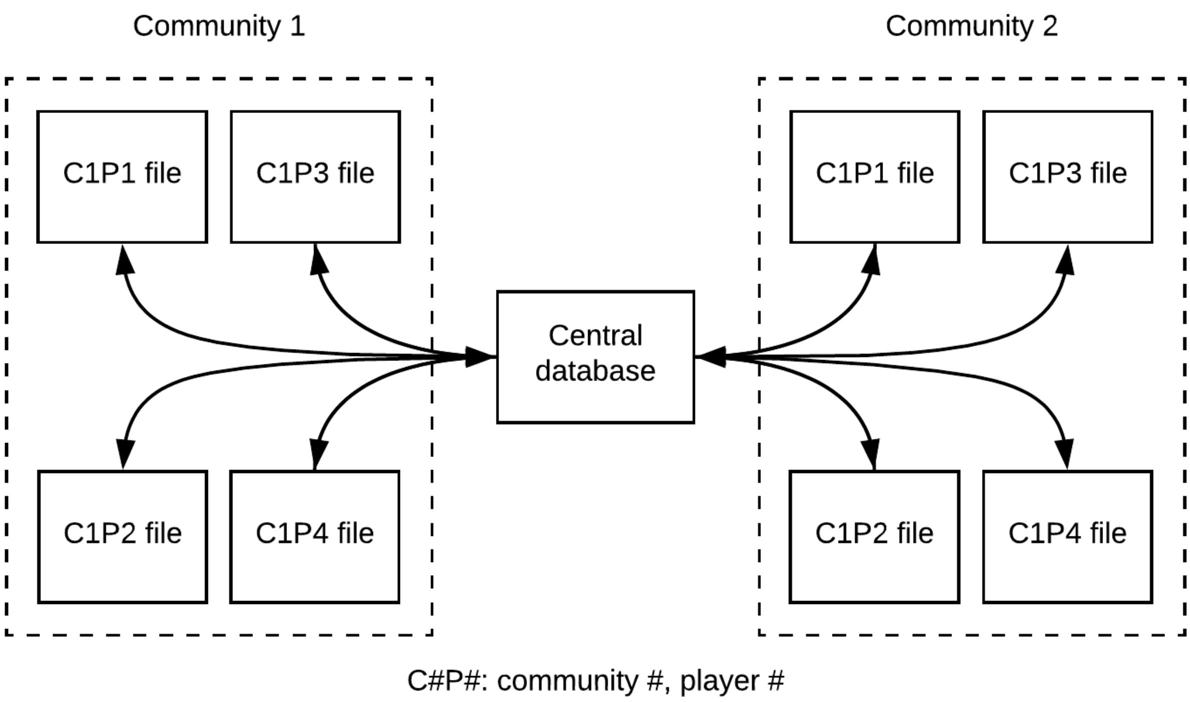

Figure 10.: Software architecture facilitating the game

5.6.2 *Sharing the costs*

In the second version of the game it is possible to share the investments costs of purchasing a Powerwall. In this way all participants in the investment can use the Powerwall. A Powerwall is assumed to have enough capacity to have benefits for all 4 members in the community. This is an assumption, because this is not yet allowed by the government. The 'Wet Onafhankelijk Netbeheer' (WON) states that a grid operator can only take care of the grid and its operations and is not allowed to produce electricity[6]. Even discharging power from a battery is considered as producing electricity, so if one was to exchange electricity with their neighbors from a battery, it would be considered as producing electricity. If a community was able to share a battery, it would be a much more attractive product to invest in, especially in the combination with solar panels. In the second and third version of the game, the assumption is made that the community can share the battery and store and extract energy freely.

5.6.3 *Three phases*

Another important change that was done in this version is that there are three subsequent phases under which the players must make their investments and realize the lowest payback period. Organizing the game in three phases puts an emphasis on the differences between the three phases. The players will experience how net-metering and blockchain influences the payback period for investments such as solar panels and Powerwalls.

- Phase 1: Net-metering enabled, blockchain disabled
- Phase 2: Net-metering disabled, blockchain disabled

6 https://www.fluxenergie.nl/alliander-verkoopt-laadpalentak-allego/

- Phase 3: Net-metering disabled, blockchain enabled

These three phases are enabled in succeeding order, where each phase has different consequences for the players. In phase 1, net-metering is enabled and thus solar panel owners can 'sell' their produced electricity for the same price as they pay for their consumption. In reality what happens is, the meter reverses and if one were to produce exactly the same as is consumed, the energy bill would be zero. As long as production is lower than or equal to consumption, the selling price of electricity is the same as the purchasing price (€ 0,25/kWh). Once a solar panel owner produces more than consumption, the price drops significantly (€ 0,03/kWh).

The second phase disables both net-metering and blockchain. In this phase, all electricity produced is sold for the low price of € 0,03/kWh. When the demand of the producer allows it, they can consume their own produced electricity, but a large portion of the time they must sell it to the grid. They cannot sell their energy to their neighbors, because the infrastructure (and the grid operator) does not allow for organizing your own market place.

In the third phase, the blockchain infrastructure is enabled. This infrastructure allows for exchange of electricity between the members of the community. Within the community, the members can indicate their preference to either 'Maximize profits' or to 'Help community'. When the community manages to have all members indicate 'Help community' as a preference for two rounds, they get a Powerwall of which they can all benefit. In this version, the software also needed to allow for a market mechanism. In this market mechanism, the input was the preference ('Maximize profits' or 'Help community') and the output is the electricity price that the households in the community pay each other for the exchanged electricity.

The assumption is made that the electricity price for which producers can sell their energy in the blockchain phase is € 0.15 per kWh for the preference 'Help community' and € 0.19 per kWh for the preference 'Maximize profits'. The market price is assumed to be fixed as € 0.22 per kWh. These preferences are enforced by the software by tracking how many players pick which preference. Then the weighted average is taken of the different prices (see equation 1).

$$P_i = n_j * H + n_k * L \tag{1}$$

where

P_i price that is paid per kWh for electricity in community i.

n_j number of players that chose 'Maximize profits'

H electricity price per kWh to be paid if every player were to chose 'Maximize profits'

n_k number of players that chose 'Help community'

L electricity price per kWh to be paid if every player were to chose 'Help community'

5.7 QUESTIONNAIRES

The questionnaires provide insights for the research as to how valid the tool is and what experiences the participants have gained. The questions are based on the requirements from section 3.2.1.

Questions that are asked post-game concern:

- Increase awareness and understanding
  - Was the gaming session a suitable tool to initiate a fruitful discussion about the system in the game?
  - Did the game increase awareness and understanding of the application of blockchain in distributed energy systems?
- Meeting the learning goals
  - Which of the three learning goals did the game have (knowledge creation, skills improvement or change behaviour)?
  - What insights did you gain from the gaming session?
- Structure and balance of the game
  - What went good and what could be improved?
  - Were there any unclarities during the game?
- Realism
  - Was the game realistic enough to learn something?
  - What elements could be improved in terms of realism?

6

RESULTS

In this chapter the results will be discussed that are obtained during the gaming sessions. The sessions provide unique insights for the game designer in how the players experience the game. Another output of the game is extracted from the discussion during the game. This discussion can provide insights in how the technology, that is experienced in the game, can develop in future scenarios. Also, critical variables that need to change before mass adaptation will occur can be discovered, such as the price of solar panels of storage capacity. The investment and choices that were made during the game can be found in the appendix. Another important output of the gaming sessions are the answers to the questionnaires that are distributed afterwards. These provide validation for the project as to whether the learning goals are achieved and whether the participants acquired insights. Sections 6.1 to 6.3 provide the discussion about the insights obtained during the game sessions. Section 6.4 discusses the other form of output of the game session, which is the perceived experiences of the players, which also validates the project.

6.1 SESSION 1: APRIL 15TH, 2018

This was the first version of the game that is tested with two fellow interns at Accenture. Both interns are covered by the Resources department within Accenture, moreover, they are both affiliated with energy cases. In this session both the interns represented a community with the goal to produce as much renewable energy as possible and be as self-sustaining as possible.

6.1.1 *Insights obtained*

Costs of technologies

Costs of solar and storage needs to drop to be attractive even in blockchain enabled phase. The costs of storage are currently still at a price that is not attractive for consumer to invest in. As the costs of storage drop, batteries are increasingly becoming an economic option for stationary applications [21]. In this session of the game, the costs of storage decreased by 40% and it became apparent that storage then becomes economically very interesting to invest in. This is because you can consume more of your own produced electricity and sell it when the price is higher.

Interests of community

Choices of the community influence how the system grows. Each player in the community if given a choice to 'help the community' or to 'maximize profits', which changes the electricity price they receive for their produced electricity. If they chose the help the community, then other players could benefit from a lower electricity price or the money that was saved could be invested in a storage unit for the whole community to benefit from.

The game also initiated a discussion about on what level investments should be done. Both solar and storage can both be invested in on an individual level, but also on a community level. Storage can be useful for all community members in terms of offering flexibility in both production and consumption of electricity. Households that own solar panels, but do not own any storage, can store their surplus electricity in the community storage to be consumed later or by others, where in both cases a higher selling price for the electricity is realized then selling it to the utility company.

6.1.2 *Feedback on game*

Showing the difference when blockchain enabled

In this version of the game, the choice was made to play a few rounds without the blockchain enabled in the communities. After a couple of rounds, the players noticed that the payback periods of the investments (in solar and storage) were very long. This fact made making more investments not attractive. After this phase of the game, the game was reset, so players would lose their investments and start over. Blockchain technology was enabled, such that the players could exchange energy with their neighbors. In this way, the difference in e.g. payback period was not immediately visible. A subsequent version will let players make investments without blockchain, subsequently enable blockchain and see how this affects their payback periods.

Realism

The players' opinion about the realism in the game was in general positive, keeping in mind that a game cannot contain all variables and elements from reality. It must be a downsized version of reality to serve a certain purpose. The purpose however was perceived to be achieved, which was increasing the awareness of the benefits of the application of blockchain technology.

Intuitiveness

The first version of the game is made to test the working and rules of the game, so not on how the aesthetics look or how intuitive the tool works. That is also why the feedback was received that the Excel tool could be improved in terms of intuitiveness. In the next version more attention will be put into the aesthetics and intuitiveness.

6.2 SESSION 2: MAY, 17TH, 2018

In this version a phase is added to put emphasis on the difference between the different set of rules in each phase. Also, the investments that are made in the first phase are taken to the next phase. In this way the player can see that the payback period changes significantly between phases.

6.2.1 *Attractiveness investments*

The attractiveness of the investments that a player can make differs per phase because of the changing set of rules for selling electricity.

Phase 1

In phase 1 net-metering is enabled and solar panel owners can 'sell' their electricity to the grid for the same price as they buy electricity. Once the solar panel owner produces more than it consumes, the electricity price decreases to €0.03 per kWh. What the player experiences because of this, is that making an investment in capacity that surpasses your consumption is not attractive. This is because any production capacity above your consumption will provide a low electricity selling price. Investing in a Powerwall will cause the self-consumption of solar panels to go up, because they can store their electricity and consume it later. But at the same time, with net-metering enabled, the electricity that is now consumed by the producer, could have been sold to the grid for the same price. This is what makes a Powerwall not attractive when net-metering is enabled.

Phase 2

In this phase both net-metering and blockchain are disabled. What this means is that when the solar panel owners want to sell their produced electricity, they only get a low selling price of €0.03 per kWh for all produced electricity. They can consume some of it, but most of the time their demand does not fit their production, so they are forced to sell it to the grid. They could invest in a Powerwall, but this is only beneficial in the form of increasing self-consumption, because of savings on the energy bill. Selling electricity to the grid, because it cannot be consumed by the producer self, will not generate much profits. The insight obtained is that the attractiveness strongly depends on legislation from the government with regards to selling electricity back to the grid, the amount of self-consumption and the size of the investment.

Phase 3

In this phase the blockchain system is installed, this is set in place without any installation costs. This assumed, because the goal was to emphasize that blockchain is a technology that is not very visible, but enables changes in organizational structures. The change that is enabled by blockchain is that the players can now exchange electricity within the community. With these extra consumers, the producers of electricity can sell their electricity for between €0.14 and €0.21 (depending on their preference[1]).

In figure 13 the investment behavior of the participants in the game is graphically shown. In round 1 and 2 (phase 1), net-metering is enabled and blockchain disabled. Next, in round 3 and 4 (phase 2), both are disabled and finally, in round 5 and 6 (phase 3) blockchain technology is enabled. In this figure one can see that investments are more pronounced in rounds 1 and 2 and in round 5 and 6. This is because the payback period is lower for those investments in these rounds because the participants can get more from selling their produced electricity. This is an insight that could be interesting for government as to how to organize legislation around buying and selling electricity. Someone that is working on legislation on i.e. subsidies

1 See chapter 5 about what preferences the players can have within a community

on solar panels can see in the game that a blockchain system would incentivize investments in solar panels.

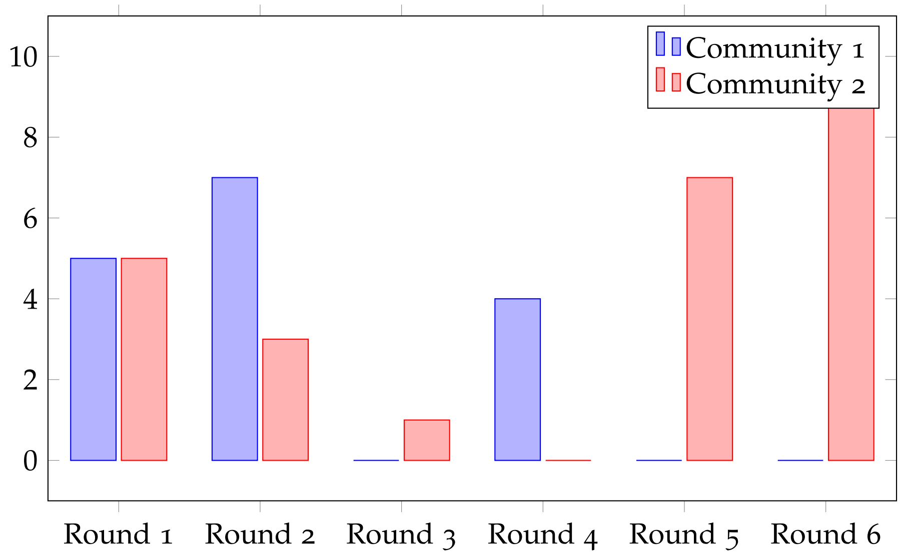

Figure 11.: Solar panels bought per community per round in session 2

6.2.2 *Encompassing insights*

Over the phases different regimes are simulated in the game. During the phases, the attractiveness of the investments changes because of the rules. These rules are realistic as net-metering is a governmental measure that is currently available to solar panel owners, but is being removed in 2020[2]. Moreover, as described in the background section, blockchain projects are enabling electricity exchange in residential areas. In the theme of energy transition and the goal that the Dutch government has imposed on the Netherlands, actions should be taken to increase renewable energy sources as much as possible. The idea in the last phase of the game is that the players can exchange electricity, which is only allowed in reality if the whole community would be behind one meter. However, if a grid operator would install a battery to store solar power and extract it later for consumers, this is not allowed. This is because the grid operator would then become a producer which would be unfair competition because they have an unfair advantage (owning the infrastructure and data) over competitors in this system. This could on the one hand facilitate the energy transition but on the other hand, it would give the grid operator a monopolistic position. The government could change legislation to allow for more electrical storage devices to facilitate more renewable energy production, but should also keep in mind which existing monopolies there are and which can arise.

As can be seen, the game facilitates a discussion about the energy transition on a meta level and lets the players think about complex systems. The players experience the game as realistic and discussions are invoked.

2 https://www.zelfenergieproduceren.nl/nieuws/zonnepanelen-en-salderen-gebeurt-er-2020/

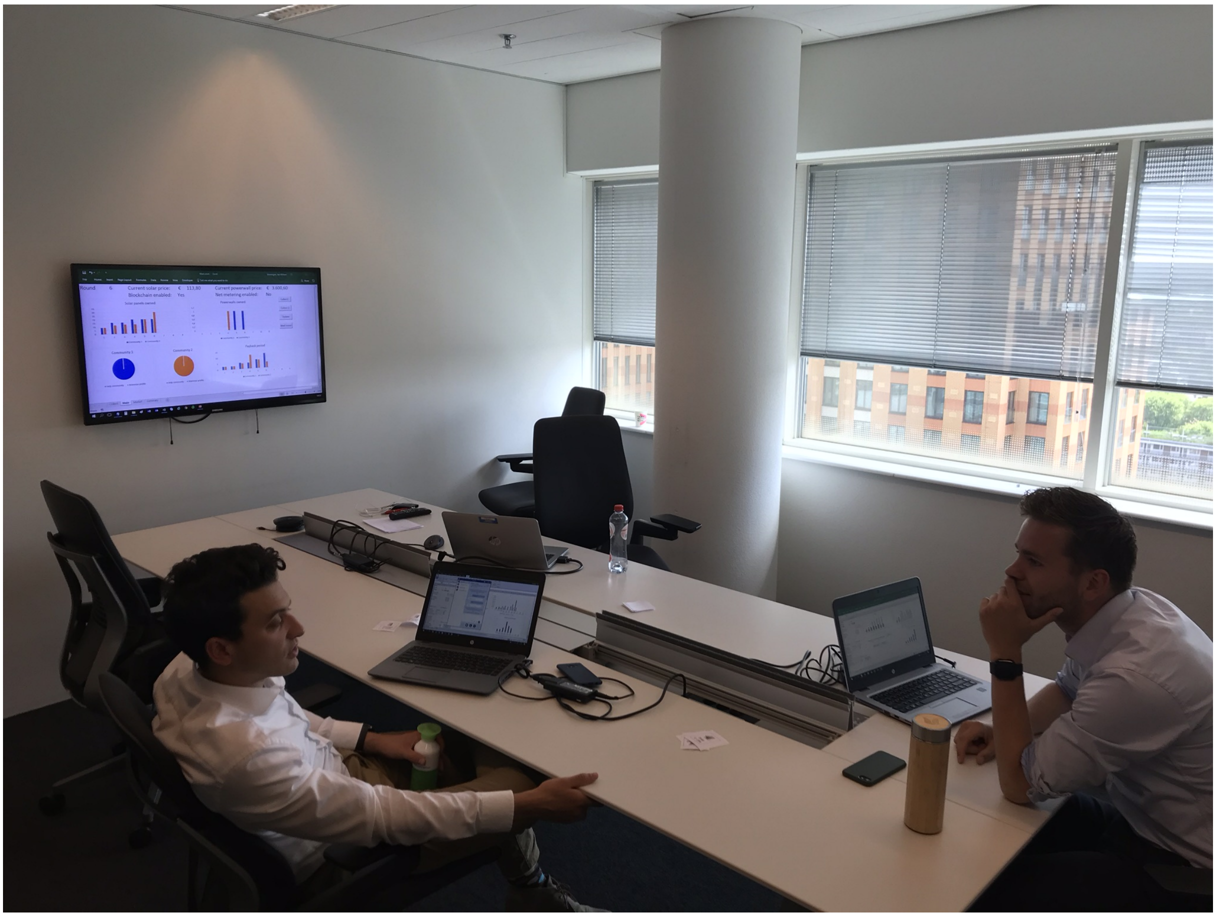

Figure 12.: Snapshot of the second session

6.3 SESSION 3: JUNE 6^{TH}, 2018

6.3.1 *Extended explanation*

After the first two sessions, the explanation in the presentation prior to the playing of the game was extended. There was more explanation about the influence of net metering on the electricity price in different situations (production lower than consumption, production approximately the same as consumption, but higher, and production much higher than consumption). By explaining this in the presentation prior to the third session, but not prior to the first and second session, during the game the participants were much more focused on how much solar panels would lead to optimizing the electricity price in the net-metering regime. This is because when a household would produce more than its consumption, the selling of that surplus of electricity

6.3.2 *Budgetary constraints*

Session 3 was the first session where participants were not limited in their investment capacity. Both communities were given € 19.300 in total, divided among the households in the community. This required deliberation in the community about who made which investment and whether they could buy a community storage unit, keeping in mind that the legislation might change during the rounds.

6.3.3 *Tipping point*

During the gaming sessions, random cards were drawn which simulated technological advances. The investment costs of solar panels and Powerwalls could decrease with 15%,25% or with 40%. The decrease in price for the investments made making the investments more attractive.

6.3.4 *Governmental influence*

In the third session the game was played with eight participants and this allowed for more data gathering about the purchasing behavior. In the previous session the results in figure 11 showed how the laws around purchasing and selling electricity influenced the investment behavior of households. In the following graph in figure 13, the results of session 3 are shown.

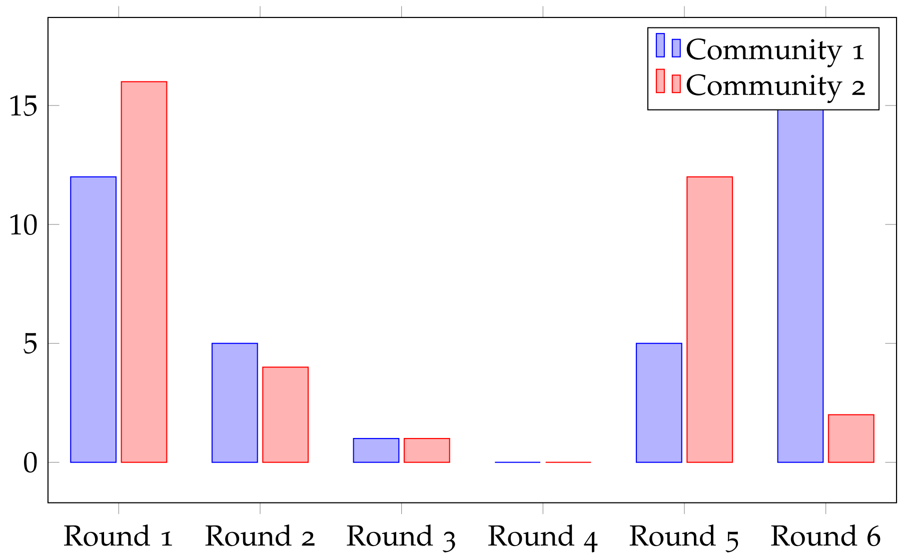

Figure 13.: Solar panels bought per community per round in session 3

In figure 13, the effects of the varying rules in the game are more pronounced. In phase 1, on average 9.25 solar panels are invested in. Next, in phase 2, 0.5 solar panels are bought and finally, in phase 3, 9 solar panels are bought on average. As can be seen, in rounds 1, the players look at their production and how high their consumption is, and invest in solar panels accordingly. In round 2 they see that their consumption fluctuates in-between rounds and they invest in some more solar panels to make sure they produce all their consumption. After round 2, net-metering is disabled and produced electricity only yield €0.03 per kWh. This increases the payback period of each households and their investments significantly. That is also why they are reluctant to invest in more solar panels, because they see how high the payback period is for a new investment.

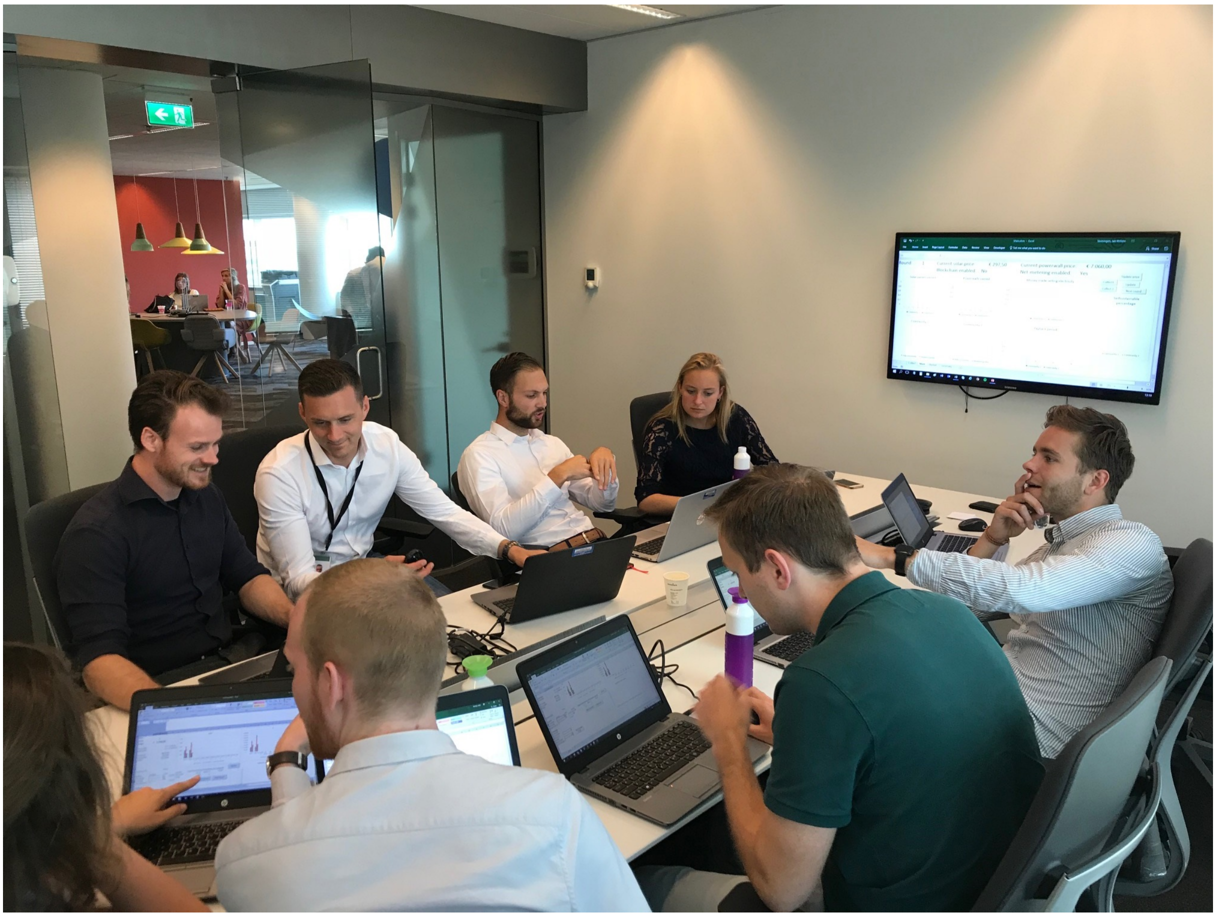

Figure 14.: Snapshot of the third session

6.4 VALIDATION

Throughout the sessions, questionnaires have been distributed about the game. These questionnaires are made as a check to see whether the gaming sessions have served their purpose and whether they are compliant to the frameworks that have been used.

6.4.1 *Session 1 and 2*

Both session 1 and 2 were played with two participants and thus are less pronounced as to how much data is collected about obtained insights, because there were less people to obtain the insights. However, the participants indicated to have increased awareness about the system in the game and see the potential of using such a game in a real-life scenario where actual households need to be convinced of a new ecosystem. Also, there were discussions about how the government momentarily organizes her legislation around supply and demand of electricity and how the government might organize it in the future.

6.4.2 *Session 3*

6.4.3 *Applicability in the company and for research*

In the questionnaire, the applicability of games for research and in a company like Accenture was questioned. The respondents indicated that they see the value of playing serious games in discovering future scenarios and understanding new technologies to be able to think of new applications in society. The game is able to initiate fruitful discussions about governmental, technological and societal issues that require thorough understanding of a system before the participants in the discussion understand each other.

6.4.4 *Realism*

During the design of the game, choices need to be made about including or excluding parts of the real world. There is a need for simplifications, but this is discussed more broadly in the discussion. The participants did however, despite of the simplifications, indicate that they felt that the game was realistic and suitable to increase awareness and understand the sustainable ecosystem that is simulated in the game.

The simplifications are made to make the game playable and not too complex, because otherwise the players would not learn anything. If the game is too simple, players would get bored and the educational value of the game would again decrease. Thus, it is important to find a balance between complexity and simplicity and according to the players of the game, knowledge was created so the goal was met.

6.4.5 *Goal of the game*

The question was asked what the participants was the main goal of the game; skills improvement, change behavior or knowledge creation. The clear majority of the responses on this question included knowledge creation, which was also set as the goal of this game. All participants indicated that they see the potential of the game to increase awareness about sustainable ecosystems such as the one in the game. Moreover, they replied that their awareness also increased by playing the game.

A few participants also answered change behavior as perceived goal of the game. This was not the main focus of the game, but was also a sub-goal of the game, to make people aware of sustainability and subsequently letting the participants incorporate sustainability in their everyday decision making.

Overall, the conclusion can be drawn that when a game is based on valid frameworks from the academic database, it can be an instrument for doing research and creating insights.

6.5 checking the requirements

The research questions and requirements in section 3.2. are checked by the questionnaires and the encompassing insights obtained during the gaming sessions.

Increase awareness and understanding

In all three sessions the participants of the game felt that the awareness of this system was increased. They gained insights in how governmental, societal and technical aspects all play a role in the implementation of new technologies in society and how sustainability aspects are influenced by a sustainable ecosystem such as in the game.

Meeting the learning goals

The goal set for the game was knowledge creation and when the choice was given to the participants which of the three they would attribute the most to this game, knowledge creation came out in 87,5% of the answers.

Structure and balance of the game

During the sessions feedback was gathered about the structure and balance of the game. This were questions about whether the game play was smooth and whether the number of elements in the game was pleasing (not too much and not too less). The respondents answered positively and the general evaluation was that the game did not contain any distracting elements and that learning was enabled.

Realism

To learn during a game, the game must be realistic enough for the participants to believe that the insights obtained during the game are transferable to the real world. The respondents indicated that the elements present in the game were a good representation of the real world and that insights obtained during the gaming sessions were valuable.

When looking at the responses of the players of the game, the conclusion can be drawn that the frameworks were used accurately and this serious game facilitated an educational session were awareness and understanding was increased about the application of blockchain in distributed energy systems.

7

CONCLUSION

During the gaming sessions of the game that was designed in this project, various insights were obtained in various fields. A game can have three goals: skills improvement, change behavior or knowledge creation. To meet these goals and to make the game realistic, balanced in complexity, playable and provide insights, various frameworks have been used to ensure this. To validate the tool, the answers to the questionnaires that were distributed at the end of each gaming session were registered along with the insights that were obtained by the players. The answers to the questionnaires indicate that the learning goals have been met and that the game was realistic and had a right balance between complexity and simplicity.

The participants of the game were colleagues from Accenture that had background from various universities and studies. This is also what made the discussions during the gaming sessions fruitful, because the game brought together perspectives from people that would otherwise maybe not exchange these perspectives. When the same information would be conveyed in the form of a presentation, the retention of that information would be lower than an interactive experience such as a game. The interactive nature of the game is also what makes that perspectives are exchanged.

In order to be innovative and be able to compete with competition in industries, companies have the need to pursue new technologies into their business. A serious game can be a tool to facilitate discovering and understanding new technologies. By playing a game, the awareness is increased and the participants can think better about how to implement a new technology. In this project, to test serious gaming as a tool to increase awareness and understanding, a case study is taken about distributed ledger technology in distributed energy systems. The choice was made to use blockchain because in the preamble to this project, blockchain is was hyped enormously as discussed in the background chapter. Companies are eager to learn what they can do with the technology and because the energy transition is also a relevant subject for bringing technologies into society, it seemed logical to combine the two.

The design of this game will be added to the knowledge exchange of Accenture, which will show employees how serious games can be designed and used for conveying new technologies to clients. Especially in a complex paradigm shift as is the energy transition, there are so many paths that the future can hold. This is what makes discovering with a serious game attractive by increasing creativeness.

The insights that were obtained were from different aspects of the complex system such as, governmental, societal, economic and technical issues.

- Governmental: During the three phases of the game, one could clearly see how the legislation on providing electricity back to the grid affects the attractiveness of investing in solar panels.

- Societal: The degree of acceptance of such a system can investigated in a gaming session. But the acceptance can also increase by playing the game, because they understand better how the system works and what it can bring them.
- Economical: The economies of investing in solar panels or storage devices is important in terms of technological advances, when does the cost for the technologies decrease enough to make it economically interesting to make it profitable.
- Technology: Issues like how much capacity needs to be installed makes the game interesting to discover with different legislation, when an investment becomes interesting. Also with the current capacity of a Powerwall (14 kWh), on what scale is it interesting, is it interesting for a single household, or does it need to be installed on a scale of dozens of households?

As can be seen the game provides insights in different areas of complex sustainable ecosystems. When the game is played, players understand the limitations of the current system (such as producing more than consumption offers a very low price for electricity for households) and how it works, which leads to fruitful discussions during and after the game. A game proves to be a suitable instrument to understand and discover the application of a new technology in society. Since Industrial Engineering and Management seeks to close the gap and build a bridge between society and technology, this project has built a bridge by designing and playing a game that increases awareness about a complex ecosystem with a new technology and offers valuable insights to the players.

8

DISCUSSION

In this section the academic contents of this report will be discussed and evaluated. This will be done considering how much resources (time etc.) were available and how much was achieved in the project.

8.1 DISCUSSION OF THE RESEARCH

During the design of the game, many academic articles are read to make assumptions about the world inside the serious game. To make the game meaningful and as realistic as possible, technical specifications about implemented blockchain solutions are taken to fill in the specifics of the elements in the game. The assumptions are made to best fit the learning goals, the goals of the project and to have a playable game. However, one must make simplifications in a game. This is because you cannot include everything. You could compare it to a map of the world; if you would include everything of the real world, then you would just have a second world and it would not be practical to use as a map. That is why you need to exclude parts to simplify and to focus on key aspects. Some examples are the flow of electricity which is assumed to be fully consumed when by the community when blockchain is enabled, while electricity is probably also sold to the utility at times. Another simplification is that the blockchain system is assumed to be installed instantly and the installation costs are not considered. These simplifications were made to not bother the participants of the game too much with details which could make the game not clear or too complex. In a game the fact that the decision do not have real monetary consequences for the player, allows them to act more freely and make decisions they would not have made otherwise, obtaining insights that would otherwise not be obtained.

8.1.1 *Validation*

There are several ways to validate a serious game and it was done by checking whether the elements of used frameworks were experienced by the players and whether the learning goals were met. Another way of validating a serious game would be to create a placebo and organize another gaming session with the crucial elements lacking and then compare the results. However, this would require putting more time into designing which would decrease the quality of the real game. The serious game in this project is used to discover and understand a new technology, thus the output of the serious game is uncertain. New application may be discovered or new ways to organize legislation around the new technology. This is what makes quantifying the criteria of a successful game beforehand difficult, but also what make a serious game interesting for discovering new things and being creative.

8.1.2 *Organizational feedback*

Another aspect that was given as feedback by a participant was that it would have been nice to play with you community in separate rooms. In this way the communities would have more privacy to discuss their strategies.

8.2 FUTURE WORK

If more time would have been available, I would put a design thinking session at the end of the gaming session. A design thinking session is a way to creatively think solutions in a structured way. Accenture uses this in workshops to have creative, but structured brainstorm sessions. Even though the game sessions unleash discussions about applications of the new technology in society, with design thinking, focused solution thinking could be initiated. Another aspect I would improve is to play it with actual households and actual grid operators, then the focus would be more on persuading the participants to get involved in a sustainable ecosystem. But looking at the time that was available and the planning that I made, the resources that I have had were put into good use.

A

APPENDIX

A.1 MOORE'S LAW

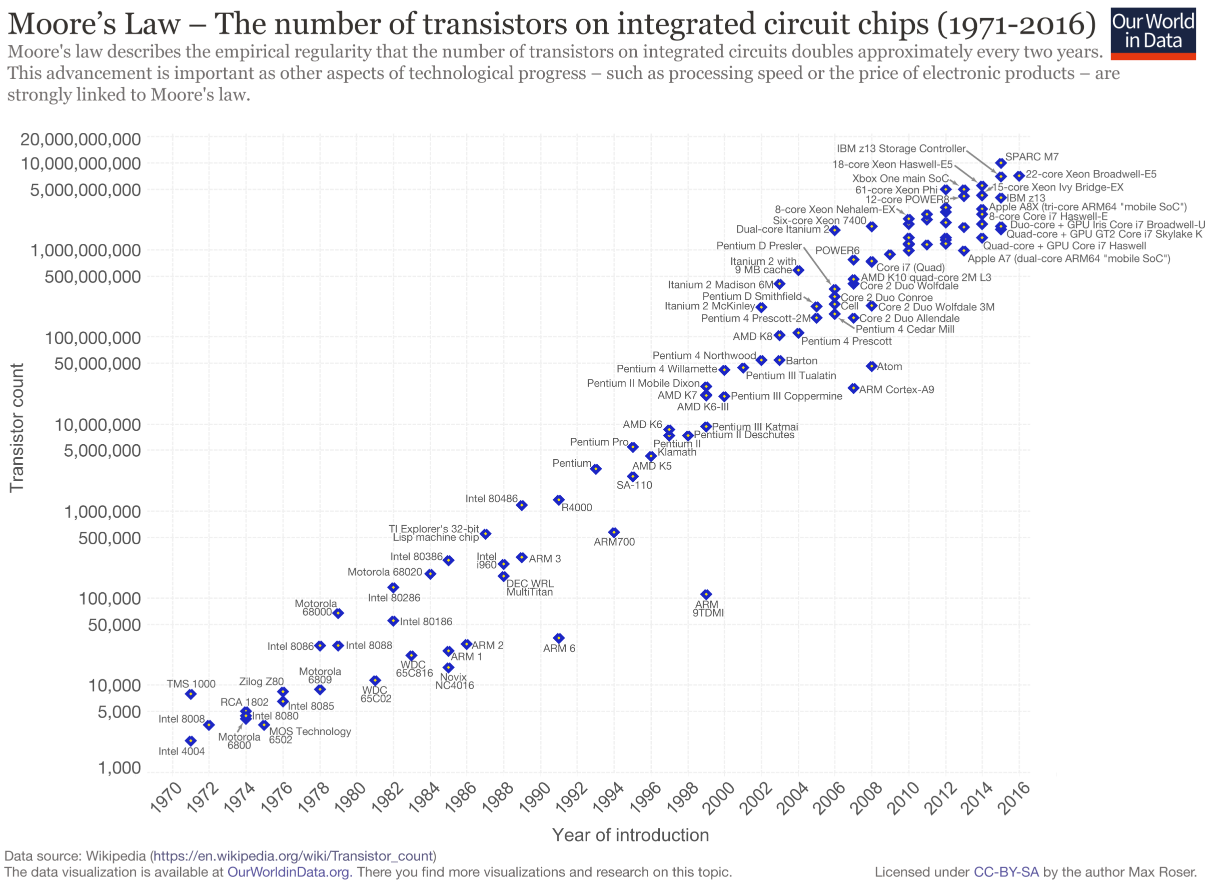

Figure 15.: Moore's Law: A plot of CPU transistor counts against dates of introduction

A.2 COMPONENTS OF WENZLER FRAMEWORK

A. Context
Problem - The problem (issue) or opportunity that we are trying to solve or address
Objective - The objectives we are trying to achieve with the simulation game
Model - The qualitative and/or quantitative model of the reality that will be simulated
Story - The story line and events driving the dynamics of the simulation game when run
B. Players
Target - The intended number of target participants and how will they be structured
Level - The organizational level (the level of responsibility) the players are coming from
Roles - The number and character of roles, their objectives, responsibilities, and decisions
Culture - The character of individual ad organizational cultures of players
C. Process
Sequence - The way in which the time will be treated during the simulation game run
Interaction - The rules of interaction of players within the simulation game
Steps - The character of role specific steps that players must follow during the run
Indicators - The system for processing and reporting the results of players decisions
D. Environment
Location - The character and number of (parallel) locations for a simulation game run
Place - The level to which the play is in a virtual and/or physical world
Material - The character of materials and artifacts required to run the simulation game
Representation - The way in which material will be attributed a substantive meaning

A.3 DECISIONS MADE DURING SESSIONS

A.3.1 *Session 1 decisions*

The exact decisions of the players in the phase without blockchain were lost due to a reset of the game. However, all the insights are discussed in the chapter 'Results', in which can be seen that the players made more investments because of the economical benefits of the enabling of blockchain.

Round 1

Player 1 Invested in: 12 solar panels and 1 Powerwall
Preference in selling electricity: 'Help community'

Player 2 Invested in: 4 solar panels and 1 Powerwall
Preference in selling electricity: 'Maximize profits'

Round 2

Player 1 Invested in: 0 solar panels and 1 Powerwall
Preference in selling electricity: 'Maximize profits'

Player 2 Invested in: 8 solar panels and 1 Powerwall

Preference in selling electricity: 'Maximize profits'

A.3.2 Session 2 decisions

This session was played with two colleagues that each represented a community. In round 1 and 2, net metering was enabled. In round 3 and 4, net metering was disabled. From round 5 onwards, net metering was disabled and blockchain enabled.

Round 1

Player 1 Invested in: 5 solar panels
Player 2 Invested in: 5 solar panels

Round 2

Player 1 Invested in: 7 solar panels
Player 2 Invested in: 3 solar panels

Round 3

Player 1 No investments
Player 2 Invested in: 1 solar panels

Round 4

Player 1 Invested in: 4 solar panels
Player 2 Invested in: 0 solar panels and 1 powerwall

Round 5

Player 1 Invested in: 0 solar panels and 1 powerwall
Preference in selling electricity: 'Help community'
Player 2 Invested in: 7 solar panels
Preference in selling electricity: 'Maximize profits'

Round 6

Player 1 No investments
Preference in selling electricity: 'Help community'
Player 2 Invested in: 10 solar panels
Preference in selling electricity: 'Maximize profits'

A.3.3 *Session 3 decisions*

Table 3.: Investment decisions during session 3

	Solar panels bought		Powerwalls bought	
	Community 1	Community 2	Community 1	Community 2
Round 1	12	16	0	0
Round 2	5	4	0	0
Round 3	1	1	0	0
Round 4	0	0	0	1
Round 5	5	12	2	1
Round 6	17	2	0	0

Figure 16.: Central display for all players to see in session 1

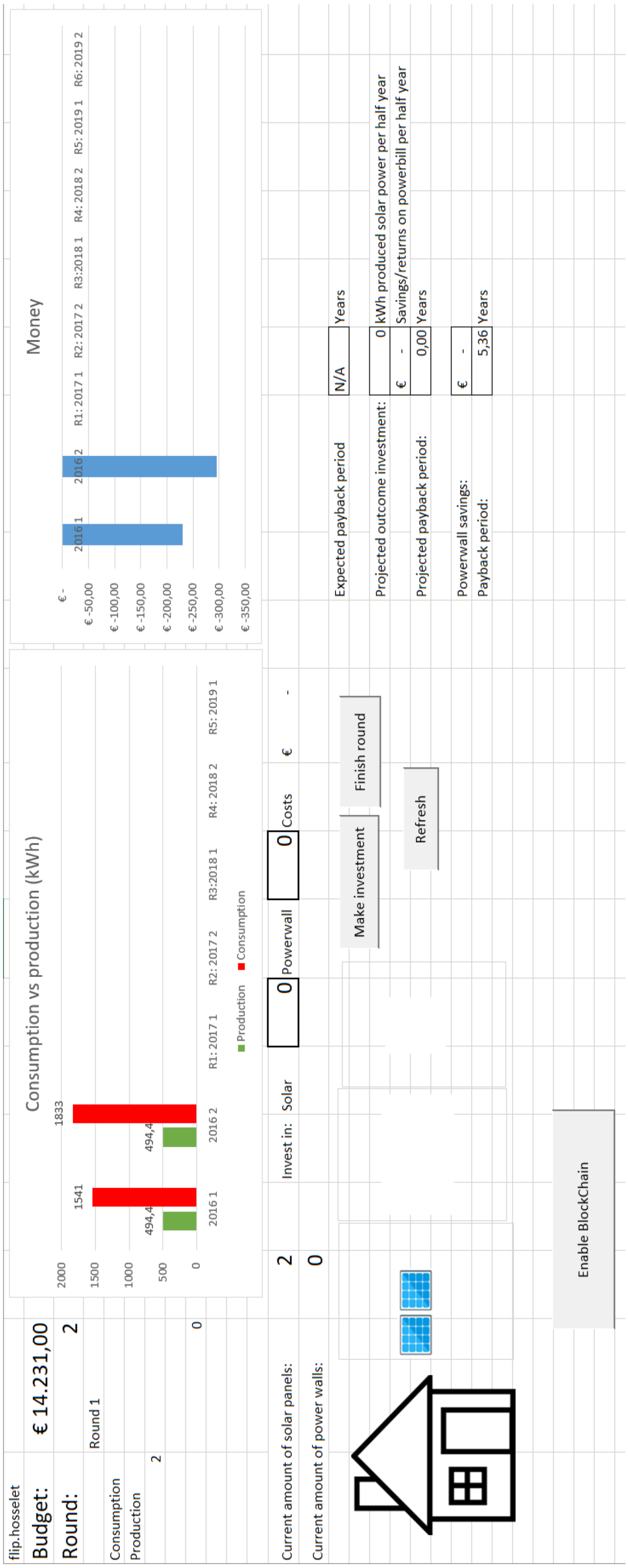

Figure 17.: Display for individual players in session 1

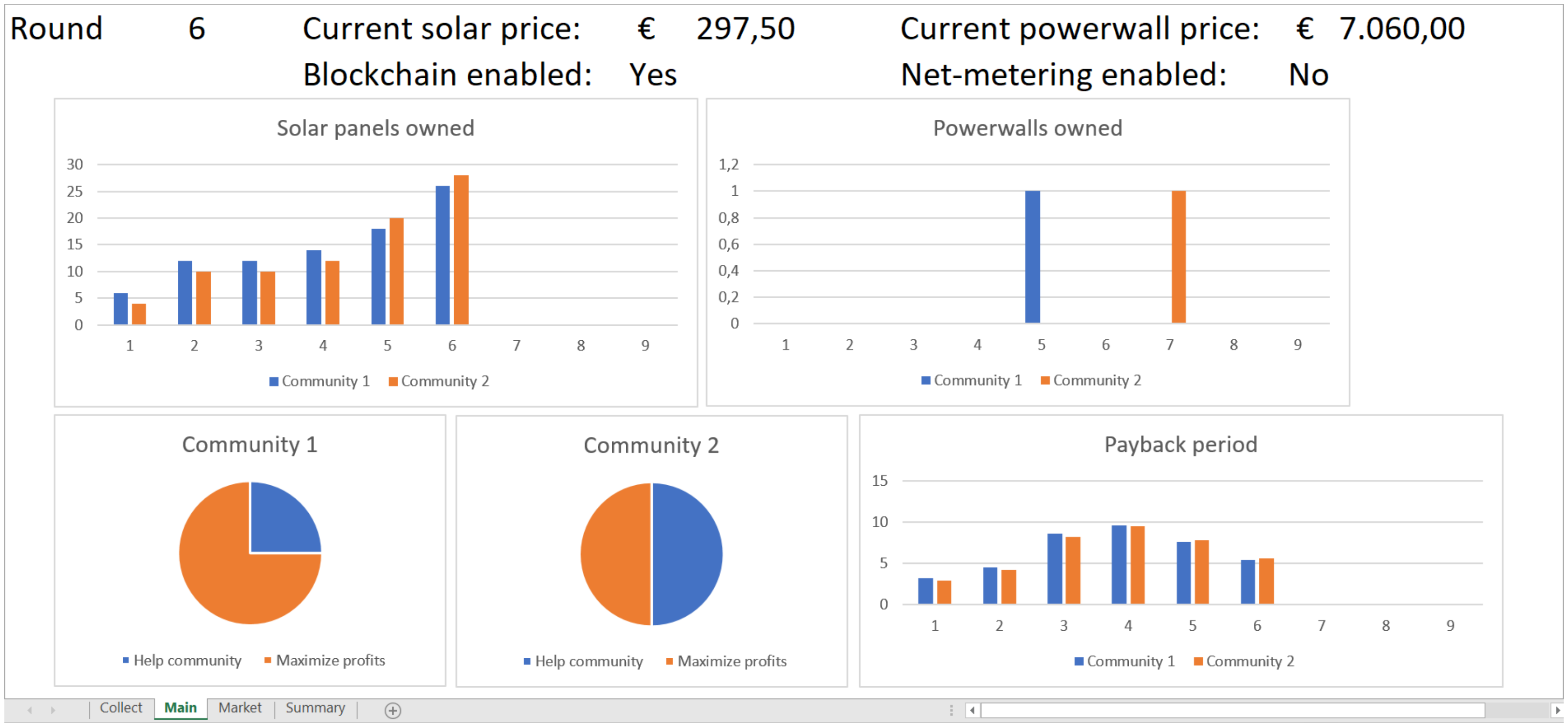

Figure 18.: Central display for all players to see

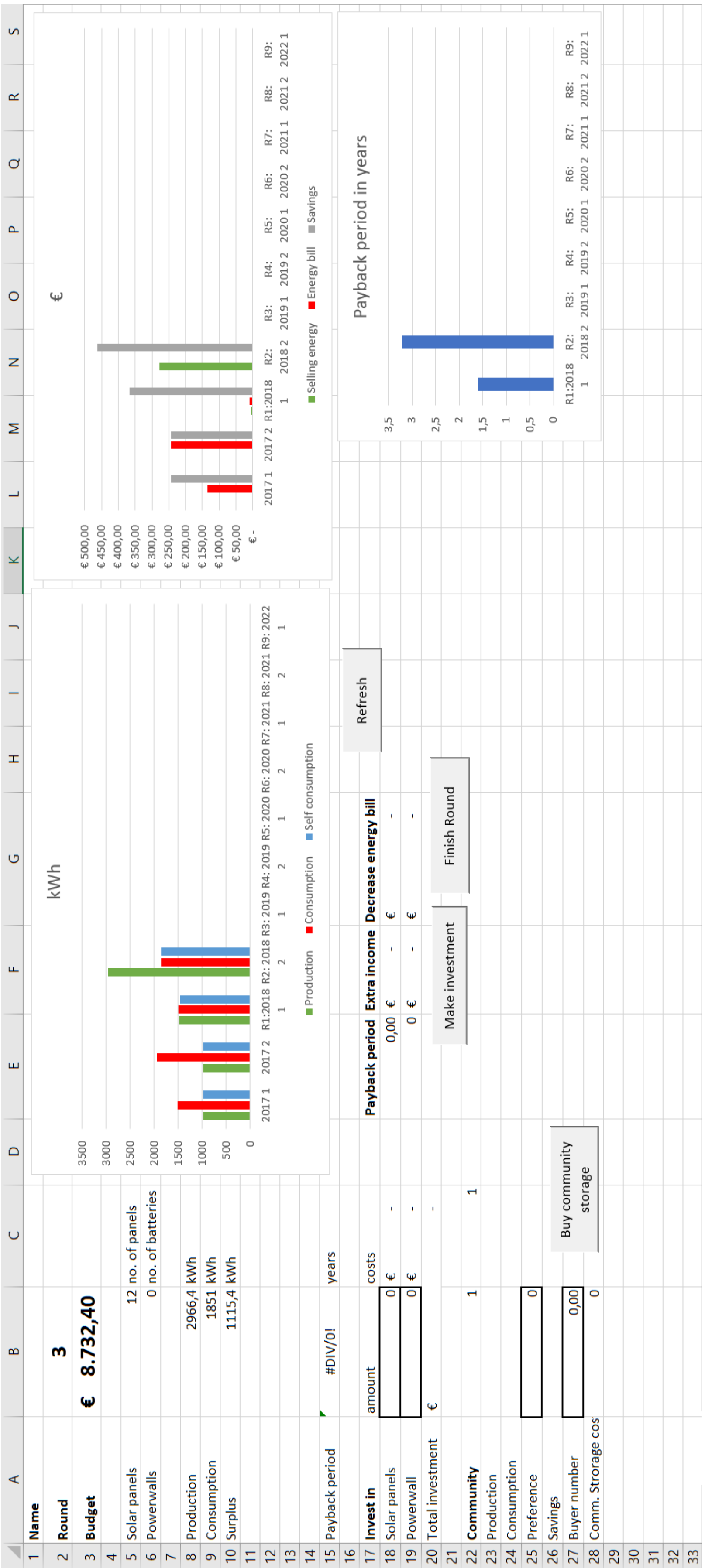

Figure 19.: Display for the player

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