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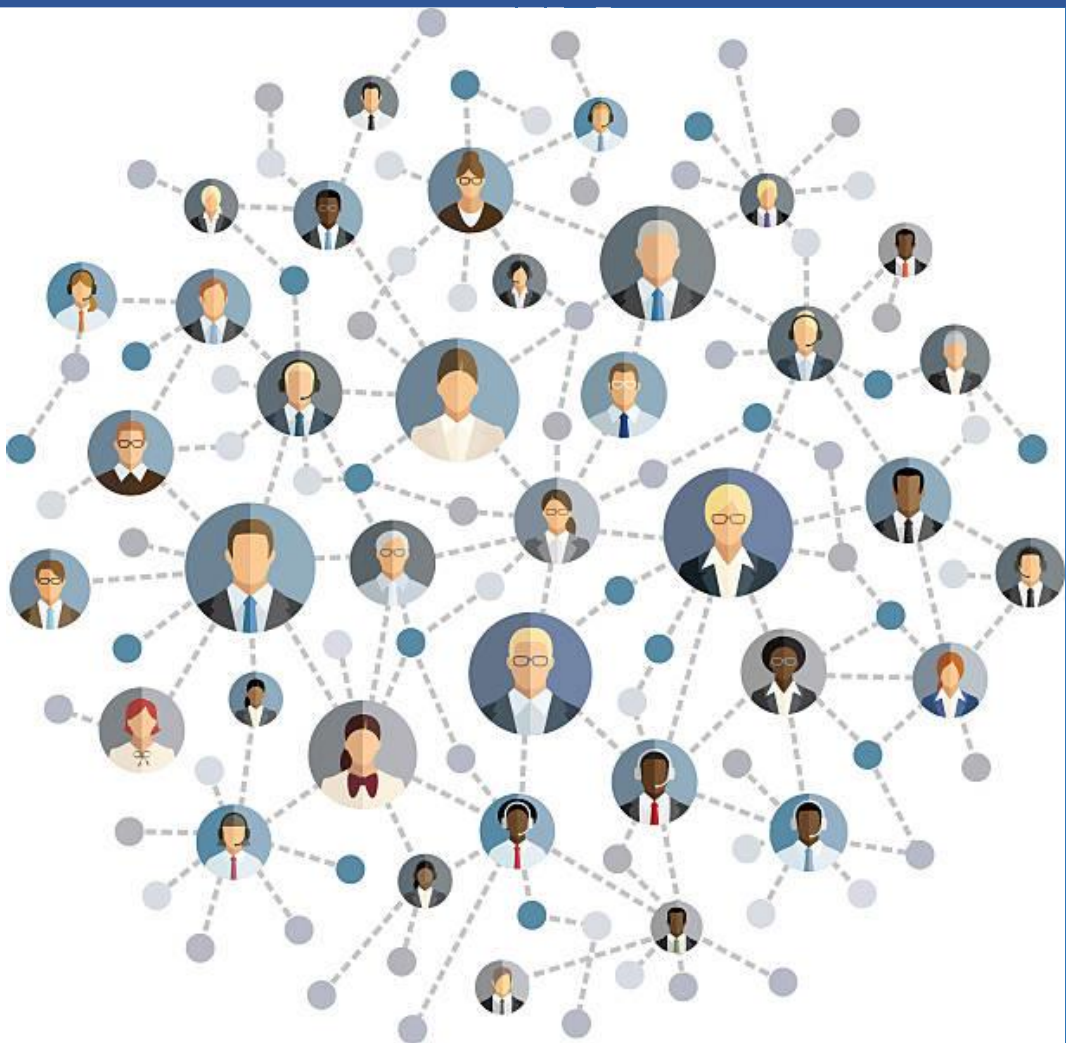
2020

Blockchain-based crowdfinancing mechanisms for renewable energy projects



A business case for consultancy & engineering firms

TU Delft
anteagroup

Blockchain-based crowdfinancing mechanisms for renewable energy projects

A business case for consultancy & engineering firms

By

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in partial fulfilment of the requirements for the degree of

Master of Science

in Construction Management and Engineering

at Delft University of Technology

to be defended publicly on Wednesday February 5, 2020 at 03:45 PM.

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Preface

This master's thesis was motivated by my personal concerns about inequality of opportunity regarding access to financial instruments utilized for capital accumulation and value creation. It is my opinion that our societies are often shaped by the preferences of a minority of wealthy individuals and politicians, while the average citizen remains powerless as a single individual, especially with regards to the energy transition. But what if the collective effort of a crowd of small investors with aligned interests could be organized efficiently? What could be possible if the majority could finally have the financial means to drive change without relying on the minority? These questions where often in my mind until I learned about blockchain technology.

When I was first introduced to blockchain technology I was immediately hooked by the potential use cases, in particular the possibility to empower crowdinvestors from anywhere in the world by giving them financial control over a project they invested in, without the need to place trust in third parties. This seemed revolutionary to me and I was automatically set on a path to find a company that would share my views and was willing to explore the possibilities that blockchain technology had to offer.

Acknowledgements

This master's thesis would not have been possible if not for Krispijn de Jonge from Antea Group, as he saw potential in my proposal and was willing to explore it with me. He was a good sparring partner throughout the research and helped me stay focused in order to not get lost in the complexity of less relevant topics. Alexander Koutamanis and Paul Chan also provided key support during the research, since they pushed me to not only think in systems, like a typical engineer, but to also try to deduce what was hidden behind the data and research findings and the implications thereof. Additionally, Jan Rellermeyer provided key insights regarding the technical side of the blockchain implementations and brought me into contact with knowledgeable programmers to discuss the technical details.

I would also like to offer my gratitude to the interviewees and expert panel members that took the time and effort to participate in the research and provided valuable insights.

Ultimately, I would like to thank my loved ones for their support and companionship during the long hours that were invested in this master's thesis. Without them this research would at the very least have taken much longer to finish.

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5AML: (EU's) Fifth Anti-Money Laundering Directive

BA: business angels

DSO: distribution system/network operator

DAO: decentralized autonomous organization

IRR: internal rate of return

KYC: know your customer

LLC: limited-liability company

PRP: Programme Responsible Party

SEP: Samenwerkende ElektriciteitsProductiebedrijven

SMEs: small and medium-sized enterprises

TSO: Transmission System Operator

UI: user interface

VC: venture capital

Wft: Wet financieel toezicht (Financial Supervision Act)

Wwft: Wet ter voorkoming van witwassen en financieren van terrorisme (Law for prevention of money laundering and the financing of terrorism)

WACC: weighted average cost of capital

WON: Wet Onafhankelijk Netbeheer (Independent Network Management Act)

Executive summary

Recently, there is a growing need to address the investment gap in renewable energy by attracting non-institutional investors that have investment preferences better suited for the energy transition. Crowdfinancing is a promising alternative, as it allows for increased innovation, more sustainable development and reduced community risks and is driven by a crowd of small investors that are less profit-driven than professional investors. However, current crowdfinancing models are limited by lack of trust, adverse selection, exclusive corporate governance and lack of liquidity. While extant research has identified these limitations and the potential of blockchain technology to solve some of them, there is a need to design the blockchain-based crowdfinancing mechanisms required and provide a business case for their implementation. The research objective of this practice-oriented design research is to provide a practical plan for the implementation of blockchain-based crowdfinancing for renewable energy projects by means of a design and business case for engineering and consultancy firms as the facilitators of the process in the Netherlands, with the purpose to give a boost to the energy transition.

A foundation for the research was provided by making an analysis of the evolution and current state of the Dutch energy market organization based on three cornerstones: market roles, production and financing. This analysis showed a high degree of decentralization in terms of market roles and production from renewables that allowed the emergence of community driven energy cooperatives, while a dependence on centralized financial intermediaries is still present; risky and small projects do not have access to bank financing and existing crowdfinancing platforms charge high brokerage fees and provide no secondary markets.

A pilot study based on the same cornerstones and consisting of interviews with relevant market parties was performed in order to supplement the analysis of the market for the formulation of design requirements for the crowdfinancing mechanisms. Qualitative desk research was done on existing smart contract applications that could be utilized to overcome the limitations of crowdfinancing and served as the building blocks for the conceptual designs. Qualitative desk research was also performed in order to quantify the costs and address the (legal) implications of implementing the mechanisms proposed.

The result was a practical plan consisting of blockchain-based crowdfinancing mechanisms that reduce brokerage fees and facilitate the organic establishment of secondary markets by making use of existing public blockchain infrastructure, and a positive business case for consultancy and

engineering firms to facilitate the process. Smart contracts govern the crowdfinancing process autonomously for low and high risk projects, where with the latter crowdinvestors are given financial control by locking project funds in trustless escrow contracts, thereby allowing them to cut losses in failing projects and thus addressing the issues of lack of trust and exclusive corporate governance, while mitigating the effects of adverse selection.

This practical plan provides a tool to further empower the crowd as the fuel for the energy transition, thereby increasing investments in renewables. However, social exclusion might result at first from the intrinsic complexity of blockchain technology and the degree to which a boost can be given to the transition remains unclear due to a lack of consensus on the effectiveness of crowdfinancing to increase support for the bigger projects.

There is further research needed into a risk management-based approach for the design of escrow contracts that release funds according to a project planning, while the delegation of control rights to more capable third parties also requires more research. Additionally, the application of decentralized governance beyond financial control requires further examination as well.

1. Introduction

Recently, there is a growing need to address the infrastructure investment gap. Infrastructure is the driver of all economic and social development, as physical infrastructure (e.g. transportation, power/electricity, telecommunications) contributes directly to production and economic development, while social infrastructure (e.g. water and sanitation facilities, health, education) facilitates social development and raise the quality of life; but the lack of financing for infrastructure development seems to be a universal problem and constitutes the biggest research theme of extant literature (Kumari & Sharma, 2017). This academic focus reflects the current state of global infrastructure, as investment projections until 2040 fall short of the amounts necessary to support expected growth rates by 19%, which is equivalent to a global investment gap of $3.7 trillion US dollars per year (Global Infrastructure Hub, 2017) – the global investment gap by subsector is depicted in *figure 1*. Government budgets alone do not seem to be enough to provide the massive investments required for infrastructure development, for both developed and developing economies (Ehlers, 2014) – in The Netherlands government budgets for infrastructure development are tens of billions of euros smaller than what will be needed the coming decades (van der Geest, 2017).

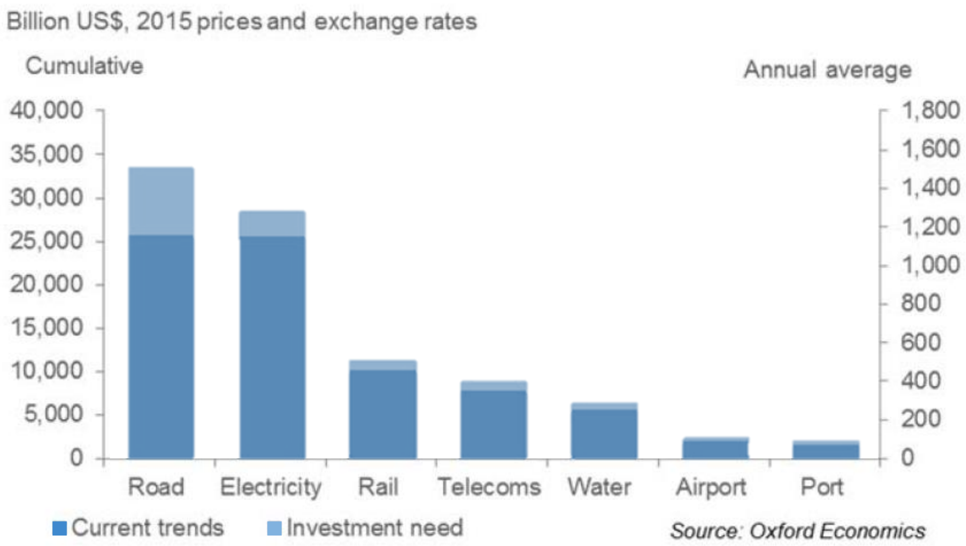

Figure 1: Global investment requirement by sector, 2016-2040, cumulative (left scale) and annual average (right scale). From *Global infrastructure outlook – Infrastructure investment needs - 50 countries, 7 sectors to 2040 (p. 25), by Global Infrastructure Hub, 2017.*

An important element of physical infrastructure is the supply of energy, since it is essential for most economic sectors and for maintaining the living standards of a modern society. But in efforts to combat climate change international commitments were made by 195 countries in the *2016 Paris Agreement* to keep the global temperature rise well below 2 degrees Celsius above pre-industrial levels (United Nations, n.d.); in order to meet this goal the EU-member states have agreed to reduce greenhouse gas emissions to 80-95% of pre-1990 levels (Rijksoverheid, n.d. -a). As a result, moving away from fossil fuels towards cleaner sources of energy while continuing to meet energy needs requires large investments in alternative generation, storage solutions and upgrades to and/or replacement of existing distribution networks, depending on the country's own resources and energy security preferences. For the Netherlands this means making additional annual investments of over € 10 billion starting in 2020, while achieving a fully sustainable energy supply by 2030 would require € 9 billion extra each year (van der Geest, 2017).

On the other hand, the financial crisis of 2008 caused a restructuring of the financial system and the way projects are financed; since banks proved to be overexposed to risk, new risk-averse regulation and liquidity requirements such as Basel III were introduced (Banken.nl, n.d.). These constraints limit the amount of risk that a bank can take and the proportion of illiquid assets in its portfolio, which affected bank investments in physical infrastructure heavily due to its high degree of illiquidity. In response to the continued decrease of the banks' share of the financing market the Dutch government is aiming at attracting other institutional investors (e.g. pension funds and insurance companies) to the infrastructure sector (NIA, n.d.), which is aligned with the efforts and recommendations of the European Commission and the OECD for the stimulation of investments in infrastructure (Vasallo et. al, 2018; OECD, 2016). But institutional investors require comprehensive business models and a pipeline of projects to reduce risks and justify the high entry costs caused by the development of sector-specific expertise (van der Geest, 2017), while the energy transition in turn requires continued innovation and therefore investments in different alternatives, which cannot be restricted a-priori by deterministic long-term decisions such as pipelines of specific projects. Additionally, the early phases of infrastructure project development are also subject to a high risk of default (Ehler, 2014); these factors are a deterrent to invest for institutional investors, who prefer to invest in infrastructure operation (brown field projects) rather than in planning and construction (greenfield projects) (Gutierrez Soto, 2017).

With the continued reliance on institutional investors for the financing of renewable energy development the status quo is proliferated and a timely energy transition remains dependent upon the investment preferences of centralized financial institutions; as the banking sector's share of the financing market continues to decrease other institutional investors are expected to take over, although they currently make up less than 1% of the Dutch financing market (DNB, 2016). But while this slow process takes place, if at all, the use of fossil fuels continues to pollute the environment and the energy production from renewable sources (henceforth to be referred to as *renewables*) remains small; in the Netherlands less than 8% of the total energy consumption was produced from renewables in 2018 (CBS, 2019-a), which is considerably less than the goal of 14% for 2020 (Rijksoverheid, n.d. -b). There is thus a growing need to address the investment gap in the renewable energy sector by attracting non-institutional investors that have investment preferences better suited for the energy transition. Crowdinvestors seem to fit this category.

The collective effort of the crowd organized through crowdfunding mechanisms could be an alternative to address the existing investment gap. Namely, Vismara (2019) find that while professional investors typically apply a market logic, small investors in equity crowdfunding are found to be sensitive also to a community logic and thus consider the non-monetary attributes of a project as well, such as the attention to community advancement and the potential for "bettering the world", thereby making them value the sustainability-orientation of companies more. Moreover, equity crowdfunding allows for increased innovation quality through the actualization of more diverse ideas (Mollic & Nanda, 2016) and could thus aid innovative firms in securing funding for the development of new energy technologies. Ergo, crowdfunding could facilitate the development of renewable energy projects that do not fit the investment thesis of financial institutions.

1.1. The problem: Crowdfinancing renewable energy projects

The global crowdfunding market went from $1 billion US dollars in 2011 to $34 billion US dollars in 2015 (Massolution, 2015) and according to the same report the industry is expected to reach an annual volume of $100 billion US dollars by 2025 and "becoming the leading financial channel for small and medium-sized enterprises (SMEs). In a more recent report published by Technavio (2018) the total crowdfunding market was forecasted to growth with a compound annual growth rate (CAGR[1]) of 17% between 2018 and 2019, amounting to $89.7 billion US dollars of market capitalization added. This steady growth has been similar in the Netherlands as well (*see figure 2*). Crowdfunding is categorized by Harrison (2013) as five types of fundraising acts, of which lending

[1] "Compound annual growth rate (CAGR) is the rate of return that would be required for an investment to grow from its beginning balance to its ending balance, assuming the profits were reinvested at the end of each year of the investment's lifespan" (Investopedia, n.d.-e)

crowdfunding and equity crowdfunding imply an expectation of financial return and will henceforth be referred to as *crowdfinancing.*

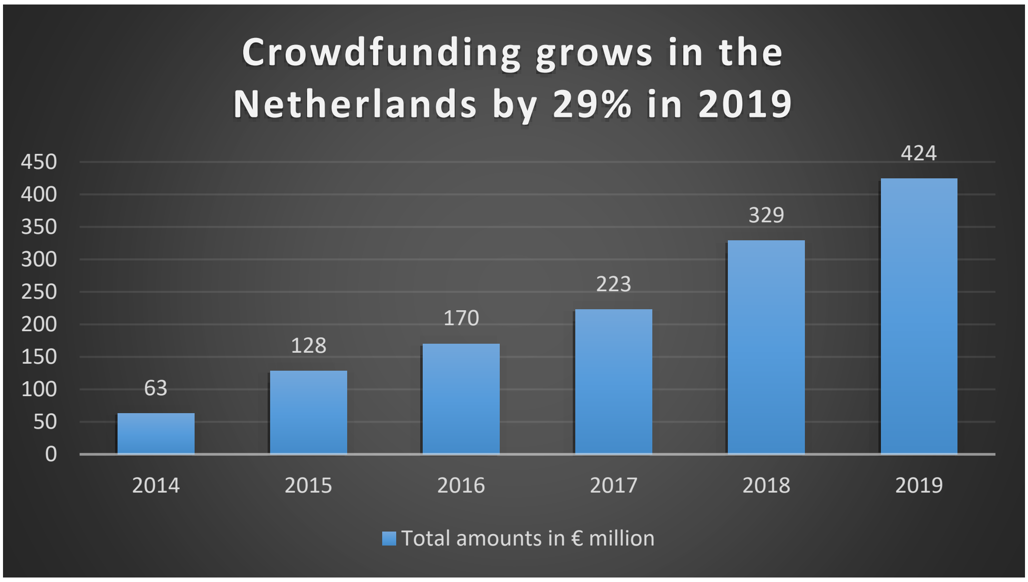

Figure 2: Total crowdfunding growth in the Netherlands. Data from *crowdfundingcijfers.nl.*

Limitations of crowdfinancing

Crowdfinancing is a relatively new method of raising financial capital that has had impressive growth, but remains fairly unexamined by literature, especially within the context of energy infrastructure financing. Still, extant literature has identified four main limitations with crowdfinancing that are detrimental to its further development. A lack of trust is embedded in crowdfunding in general, since a track record of the project initiator's past performance is often not available and the distance factor exposes investors to scammers; unsurprisingly, Gerber & Hui (2013) identified *Distrust of Creators' Use of Funds* as the sole deterrent to crowdfund for supporters. Additionally, Ahlers et al. (2015) find the crowd to lack the ability to assess investment opportunities, i.e. crowdinvestors are unsophisticated, as social and intellectual capital are shown to have little or no impact on funding success in equity crowdfunding platforms. The consequences of this adverse selection problem can be seen in the fact that 18% of firms funded through Crowdcube failed, but none failed if initially backed by qualified investors (VCs or BAs) (Signori & Vismara, 2018). Moreover, the geographical distribution of investors and the rather small size of individual investments are a deterrent to participate in corporate governance, thereby exposing small investors to the opportunistic behavior of larger ones, as they would have higher voting power relative to their cash-flow rights (La Porta et. al, 2002). Lastly, the registration of securities acquired through crowdfunding is a relatively slow and inefficient process, while the trading thereof is mostly restricted to the issuing platforms, if at all possible. This lack of liquidity puts equity crowdfunding right in the middle between public and private finance, as "the prospects for exiting a successful venture are unclear outside of acquisitions or IPO's" (Cumming, Meoli & Vismara, 2019); equity crowdfunding is linked to high risks and discourages potential investors from participating, given the limited exit strategies (Zhu & Zhou, 2016).

Recent studies explore the practical value of blockchain technology to overcome some of the limitations of crowdfinancing. In order to solve the illiquidity problem Zhu & Zhou (2016) highlight the superiority of blockchain-based crowdfinancing relative to centralized solutions for the settlement of transactions, while Gomber, Koch, & Siering (2017) emphasize the need for research on the application of blockchain technology for the provision of secondary markets. Zhu & Zhou (2016) also suggest the use of blokchain-based voting systems to facilitate the participation of crowdinvestors in corporate governance. Additionally, already existing applications of blockchain technology show that it is now possible to lock project funds in trustless escrow systems, thereby giving financial control to investors as a hedge against potential malicious actors (addressing the trust problem) and allowing them to cut their losses in failing projects (addressing the adverse selection problem).

While current research has identified the limitations of crowdfinancing and the potential of blockchain technology to overcome some of these issues, there is a need to design the blockchain-based crowdfinancing mechanisms required and provide a business case for their implementation. This thesis adds to the body of knowledge by satisfying this need for the purpose of boosting investments in the energy transition. To this end, the research objective of this practice-oriented design research is *to provide a practical plan for the implementation of blockchain-based crowdfinancing for renewable energy projects by means of a design and business case for engineering and consultancy firms as the facilitators of the process in the Netherlands.*

1.2. Research questions

In order to achieve the research objective, the following main question will be answered: How can blockchain-based crowdfinancing be implemented to finance renewable energy projects in The Netherlands?

An answer to the main question will be procured by means of the following sub-questions:

1.2.1. Foundation/background questions:

1. How has the Dutch energy market been organized (historically), in terms of:
    a. market roles?
    b. production?
    c. financing?

1.2.2. Research questions:

2. What success criteria for crowdfinancing renewable energy projects are identified by relevant market parties?
3. How can blockchain-based crowdfinancing mechanisms be designed in light of the analysis of the energy market and the success criteria?
    a. What existing smart contract applications can be utilized to overcome the four main limitations of crowdfinancing?
    b. What design requirements can be deduced from the theoretical analysis and the success criteria?
4. How can these mechanisms be implemented by consultancy and engineering firms as facilitators of the crowdfinancing process?

1.3. Conceptual research design

This is practice-oriented design research, an approach to the problem of crowdfinancing renewable energy projects by means of a practical plan for the implementation of blockchain-based crowdfinancing. Namely, this thesis presents designs for crowdfinancing mechanisms that fit the requirements of the operating environment and potential end-users, but that also result in a positive business case for the facilitator of the process. To this end, a set of design requirements constituting the theoretical research perspective (see sub-section 7.1.1) were derived from theoretical analysis (see chapters 2 and 3) and preliminary research (see chapter 5). Then the design requirements were confronted with reference smart contract applications (the research object) in order to produce conceptual designs for the crowdfinancing mechanisms, which combined with a business case for the facilitator of the process resulted in a practical plan for the implementation of blockchain-based crowdfinancing for renewable energy projects (the research objective).

This thesis is structured as follows: Chapter 2 (Theory) defines relevant terms and discusses the benefits and downsides and crowdfinancing and blockchain technology, as identified in extant literature; chapter 3 (Analysis of the energy market) provides a (historical) context as a foundation for the research; chapter 4 (Research methodology) describes the technical research design; chapter 5 (Pilot Study) discusses the interviews with relevant market parties; chapter 6 (Reference smart contract applications) shows existing applications of smart contract that could be utilized to overcome the limitations of crowdfinancing; chapter 7 (The solution: a practical plan for the implementation of blockchain-based crowdfinancing) elaborates the designs and business case for the implementation of blockchain-based crowdfinancing; chapter 9 (Discussion) discusses the results and limitations of the research; and chapter 10 (Conclusions) provides concluding remarks and recommendations for further research.

2. Theory

2.1. Financing

The term *financing* is rarely defined in extant literature and is often used loosely and interchangeably with the term *funding*. The latter is generally used throughout literature to refer to the capital provided to realize a goal, often up-front and regardless of an expectation of financial gain; but it is also referred to as the source of capital that ultimately re-pays for the up-front costs of construction and the financing costs (O'Brian & Pike, 2019). This use of the word funding is similar to the second meaning of the word financing as defined by the Cambridge dictionary (n.d.): "(1) the act or process or an instance of raising or providing funds, or (2) the funds raised or so provided"; while the first meaning is predominant in the few cases where the definition of financing is addressed in literature.

Within the context of infrastructure, O'Brien, O'Neil & Pike (2019) define financing as "organizing the capital investment in infrastructure and meeting its costs"; but more elaborate definitions can be found, which describe said organizing as "the packaging up of infrastructure projects by actors with risk, return and maturity profiles to attract financial institutions to provide investment capital" (Allen and Pryke, 2019, as cited in O'Brian & Pike, 2019). Financing can thus be viewed as the process of raising and structuring capital for any specific purpose, or the capital raised through this process. For the sake of clarity, the term *financing* will be used throughout this master's thesis as the process of raising and structuring capital, while *funding* will refer to the capital provided by this process; the term *capital* itself will refer specifically to financial capital.

But the digitalization of the financial sector has introduced new ways of raising financial capital. Gomber, Koch, & Siering (2017) go on to define digital financing as "all digital types of making available financial capital, such as digitalized services in the area of factoring[2], invoicing, leasing, and crowdfunding". The latter specifically has many variations, which will be discussed further in the next sub-section.

[2] "type of supplier financing in which firms sell their creditworthy accounts receivable at a discount (generally equal to interest plus service fees) and receive immediate cash'' (Klapper, 2006)

2.1.1. Crowdfinancing

Internet technology has facilitated the exchange of information and cross-border payments in a way that is unprecedented, mainly because it removed pre-existing barriers for people to interact with each other. This has organically given rise to individuals pooling resources with a common purpose over the internet, initially through informal arrangements in forums and chat rooms and later through web-based platforms, the first being launched in 2009 by Grow VC (Kukkosuo, 2009).

Crowdfunding is often described as the coming together of crowdsourcing (the collection of contributions from a large group of people to achieve a big task) and microfinance (the lending of small amounts of capital to individuals that are unable to access conventional sources of finance) (Harrison, 2013) and is generally used as an umbrella term for a wide range of fundraising practices in an online environment. A definition of this term that is often cited in literature describes crowdfunding as "an open call, mostly through the Internet, for the provision of financial resources either in the form of donation or in exchange for the future product or some form of reward to support initiatives for specific purposes" (Belleflamme, Lambert, & Schwienbacher, 2014). Crowdfunding is further broken into 5 different business models as depicted by Harrison (2013): (1) donation crowdfunding, for the provision of funds with a philanthropic character for not-for-profit purposes; (2) reward-based crowdfunding, offering contributors a nominal token (e.g. early access to a service, an acknowledgement of contribution) for their funding; (3) pre-purchase crowdfunding, providing the contributor with the product that is being produced; (4) lending crowdfunding, allowing contributors to receive interest on their investment[3]; (5) equity crowdfunding, offering investors a stake or share of the profits in the project or company that is to be funded. However, the lines between the different business models of crowdfunding are blurred, since contributors driven by financial rewards are also found to consider non-monetary aspects in their investment decisions (Ordanini et al., 2011), to a greater extent than professional investors (Vismara, 2019).

Additionally, within an entrepreneurial context, Mollick (2014) defines crowdfunding as "the efforts by entrepreneurial individuals and groups – cultural, social, and for-profit – to fund their ventures by drawing on relatively small contributions from a large number of individuals using the

[3] Investing is the act of allocating funds to an asset or committing capital to an endeavour (a business, project, real estate, etc.), with the expectation of generating an income or profit. In colloquial terms, investing can also mean putting in time or effort - not just money - into something with a long-term benefit, such as an education (Investopedia, n.d.-a)

internet, without standard financial intermediaries". However, the author highlights the fact that his definition is somewhat limiting, because initiators (as I will refer to individuals or companies seeking funding through crowdfunding) may have more goals for the crowdfunding effort than merely acquiring funding; they may want to demonstrate market demand and create interest in the project in the early stages of development. Nevertheless, since contributors in lending and equity crowdfunding participate in the crowdfunding process with the main purpose of investing, with the expectation of financial rewards (Ordanini et al., 2011), and in accordance with the previous definition given for financing, the process of raising and structuring capital by means of lending and/or equity crowdfunding will be referred to throughout this master's thesis as *crowdfinancing*.

2.1.2. Crowdfinancing renewable energy infrastructure

The growth and potential of the crowdfinancing market has been acknowledged by academics, as "the data show that equity crowdfunding will likely pose great challenges for venture capital (VC) and business angel financiers in the near future" (Vulkan, Thomas & Fernandez, 2016), but the potential of crowdfinancing to provide (part of) the energy infrastructure financing necessary to support economic growth while meeting energy sustainability[4] goals remains unexamined. Even within the wider context of infrastructure as a general term there is limited literature available, but Gasparro (2016) did identify potential social and long-term benefits of integrating project finance and crowdfunding (as an umbrella term) for infrastructure projects, such as: (1) reducing demand risk, (2) increasing political will, (3) improving civic decision making and (4) providing strategic financing, by means of four case studies of municipal infrastructure projects that were successfully financed through crowdfunding in the US and the UK. But these rather small-scale projects do not produce direct financial benefits and most fall therefore within the civic crowdfunding category[5], for which there is little evidence supporting its use for major infrastructure projects (Sedlitzky & Franz, 2019); absent financial rewards, philanthropy is more influential than personal interests as social and spatial proximity decreases, thus the potential of civic crowdfunding is limited by disposable income and distance factors. But infrastructure projects that produce revenue streams, such as in renewable

[4] Sustainable energy implies energy that "meets the needs of the present without compromising the ability to meet the needs of future generations" (International Institute for Sustainable Development, n.d.)

[5] Similar to donation crowdfunding, civic crowdfunding bears a charitable character, as the fundraising has a social aim or targets the financing of a public good, without the expectation of financial returns (Sedlitzky & Franz, 2019)

energy production, are not dependent upon disposable income and can instead be a good fit for crowdfinancing.

In the following sub-sections, the benefits of adopting crowdfinancing in the renewable energy sector will be discussed.

2.1.2.1. Increased innovation

Studies on general crowdfunding practices show that the input of the crowd can be of great value even in highly subjective environments. Mollic & Nanda (2016) find that “crowdfunding can play an important role in complementing expert decisions, particularly in sectors where the crowds are end users, by allowing projects the option to receive multiple evaluations and thereby lowering the incidence of false negatives”, which highlights the role of crowdfunding in democratizing entry among projects that might otherwise have been rejected, allowing for increased innovation quality through the actualization of more diverse ideas. Their study also shows a statistically significant congruence between crowdfunded projects and positive evaluations from experts, with increased prediction rates of project success when the judgement from both the crowd and experts is utilized for project screening. Consequently, the “wisdom of the crowd” could supplement experts’ decisions on project (re)development, leading to more innovation as a result. This is of great relevance for innovative SMEs, since they suffer from a structural problem in the financial system which restricts them from accessing financing, especially after the financial crisis (Lee, Sameen & Cowling, 2015).

2.1.2.2. Reduced community risks

Energy projects can sometimes affect their immediate environment (e.g. windmills can cause noise and visual pollution) and encounter opposition by local inhabitants. This can be detrimental for project development and cause delays, sometimes even completely freeze the undertaking. But involving the locals in the project and encouraging their (financial) participation can stimulate support from them. Namely, Ordanini et al. (2011) find that contributors that identify themselves with a project act as agents of the offering and engage in promotion organically. In civic crowdfunding, a variation of crowdfunding that is similar to reward-based crowdfunding when the supporters are predominantly local citizens, the locals are more engaged in the urban development process and therefore the results are more beneficial to and accepted by the community (Sedlitzky & Franz, 2019).

2.1.2.3. Sustainable development by empowering the crowd

Crowdinvestors have shown to be less profit-driven than professional investors, as they value sustainability and community orientation more in their investment decisions (Vismara, 2019). Hence, crowdfinancing can be utilized to facilitate the collective effort of many small investors and bring together demand and supply in capital markets – a demand for renewable energy projects from countless citizens driven by more than financial rewards and a supply of otherwise difficultly financed energy projects that do not fit the investment criteria of a powerful minority of individuals and institutions. This organization of the crowd's efforts would then allow society to bypass current bottlenecks of the energy transition due to financing gaps and never-ending political debates, by facilitating investments in sustainable development with regards to an arguably inevitable transition away from fossil fuels.

2.2. Blockchain technology

A blockchain is an integration of peer-to-peer networks and public key cryptography that is described as a distributed ledger that records transactions between network participants, which are verified and added to the blockchain according to a majority consensus mechanism (Gatteschi et. al, 2018). The first application of blockchain technology took place in 2009 with the birth of Bitcoin, a decentralized, transparent, immutable, censorship-resistant digital currency that for the first time allowed people to transact with each other over the internet without the need for trusted intermediaries. This financial innovation kickstarted what is considered by many a financial revolution and has already moved past its application for currency to the finance sector.

2.2.1. Smart contracts

Second generation blockchains made it possible to deploy smart contracts, which are "pieces of code stored on the blockchain that are programmed to behave in a given manner when certain conditions are met and can be executed automatically without control of a third party" (Gatteschi et. al, 2018).

But what is game changing about smart contracts running on decentralized protocols is that they redefine the way in which agreements are settled. A traditional contract is nothing more than an binding agreement between two or more parties about their future actions and is only effective as long as a third party (e.g. the legal system) is able to enforce it, while there are no guarantees that any of the parties involved will live up to their promises and thus a certain degree of trust is always required. On the other hand, a blockchain-based smart contract restricts the actions that the participating parties are able to take and self-executes based on a set of immutable rules previously agreed upon. This opens up a world of possibilities with regards to trustless transactions between parties unknown to each other and without the need for intermediaries, which facilitates a variety of use cases in digital finance, such as decentralized exchanges, collateralized loans, liquidity pools and crowdfinancing mechanisms.

2.2.2. Blockchain-based crowdfinancing

2.2.2.1. Benefits relative to current crowdfinancing models

The challenges of current crowdfinancing models (see *figure 3*), as introduced in section 1.1, can restrict a sustained growth of the crowdfinancing market and thereby its ability to give a meaningful boost to the energy transition. But blockchain technology offers potential solutions to these problems.

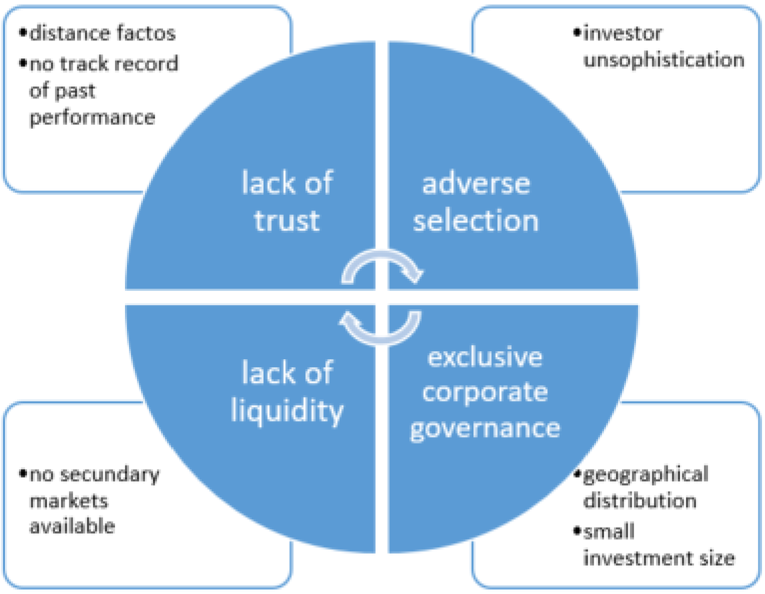

Figure 3: Challenges of current crowdfinancing practices (in blue) and the causes thereof (in white)

Zhu & Zhou (2016) find that with regards to the illiquidity problem, blockchain-based crowdfunding platforms are a superior alternative to centralized solutions proposed by some scholars; among others, distributed ledger technology provides the transparency, integrity, data security and anti-tampering and anti-forgery features necessary for a "credible, affordable and efficient third-party system for equity transactions and settlements of these transactions". Similarly, in a review of the current state of research on Digital Finance, Gomber, Koch, & Siering (2017) highlight the need for research in "the application of the blockchain technology for providing secondary markets for crowdinvesting", thereby linking the technology with Digital Financing - one of the business functions of Digital Finance. Zhu & Zhou also suggest the use of a blockchain-based voting system to facilitate the participation of investors from different regions in corporate governance in an efficient and low-cost way, which redistributes voting power to their rightful owners.

On the other hand, the literature also argues that the adverse selection problem requires more investor protection in the form of further post-campaign monitoring of firms in order to ensure a sustainable crowdfinancing market (Walthoff-Borm et. al, 2018). But this approach circles back to increased intermediation and regulatory oversight, resulting in additional costs with a source of funding that is already down in the ranking order relative to other sources in terms of cost of capital.

The issue of lack of trust seems to remain unaddressed by extant literature.

2.2.2.2. Downsides relative to current crowdfinancing models

Social exclusion

Whenever a new technology is presented to the public, it takes some time for it to be widely adopted and the older generations are often the last ones to assimilate disruptive changes. Therefore, using blockchain technology as a tool to share the benefits of renewable energy production with local communities can be selective at first towards the first adopters of the technology. This issue has already been identified with the utilization of civic crowdfunding for the strategic involvement of crowdinvestors in urban development projects, since the participation process can be socially selective towards investors that can and want to be part of the process, thereby degrading the external validity of their collective feedback to the project as a result of issues of accessibility and representation (Sedlitzky & Franz, 2019). Thus, using blockchain-based crowdfinancing to target specific groups (e.g. local inhabitants affected by a project) could be ineffective if the targeted investors are not comfortable with or able to use blockchain technology.

Irreversible transactions

One of the added values of a distributed ledger is the immutability of its data, since transactions cannot be reversed unless there is majority consensus among network validators to invalidate part of the transaction history. Achieving this consensus is extremely difficult and costly, if at all possible, which makes reversing small transactions a practical impossibility. Consequently, blockchain-based crowdfinancing entails that participants are exclusively responsible for their transactions and their security. This could be a deterrent for participation, for both investors and project initiators, since there is no central authority to appeal to in case of mistaken or unauthorized transactions. Namely, our society is accustomed to centrally controlled (financial) systems (e.g. credit cards, banks, payment processors) and thus not everyone might be willing to assume the increased responsibilities that individual actors have in decentralized networks.

Smart contract failure

Smart contracts can fail if hackers find a vulnerability to exploit, so a thorough audit should take place before deploying any unproven contract. This risk increases considerably for decentralized autonomous organizations (DAOs) if funds are locked in a contract, because hackers have incentives and time to find vulnerabilities. These failures have happened in the past, especially in the early days of smart contract development (Coindesk, 2016), but have become less common as the industry matured. Nevertheless, this risk is always present with open source systems and it should be properly mitigated.

3. Analysis of the energy market

The Dutch energy market is a complex system of interrelated actors that has evolved considerably over the last two decades. In this chapter a comprehensive overview of (the evolution of) this market's organization is provided as a foundation for the research. To this end, the analysis has been broken down into three corner stones: market roles, energy production and financing.

3.1. Market roles

3.1.1. Market roles in the early days

Before the industrial revolution humanity's energy production was fully decentralized, as heat and lighting were sourced from burning wood and animal fats/oils (The Historical Evolution of Lighting, 2019) for small scale use. But the industrial revolution allowed us to take advantage of the added benefits of the economies of scale of centralized energy production from fossil fuels: the invention of the modern steam engine and the electric generator made power plants possible, while natural gas could also be gathered from gas wells, processed, transmitted over long distances and ultimately distributed to individual homes by local distribution companies (American Gas Association, 2019).

The first initiatives for the large-scale supply of energy in the Netherlands were taken by individuals – entrepreneurs engaging in commercial practices to provide a necessary service – with the first power plant being launched in Rotterdam in 1886. However, in 1895 the municipality of Rotterdam took over the supply of electricity and other municipalities followed at the beginning of the 20th century (CBS, 2015). In 1920 a total of 550 electricity production companies existed, but a trend towards centralization started to arise and municipal energy companies started fusing together into regional and provincial companies, all directly or indirectly controlled by municipalities and provinces. In 1949 the 10 biggest electricity suppliers established the public limited-liability company (LLC) Samenwerkende ElektriciteitsProductiebedrijven (SEP) to jointly steer the production of electricity and the construction of new power plants, while the process of centralization continued until only 4 energy companies remained in 1988 (LAKA, 2008).

The organization of the energy market was based on an all-encompassing top-down approach where all matters related to energy – from technology advancement to environmental effects – were dependent upon government action. This was clearly not an ideal situation but fossil fuels were cheap and carbon emissions were not a mainstream concern throughout most of the 20th century.

With regards to the flow of capital, the energy companies had complete monopolies of the energy supply chain – from production to transmission, distribution and retailing – in the region where they operated, thus consumers could not choose the source or provider of their energy and the prices thereof were imposed upon them (De Energiegids, n.d.). Since energy companies were state-owned, their projects were funded with public funds – financed through taxation or issuance of government debt. A simplified representation of the exchanging relationships that took place back then are depicted in Appendix A – section A.1 and *figure 4*.

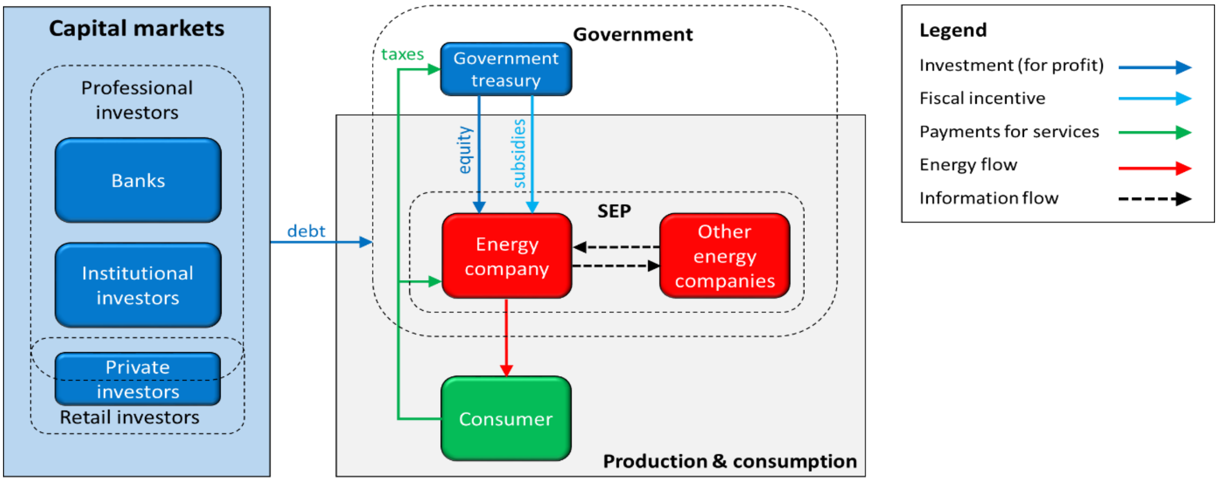

Figure 4: organization of the energy market in the early days. Drawn from *(CBS, 2015), (De Energiegids, n.d.), (Energiewijzer, n.d.), (Innova Energie, n.d.), (Investopedia, n.d.-a), (Investopedia, n.d.-b), (Investopedia, n.d.-d), (LAKA. 2008), (NVP, n.d.), (Rijksoverheid, 2019), (Robeco, n.d.)*

3.1.2. Market roles after the 1990's

The state-owned energy companies mentioned earlier were considered slow, inefficient and lacking transparency, which gave rise to a trend in politics towards liberalization and privatization in the late 1980s (Energy Watch, n.d). These concerns were proven right, since the SEP could not cope with developments in the energy market: starting in the 1990s the private sector was allowed to produce electricity from their wasted thermal energy by means of combined heat and power plants and feed it into the electricity grid, while the SEP continued to build redundant power plants (Joosten, 2019). Consequently, the energy market was liberalized with the electricity and gas laws of 1998 and 2000 respectively by allowing consumers to choose their own suppliers of energy (LAKA, 2008). Subsequently, most municipalities sold the production and retailing side of the energy companies to the private sector, but were required by law to keep majority shares in the regional distribution system operators (DSOs), while the transmission system operator (TSO) remained 100% in the hands of the state (Innova energie, n.d.). A subsequent law called "Wet Onafhankelijk

Netbeheer (WON)" came into effect in 2011, which required energy companies with both roles of network operator and energy supplier to split into independent entities, thereby decoupling the roles of network operators from energy suppliers entirely (Energiewijzer, 2019). These laws liberalized and privatized the supply of energy but kept the maintenance and operation of the connecting infrastructure (the national transmission system and regional distribution systems) as a responsibility of the state and local governments respectively.

This re-structuring of the energy market allows public bodies to keep oversight of the market and arguably safeguard public interests by maintaining control of the connecting infrastructure, given its inherent characteristic of natural monopoly[6], while creating a level playing field for the private sector to innovate and compete. However, since the private sector is primarily driven by profit generation, in order to stimulate the energy transition the government had to incentivize investments in renewable energy. To that end, different forms of subsidies and exemptions were created to remove the unprofitable component of investments in renewables and accelerate innovation and adoption (e.g. solar panels are 5 times cheaper today than 15 years ago, when subsidies for solar panels in households were introduced [GreenHome, 2019]). Thus, public funds are still the source of capital for the (re)development of connecting infrastructure, but also for the subsidies geared towards supporting specific government policies, such as the *Stimulation of Sustainable Energy Production (SDE+)* for the generation of renewables, which at the moment favor a transition towards renewables.

With regards to the private sector, the liberalized market economy allowed more parties to be involved in different stages of the energy supply chain and new roles to emerge. Production and retail of energy are not done necessarily by the same parties anymore – the third biggest energy retailer of the Netherlands does not produce any energy but acquires it from the market (Goedkope Energie & Gas, n.d.) – and energy is traded on international exchanges, since many neighboring countries are connected to the same international grids. Subsidies aside, all these activities are being

[6] Given the high capital investment (CAPEX) required for new energy transmission and distribution systems, it would be impractical to have more than one company running the system.

financed by means of private capital. A simplified representation of the exchanging relationships that take place in today's market are depicted in Appendix A – section A.2 and *figure 5*.

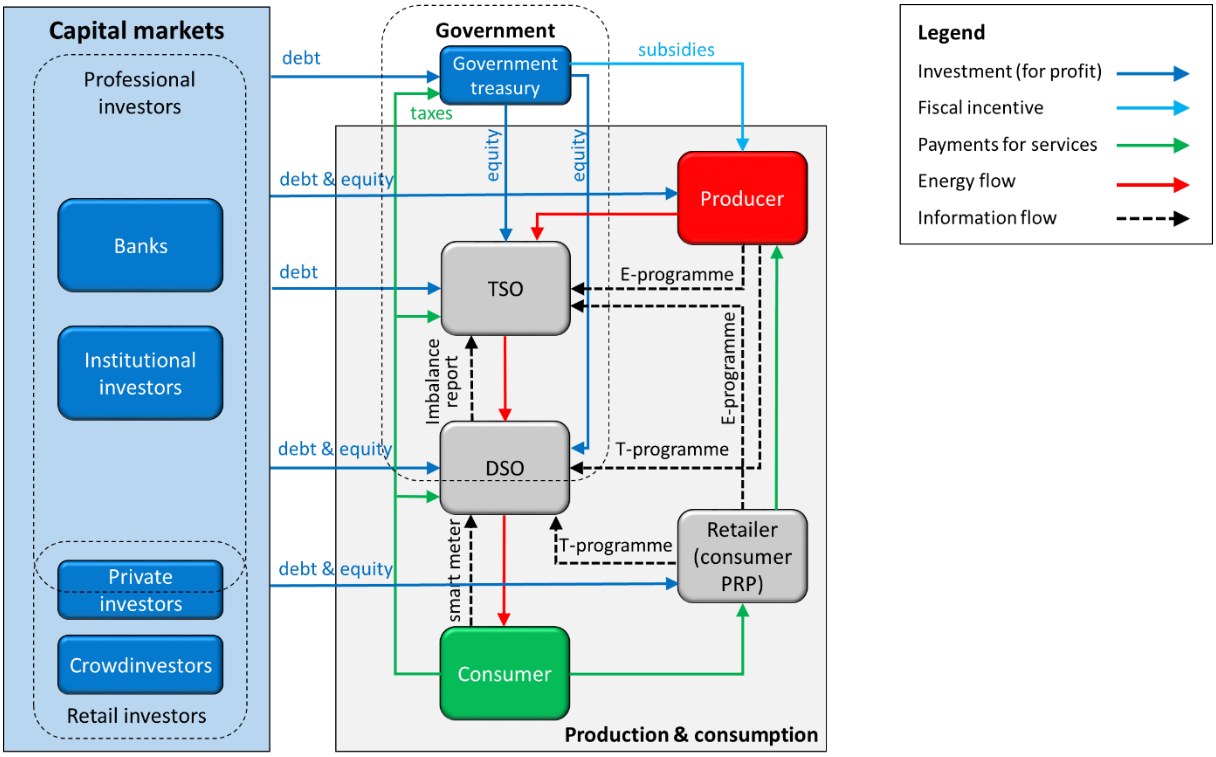

Figure 5: organization of the energy market after liberalization and privatization, with the energy retailer as Programme Responsible Party (PRP). Drawn from *(CBS, 2015), (CBS, 2018), (CBS, 2019-a), (de Brauw, n.d.), (De Energiegids. (n.d.), (Energiewijzer, n.d.), (Essent, n.d.-a), (Goedkope Energie & Gas, n.d.), (Independer, n.d.), (Innova Energie, n.d.), (Investopedia, n.d.-a), Investopedia, n.d.-b), (Investopedia, n.d.-c), (Investopedia, n.d.-d), (LAKA. 2008), (NVP, n.d.), (RVO, n.d.-b), (RVO, n.d.-c), (RVO, n.d.-d), (Rijksoverheid, 2019), (Robeco, n.d.), (Tennet, n.d.-a), (Tennet, n.d.-b), (Tennet, 2018), (Wenting, 2002)*

Prosumer economy

The introduction of subsidies and new market rules (e.g. feed-in tariffs[7]) for renewables stimulated the production of energy by the consumers themselves, as their production is deducted from their consumption (Essent, n.d.-b), while also being rewarded for overproduction (Energievergelijkers, n.d.). This effectively made them *prosumers*, which entails that consumers are investors, producers and consumers at the same time. A simplified representation of the exchanging relationships with this market organization can be found in Appendix A – section A.3. The term

[7] When there is overcapacity (production surpasses consumption) consumers are compensated for their feeding back into the electrical grid at a reasonable rate

prosumer is often used to refer to households and companies, but new forms of prosuming have emerged in the renewable energy market, such as:

- Local production through energy cooperatives: groups of households team up to produce energy in their own neighborhoods by leveraging unused spaces (e.g. industrial rooftops) for larger scale production. A tax benefit exempts them from paying taxes on their produced energy and each member has rights to the production proportional to his/her investment (Postcoderoosregeling, n.d.). But the cooperative has to collaborate with an energy retailer in order to settle their production and consumption in their energy bill. A simplified representation of the exchanging relationships with this market organization can be found in Appendix A – section A.4.
- Remote production through retailers: some energy retailers offer their customers the possibility to buy sun certificates (pieces of the production of solar power plants in remote locations), thereby allowing projects to leverage economies of scale and prosumers to produce energy by proxy, by transferring the responsibilities of production to a third party (e.g. Vrijopnaam). A simplified representation of the typical exchanging relationships with this market organization can be found in Appendix A – section A.5.
- Crowdfinanced production: consumers invest in renewable energy projects through crowdfinancing mechanisms. The revenues from the production are then wired to their bank accounts (e.g. with the company Solar Greenpoint). A simplified representation of the typical exchanging relationships with this market organization can be found in Appendix A – section A.6.

The Dutch energy market thus consists of several key players that are active in different environments, at different times and for different reasons. A description of these key players can be found in Appendix B.

These trends are showing fundamental changes in the role of the consumers in the energy market, as they go from having a peripheral role to becoming the fuel of the transition. Namely, they are not just influencing the market by choosing green energy retailers as their PRPs, but are financing, producing and even becoming retailers of renewable energy themselves (e.g. Energie Vanons, OM nieuwe energie).

3.2. Energy production

The liberalization and privatization of the energy market have facilitated competition among emergent market players, as any legal person can assume the responsibility of managing a physical connection to the energy grids (e.g. electricity, gas, district heating) for the supply and/or consumption of energy. The legal person has to be registered with the TSO as the *Programme Responsible Party (PRP)* and inform them by means of E-programmes[8] of their planned transactions with other PRPs (Wenting, 2002); namely, all market parties in the Netherlands are free to buy or sell energy among each other (Tennet, n.d.-a). At the end of each day the TSO charges PRPs for any imbalance in the grid created by discrepancies between their E-programmes and the actual consumption. Due to the complex responsibilities of PRPs and the small net potential savings for small consumers the role of PRP is generally outsourced to third parties (primarily to energy retailers), but the fact remains that access to the grids is unrestricted and anyone can become a market participant.

These developments have coincided with the transition to renewables, which are inherently decentralized sources of energy (relative to fossil fuels) due to space restrictions and their often-distributed availability. Production from these sources does gravitate towards certain degrees of centralization due to economies of scale and better locations (e.g. offshore wind), while some energy sources are only available on specific locations (e.g. hydro power). The degree of decentralization for each source of renewable energy is shown in *figures 6-12* based on the current production supported by the SDE+ subsidy.

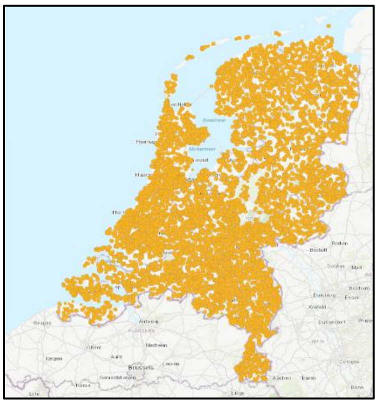

Figure 6: Production from **solar** energy (RVO, n.d.-d)

Figure 7: Production from **wind** energy (RVO, n.d.-d)

Figure 8: Production from **biomass** (RVO, n.d.-d)

[8] The sum of all transactions entered into by each PRP is called an Energy Programme or E-Programme (Tennet, n.d.-a).

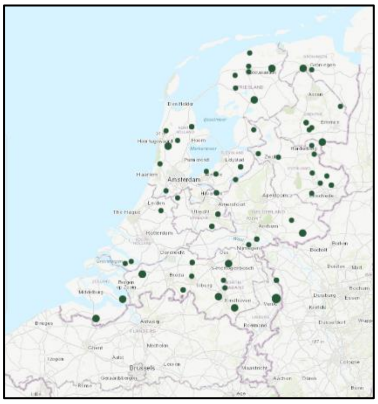

Figure 9: Production from **biogas** (RVO, n.d.-d)

Figure 10: Production from **geothermal** energy (RVO, n.d.-d)

Figure 11: Production from **waste** (RVO, n.d.-d)

Figure 12: Production from **hydro** power (RVO, n.d.-d)

The liberalization and privatization of the energy market have thus allowed new production models to emerge organically, depending on energy source and local market conditions, resulting in a mix of different energy production technologies implemented throughout the Netherlands.

3.3. Financing

Since producing renewable energy is not profitable for most projects yet, they rely on subsidies to achieve a positive business case. The most prominent subsidy is the SDE+ (to become SDE++ in 2020), which together with preceding subsidy programmes (SDE and [OV]-MEP) is currently facilitating the yearly production of 15,76 $*10^9$ kWh from renewable energy sources (RVO, n.d.-e). This constitutes 36% of all renewable energy production and in case of renewable electricity specifically, 76% (CBS, 2019-a); therefore, throughout this thesis I base my analysis on the premise that this is the subsidy of choice for new projects. But besides subsidies, the rest of the capital required for project development needs to come from somewhere; this section provides clarity into the sources of funding available.

Banks have historically been the main providers for debt in the capital markets and continue to be today, but after the banking crisis of 2008 their risk exposure had to be reduced; their acceptance criteria have been consistently tightened and companies are being monitored more strictly (CBS, 2018). Consequently, the banks' share of the financing market has been decreasing, while the biggest SMEs and corporations are opting for corporate bonds instead (see *figure 13*).

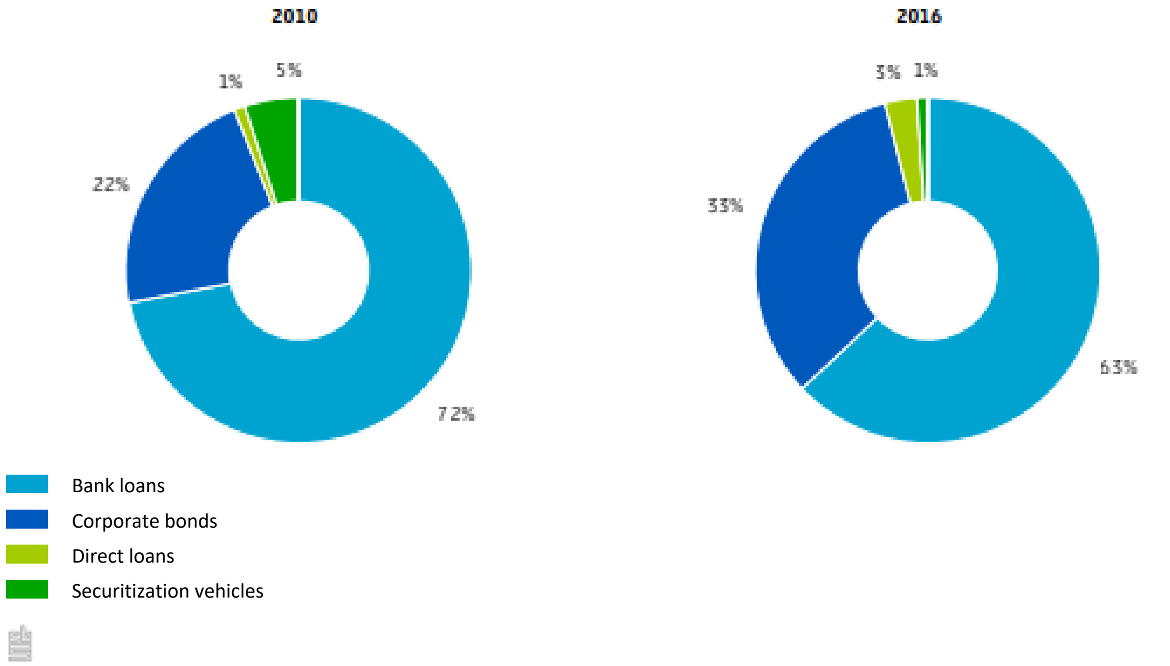

Figure 13: Sources of capital in the Dutch financing market. From *(CBS, 2018)*

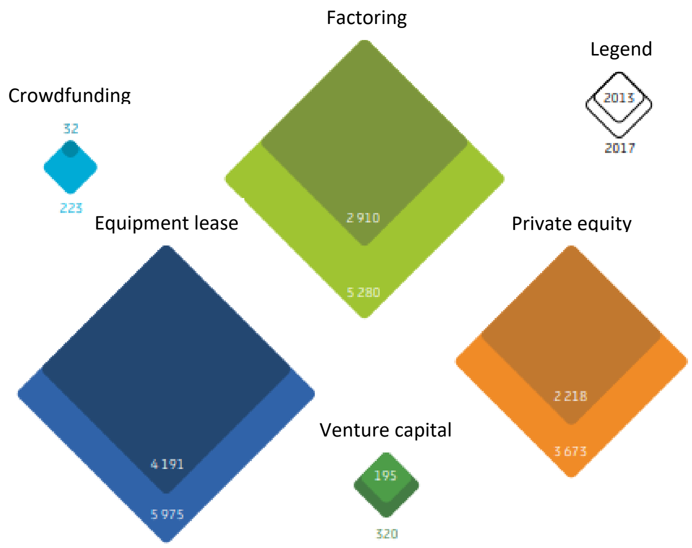

Figure 14: Alternative sources of capital (million EUROS), 2013-2017. From *(CBS, 2018)*

In turn, the smaller ventures are relying the most on alternative sources of capital, such as factoring, equipment lease, private equity, venture capital and crowdfinancing; the latter has had the most growth percentage wise since 2013 (see *figure 14*). In the next sub-section I zoom in further into this source of capital.

3.3.1. Crowdfinancing

In the crowdfunding market funds are raised for several types of projects, but the data shows that the bulk of funds go to business ventures (see *figure 15*). It is also striking that loan-based crowdfinancing takes up most of the market share (see *figure 16*), which shows that crowdfinancing is being used primarily by SMEs to acquire capital for their projects, absent access to bank loans.

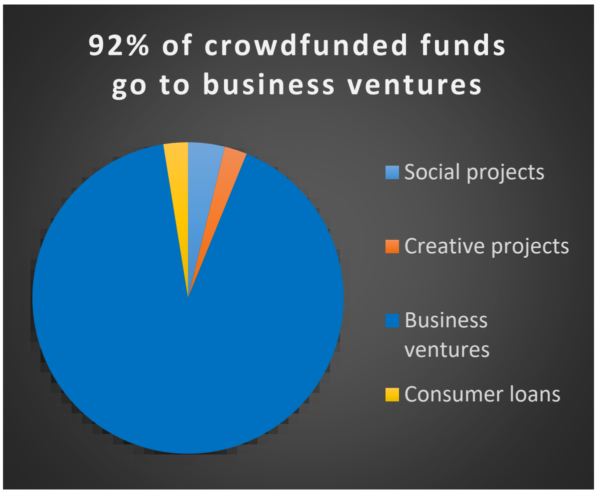

Figure 15: market share of the different project types. Data from *Crowdfundingcijfers.nl*

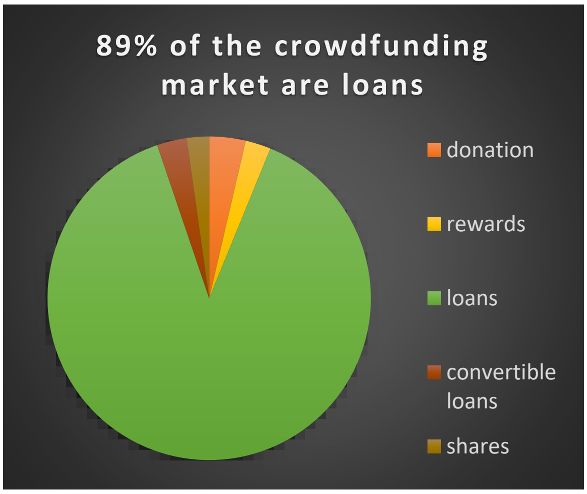

Figure 16: market share of the different crowdfunding categories. Data from *Crowdfundingcijfers.nl*

But zooming in further reveals that 35% of the crowdfinancing market consists of sustainable investments, of which 75% go to renewable energy projects (ASN Bank, 2019). These projects raise on average € 400.000 and are therefore generally too small to have access to bank loans – banks only finance (bundled) projects starting at € 1-2 million (Hier opgewekt, 2016; Zonnepanelendelen, 2018) – so they have to bear the higher interest rates that crowdinvestors require. Also, the brokerage fees should be taken into account.

3.3.1.1. Current (direct) costs of crowdfinancing

Taking a closer look into the costs incurred by projects raising funds through crowdfinancing platforms, it can be seen that the net cost of borrowing lies considerably higher. Appendix C shows a breakdown of the cost of crowdfinancing for 5- and 15-year loan terms, for both borrowers and lenders, through different platform types and sizes. An extract of the calculation for a € 400.000 loan at a 5% interest rate is displayed in *table 1*, showing that during a 5 year term a non-profit platform (Greencrowd) charges 3.24% in brokerage fees to borrowers, while the for-profit platform with the most volume charges 4.80% (Geldvoorelkaar); the same loan but during a 15 year term would cost borrowers 3.43% and 6.20% on the respective platforms. These brokerage fees will be brought into perspective by looking at a project's ability to cover them.

	Investment platform				
Platform details	**Geldvoorelkaar**	**NPEX**	**Oneplanetcrowd**	**Greencrowd**	**Greenfundholland**
Type	Crowdfinancing (market leader)	Securities exchange	Crowdfinancing	Crowdfinancing (non-profit)	Crowdfinancing
5 year loan term					
Net cost of borrowing (excl. tax shield)	9.80%	18.76%	10.82%	8.24%	15.99%
Brokerage fees for borrower	4.80%	13.76%	5.82%	3.24%	10.99%
Net rate of return (excl. loan defaults)	3.27%	0.90%	2.85%	5.00%	2.82%[1]
Brokerage fees for lenders	1.73%	4.10%	2.15%	0.00%	0.00%
15 year loan term					
Net cost of borrowing (excl. tax shield)	11.20%	26.78%	14.02%	8.43%	23.36%
Brokerage fees for borrower	6.20%	21.78%	9.02%	3.43%	18.66%
Net rate of return (excl. loan defaults)	2.69%	-2.73%	0.07%	5.00%	2.82%[1]
Brokerage fees for lenders	2.31%	7.73%	4.93%	0.00%	0.00%

Table 1 (extract of appendix C.1): cost of crowdfinancing for a € 400.000 loan at a 5% interest rate. Data from *geldvoorelkaar.nl, npex.nl, oneplanetcrowd.com, greencrowd.nl and greenfundholland.nl*

The calculations for the SDE+ subsidy are based on the assumption of 12-15% required return on investment for equity investors in the renewable energy sector, depending on the energy source, from which the participation costs[9], brokerage fees and project development costs have to be paid (PBL, 2018). Based on the further assumption that bank loans can be obtained for 70-80% of the capital investment at a 2.5-3% rate, the SDE+ currently calculates (and subsidizes) an after-tax WACC of 3.9-6.1% for the average project, depending on the energy source. This after-tax WACC can thus be viewed as the internal rate of return (IRR)[10] of an average project. Consequently, a hypothetical project without access to bank loans would only be incentivized to utilize crowdfinancing if they

[9] Participation costs are the costs incurred by infrastructure projects to inform local inhabitants about project development and involve them in the process. All on-shore wind projects in The Netherlands are required to do this by law (NVDE, 2019)

[10] The IRR is a metric used to evaluate the return of a potential investment, i.e. the discount rate at which the net present value (NPV) of a projects' projected cash flows equals zero (Investopedia, n.d. -f).

don’t have enough funds to meet the required private equity, or if the project’s IRR is equal or greater to 25% less than the net cost of borrowing (taking a 25% tax shield into account), thereby allowing the use of borrowed money as leverage. The latter implies that issuing debt on existing crowdfinancing platforms cannot be used as leverage for the average renewable energy project, even in the riskier categories (IRR=6.1%); without leverage it’s difficult to cover the participation and project development costs while still providing acceptable returns for equity investors.

These facts suggest that an average renewable energy project using the SDE+ subsidy is not likely to be financed through a crowdfinancing platform, or at least not entirely, as the brokerage fees would be too high and therefore the return on equity too low for equity investors. Unsurprisingly, many renewable energy projects are making use of loan-based crowdfinancing mechanisms with rates of return based on project revenues (ASN Bank, 2019). Nevertheless, the ability of platforms to match supply and demand seems to be valued by the market, as projects with business models that can afford the costs of crowdfinancing are still choosing this alternative. Namely, 90% of all crowdfinancing for sustainable projects goes through platforms, while the other 10% goes through individual websites of mainly energy cooperatives (ASN Bank, 2019); cooperatives have a specific target group, as they raise funds directly from their members (prosumers) and often make use of a different subsidy in the form of an energy tax exemption (i.e. the *Postcoderoosregeling*) (Hier opgewekt, 2018).

On the other hand, the available data shows interesting trends in the crowdfinancing market for renewable energy projects. Although the current interest rates in the overall crowdfinancing market are 6-8% (Investeerders, n.d.), a scan for crowdfinancing campaigns for renewable energy projects on existing platforms shows that these projects are often financed at 5% of less. This trend is clearly visible on the interest rates at which energy projects utilizing the SDE+ subsidy have been financed (see *figure 17*), showing a peak at 2.5-3% (bank loans) and another at 5%.

Additionally, although the net rates of return for loan-based crowdinvestors are often considerably lower than the nominal interest rates of their investments (See Appendix C or *table 1*), crowdinvestors are still showing high demand for new projects. The average duration of a crowdfinancing campaign has been reduced to hours (AFM, n.d.-d), while the average individual investment in a renewable energy project has increased to € 3.400, which is 2.43x the average for sustainable projects in general (ASN Bank, 2019). These trends are in line with literature findings on the non-monetary drivers of crowdinvestors (Ordanini, 2011; Vismara, 2019).

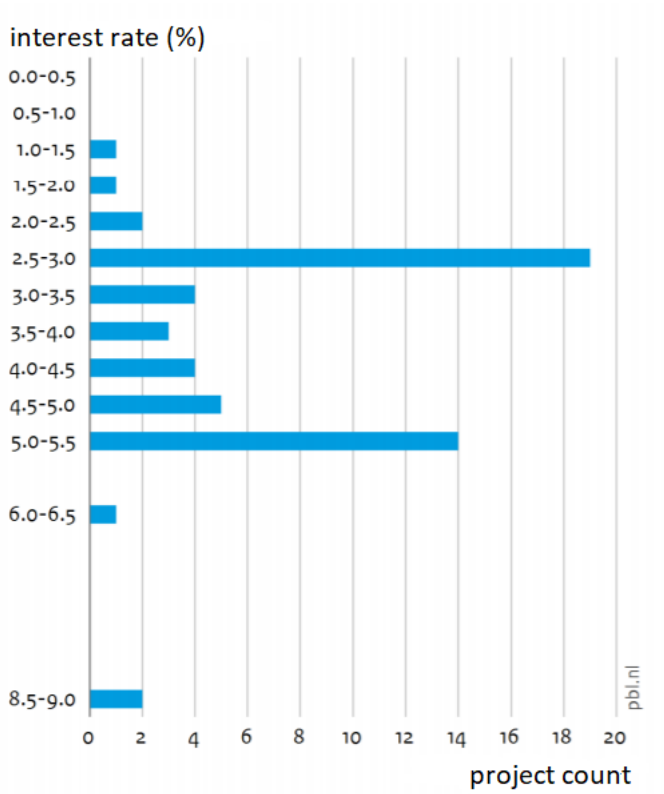

Figure 17: interest rates on loans for renewable energy projects utilizing the SDE+ subsidy in 2017. From *(PBL, 2018)*

3.3.1.2. Cost of liquidity

As was initially brought forward in the Introduction chapter, investments through current crowdfinancing platforms are highly illiquid, since there are often no secondary markets available. The bulk of loan-based crowdfinancing is taking place in the form of direct loans to projects instead of (tradeable) securities and thus the majority of platforms only have a permit for attracting redeemable funds (AFM, n.d.-f). This can arguably be a serious deterrent for the crowd to invest in renewable energy projects, since the possibilities to exit an investment are often limited, if at all available.

Some platforms do facilitate the issuance of securities, but there is almost never a liquid market available for trading. Whenever there is a market, such as with securities exchange NPEX, the brokerage fees to both borrowers and lenders are too high for the € 400.000 target that renewable energy projects seek to crowdfiance on average (see Appendix C; *table 1*). The costs of issuing bonds on the NPEX go down as the issue size increases (e.g. for the same bond issue shown in *table 1,* but with a size of € 4.000.000, the brokerage fees for the issuer are 5.07% for a 5 year loan and 6.35% for a 15 year loan), which demonstrates that liquidity is only provided at reasonable costs for the bigger projects. This explains why the increased share of corporate bonds in the financing markets (see *figure 12*) is mainly attributed to issues by the biggest SMEs and corporations (CBS, 2018).

3.3.2. Financing gap

In the previous sub-section it was shown how crowdfinancing is being used in the renewable energy market primarily by small projects without no access to bank financing. But the platforms' brokerage fees result in considerably high net costs of borrowing, thereby increasing the barriers to entry even more; hence, the difficulty and cost of financing for renewable energy projects does not only depend on risk, but also on project size. These findings are represented qualitatively in *figure 18*, where the availability of financing for small prosumers (for in-house production) is also included, since asset-backed loans are easily available and standard practice in the banking sector (Vereniging eigen huis, n.d.; Hier opgewekt, 2016). The financing gap then lies in the yellow zones, based on the premise that the red zones cannot be financed because of exceedingly high risks.

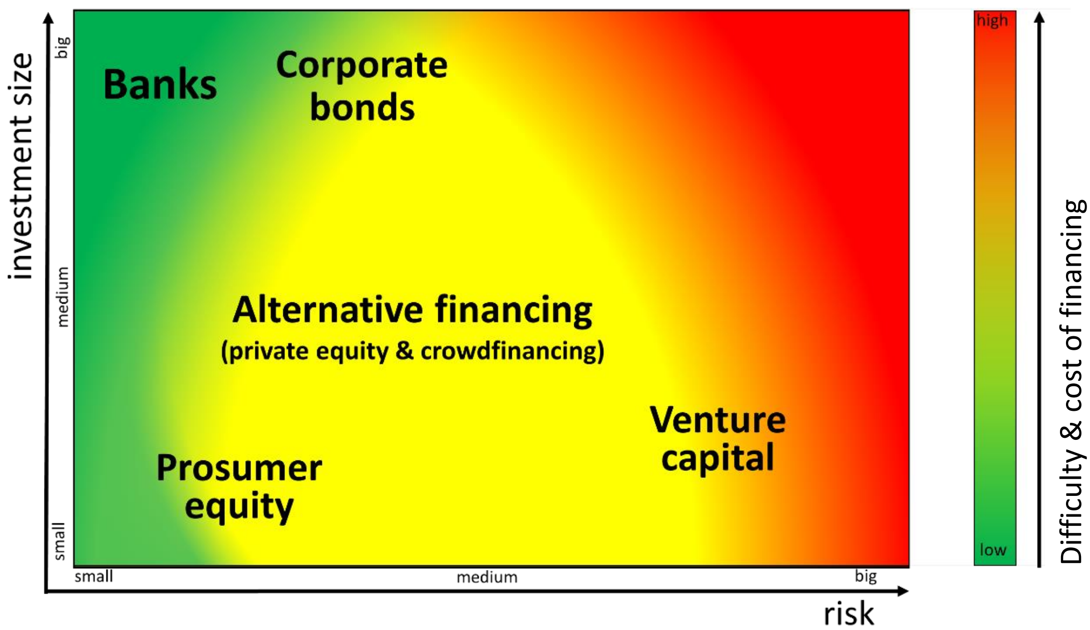

Figure 18: Financing availability heat map. Drawn from: *(CBS, 2018), (Compendium voor de Leefomgeving, 2018), (Crowdfundingcijfers.nl, n.d.), (Hier opgewekt, n.d.), (Investopedia, n.d.-a), (Investopedia, n.d.-c), (Investopedia, n.d.-d), (Lodders, 2019), (NVP, n.d.), (Overbeek, A., 2019), (Van der Geest, 2017), (Vereniging eigen huis, n.d.)*

The financing market for renewable energy is thus tailored towards the bigger projects. The banking system sets the interest rates and controls the money supply, and is therefore the most competitive source of debt, but they generally only provide loans for projects starting already in the 7 figures; this results in higher costs of capital in alternative markets for the smaller projects. On top of that, making use of existing liquid investment vehicles to raise funds is only affordable for the bigger projects as well. Lastly, the Dutch government does not take the higher cost of capital into account for the calculations of the SDE+ subsidy, even though according to their own reports the cost of debt is often considerably higher than assumed (PBL, 2018). Existing crowdfinancing platforms have been filling the financing gap whenever possible, but their brokerage fees are relatively high and arguably a bottleneck for further growth of the crowdfinancing market.

The background question for this research was *how is (and has been) the Dutch energy market organized, in terms of market roles, production and financing*. From the analysis presented in this chapter it can be concluded that the energy market has achieved a high degree of market role decentralization with the opening up of production and retail to the private sector. Production itself has become more decentralized as well due to inherent characteristics of renewables, which together with the indiscriminate access to the grids have allowed a wide range of production models to arise. But the financing of projects has remained dependent upon centralized financial intermediaries, as only low-risk, big-sized projects have access to bank financing or crowdfinancing with liquid secondary markets at reasonable costs.

4. Research methodology

This chapter constitutes the technical research design and is based on the work on research methodologies by Verschuren & Doorewaard (2010). It justifies the research methods chosen and the steps taken throughout this thesis.

4.1. Research strategy

This section describes the way each sub-question was approached in order to answer the main research question and achieve the research objective.

The first sub-question provides the theoretical foundation of the research. Desk research was carried out by utilizing relevant search methods in online databases and domains. Thus, in answering this question breath was chosen instead of depth in qualitative desk research, since a large-scale approach was necessary in order to capture the evolution and current state of the energy market from available documentation. The answer to this question is found in chapter 3.

The second sub-question required in-depth, qualitative knowledge of empirical nature obtained from a pilot study, where relevant market parties were interviewed with the aim of obtaining success criteria for crowdfinancing renewable energy projects. The answer to this question is found in 5.2.

The third sub-question required different research strategies. An answer to sub-question 3.a was found by performing qualitative desk research on existing smart contract applications that could be utilized to overcome the limitations of crowdfinancing identified by extant literature, which is found in chapter 6. Sub-question 3.b was answered by performing a stakeholder analysis, based on the theoretical analysis and the findings from the pilot study, from which the design requirements were deduced (see sub-section 7.1.1). The final answer to the third sub-question was found by translating the design requirements into conceptual designs for blockchain-based crowdfinancing mechanisms, which are found in section 7.1.

The fourth and last sub-question required breath again, as qualitative desk research was performed in order to quantify the costs and address the (legal) implications of implementing the mechanisms proposed. The resulting business case is found in section 7.2.

4.2. Preliminary research (pilot study)

This section deals with the design of the pilot study, whose purpose was to find out on empirical grounds, from the perspective of relevant market parties within the renewable energy sector, whether crowdfinancing is a promising alternative method to finance renewable energy projects in the Netherlands – this is a supplement to the theoretical analysis – and what the success criteria are the ideal crowdfinancing process.

4.2.1. Interview design

Semi-structured interview: this type of interview was chosen in order to generate qualitative data by means of open-ended questions. This provided the interviewer with flexibility to explore a spectrum of possible points of view of the interviewees, expressed in their own words, and to steer the conversation by asking for further explanation if necessary. Therefore, reliability was sacrificed for the sake of validity, thereby possibly allowing new ideas/topics to emerge that were not previously thought of by the interviewer. Nevertheless, an interview guide was prepared beforehand with a framework of topics and questions stemming from the theoretical analysis (see Appendix D), thereby ensuring a certain degree of structure by presenting each interviewee with the same core questions and in the same order.

The interview guide was structured according to the analysis of the energy market (see chapter 3), thus resting on three corner stones: (1) market roles, (2) energy production and (3) financing. Additionally, the guide was separated in three sections: (1) Evolution of the energy market (before and after privatization), (2) Energy transition and (3) Outlook for the future. These choices were made for the purpose of supplementing the theoretical analysis, thereby laying a firm foundation for the research, while stimulating the interviewees to think about the future of energy based on past and current trends and/or needs.

The questions in the interview guide consist of open-ended main and sub-questions that appear either as a clarifying or a probing question. Clarifying questions are meant to clarify facts, while probing questions stimulate creative and reflective thinking. By taking this approach interviewees were given the freedom to interpret and answer the main questions freely, while the sub-questions allowed the interviewer to steer the conversation towards topics of specific interest.

The interviews were performed in person and had an average length of 60 minutes.

4.2.2. Interview participants

Throughout the last two decades the energy market has changed considerably, as new market roles have emerged and a variety of production models are being used, so a further transition towards renewables can be expected to drive more changes. This state of high uncertainty makes it difficult to predict the future market organization and the parties that will take the initiative to produce renewable energy. Additionally, the use of blockchain-based crowdfinancing could facilitate the emergence of new business models and organizations for the production of energy never seen before, again making it hard to identify potential project initiators. Nevertheless, interviewing relevant participants in today's market environment can give an indication of the biggest challenges to overcome and the requirements for short term success. The following market parties were interviewed:

1. A municipality (potential initiator of big projects)
2. An energy supplier / retailer (potential initiator of big projects)
3. An entrepreneur in the development of new technologies (potential initiator of small projects)
4. A consultant (advisor for project initiators of all sizes)
5. A crowdfinancing platform (potential facilitator of the process)

Interviewees with different market roles were chosen with the aim to receive input from market parties with different perspectives on the energy market.

This pilot study is not quantitative research and therefore the concept of external validity does not apply. Instead, the transferability of the results is ensured by providing a comprehensive description of the research context (Statistics Solutions, n.d.), i.e. a thorough analysis of the energy market, which would provide readers with evidence that the research findings could be applied to other contexts. Nevertheless, the findings from the pilot study will only be deemed indicative, and not final, of current market conditions.

4.3. Desk research on reference smart contract applications

Research on the current state of the art in the blockchain sector was conducted in order to identify existing smart contract applications that provide potential solutions to the limitations of current crowdfinancing practices and could therefore be used as reference for the design of blockchain-based crowdfinancing mechanisms. It was chosen to focus on public blockchains because that would make it possible to utilize existing infrastructure that is free to use besides the relatively low transaction cost (see sub-section 7.2.4 for more details), thereby reducing investment costs while also avoiding the counter party risks associated with permissioned blockchains.

At the time of writing this thesis there are many blockchains available that support smart contracts, but this research is focused on the Ethereum blockchain because it is currently the biggest public blockchain with smart contract functionality in terms of daily trading volume and market capitalization (Coinmarketcap, n.d.). Ethereum is an open source protocol upon which developers can build products without permission or censorship, which has facilitated the adoption of finance related applications; at the time of writing this thesis there is more than $800 million US dollars in value locked in Decentralized Finance (DeFi) projects (Defi Pulse, n.d.). Additionally, Ethereum is set to transition towards *Proof of Stake* – a consensus algorithm that is considerably less energy demanding than *Proof of Work* – and would therefore not undermine the efforts to reduce carbon emissions by increasing energy consumption while fossil fuels are still the main source of energy.

4.4. Validation strategy

The validation of a system or product is normally performed by testing it in a user environment setup (test site or simulator) in order to evaluate whether it meets end-user and environment requirements. But since the smart contracts have not been built yet, a different approach was taken. A panel of experts with relevant areas of expertise was set up, consisting of:

- A stakeholder manager for infrastructure projects from Antea Group
- An infrastructure project manager from Antea Group
- A representative from the department of Strategy & Innovation at Centric, a Dutch IT company with existing research on blockchain technology

The first two panel members were chosen due to their experience and professional discipline, as they could judge the usefulness of the crowdfinancing mechanisms in practice. The last member was chosen due to his knowledge and expertise on information systems.

The panel was provided with digital copies of the proposed solution beforehand and during the validation meeting a presentation was given where the problem, context and proposed solution were explained. Feedback about the assumptions and proposed solution was asked from the panel in the form of open-ended questions, followed by clarifying questions geared towards the distillation of the criteria on which they based their statements.

5. Pilot study

The previous chapter addressed the research methods used in this thesis, including the technical research design of the pilot study. In this chapter the results of this study are presented and an answer is provided for the second research question (see section 5.2).

5.1. Summary of interviewees' statements

Most interviewees had limited or non-existing knowledge of the historical evolution of the energy market, so questions related to this topic remained generally unanswered. Thus, the interviews revolved around the current state of the market regarding the energy transition and the outlook for the future (see Appendix D). The following list constitutes a summary of statements that most interviewees made/ agreed upon:

1. Regarding the transition:

- The production from renewables creates peaks in the supply of energy that are already causing problems. An increased share of renewables in the market is only sustainable if storage solutions are found, or other sources of energy that are stable (e.g. nuclear power) provide the necessary base load.
- The bigger projects are generally being started by Dutch energy retailers or (international) developers, while the smaller projects are often the initiative of energy cooperatives.
- The bigger projects are normally financed with bank loans for 70-80% and the remaining 20-30% is provided in the form of private equity, often from the balance sheet of the project initiator. The smaller projects don't have access to bank loans and thus have to find alternative sources of funding.
- Municipalities are finding it important that local inhabitants profit financially from the projects as well, either by compensation or through financial citizen participation.
- There are enough funds available in the market for the bigger projects with proven technologies. The problem is not about financing for them, but about difficulties with permits and opposition from (local) citizens (e.g. public interest groups, NIMBY movements).
- The population needs to be involved in the transition and support it, so that funds can be made available and projects can move forward unrestricted.

- Subsidies are geared towards proven technologies (e.g. solar and wind), but newer technologies are less supported and thus difficultly financed.

2. Regarding the outlook for the (perfect) future:

- The supply of energy would consist of a mix of different sources and storage solutions. Production would be decentralized compared to legacy systems, but economies of scale would still be useful on favorable locations (e.g. offshore wind).
- Communities would produce energy themselves and become energy independent.
- New economic models would be developed so that everyone can profit financially from the production of energy.
- Banks would still be the main financiers, but the crowd would be able to invest as well. Thus, crowdfinancing would be used as a tool for citizen participation.

The interviewees did not agree on the following topic:

- Most interviewees maintained that a lack of funds was not the problem of the transition, but the entrepreneur's opinion was that there are not enough sources of funding available. The latter was looking at the problem from the perspective of a developer of new technologies, while the rest of the interviewees were looking at the availability of funding for investable projects, i.e. proven technologies ready for implementation. These results are in line with the financing gap identified in sub-section 3.3.2.

5.2. Success criteria for the ideal crowdfinancing process

The following success criteria were identified by the interviewees:

- Loan-based crowdfinancing should be the main form of financing, since this is what most project initiators are often interested in.
- A crowdfinancing platform should be cost-efficient, since crowdfinancing is a high-volume business for them.
- Compliance with regulation is a must, as the crowdfinancing sector is becoming more regulated by the day
- Local communities should be given priority in the crowdfinancing process

5.3. Takeaways from the interviews

The interviewees were well-informed and their statements were mostly in agreement with the analysis of the energy market, but they all looked at the energy transition from their own points of view and according to their current role in the market. They had different visions of the future, especially related to the production of energy, which highlights the current state of uncertainty regarding the energy transition.

The most striking revelation from the interviews was that there did not seem to be a sense of urgency towards the transition but from the entrepreneur, which was also the only one addressing the fact that the share of renewables in the Dutch energy market is currently really low and more investment is needed in new technologies. When confronted with the fact that investments in renewables need to be increased considerably, no one gave a straight answer about where the extra € 10-19 billion per year that are necessary would come from and their opinion remained that financing is not a problem for most initiatives, that projects are being realized all the time. Although the interviewees' answers were true, there seems to be a mismatch between the perception and the reality of where the Netherlands stands with regards to production from renewables, even with individuals that are actively involved in the energy market.

In general, the interviews took more time than expected and the result was that sometimes not all the questions were addressed. Prioritization was needed as the conversations led to different topics that were also relevant to the research.

6. Reference smart contract applications

This chapter provides an answer to research question 3.a by means of an overview of existing smart contract applications running on the Ethereum blockchain that provide potential solutions to the limitations of current crowdfinancing models.

6.1. Digital assets (tokens)

Smart contracts can be used to create tokens with specific characteristics that can represent (or replace) real world assets. This makes it possible to issue security tokens, which are tamperproof and non-replicable digital certificates of ownership that remove the need for traditional notaries for authentication. Most tokens are designed according to certain ERC token standards, such as the commonly used ERC-20 (Ethereum Improvement Proposals, 2015), which allows for the implementation of a standard API interface for interoperability with third party applications.

6.2. Stable tokens

Most cryptocurrencies are extremely volatile, so they are therefore unsuitable mediums of exchange to make transactions between participants in crowdfinancing. However, fiat-pegged stable tokens maintain their value over time and most are collateralized off-chain 1:1 with fiat currencies; at the time of writing this thesis 38 fiat-pegged stable tokens have been announced, of which 22 are live (Blockdata, 2019). There are risks related to holding these tokens in the long term because often a third party maintaining the fiat reserves has to be trusted, so choosing the right stable token is of paramount importance. Making this choice requires more investigation and falls outside the scope of this research.

6.3. Decentralized exchanges

Decentralized exchanges are third party applications that allow traders to make peer-to-peer transactions facilitated by smart contracts that match orders and settle transactions autonomously. Some of these exchanges do not even require a listing fee (e.g. ForkDelta, Token.store, Uniswap) and rarely charge more than 0.3% of trading fees. These exchanges can thus facilitate secondary markets to emerge organically and on-demand for the trading of securities, as long as there are willing buyers and sellers. The amount of liquidity available is thus dependent upon the size of the order books.

6.4. Decentralized autonomous organizations

The trustless nature of smart contracts facilitates the creation of decentralized autonomous organizations (DAOs) by encoding the rules for decision making and management of groups of people (Gatteschi et. al, 2018). DAOs can be built around a pool of funds with distributed ownership that is governed by (security) token holders with voting rights for the spending of the funds in the pool. Existing initiatives such as DAOstack and Daohaus facilitate the creation of such organizations, which can be used to finance projects while the investors retain control of the funds.

7. The solution: a practical plan for the implementation of blockchain-based crowdfinancing

In the previous chapter the groundwork for the design phase was laid by identifying reference smart contract applications that serve as building blocks for the design of the blockchain-based crowdfinancing mechanisms. This chapter shows the conceptual designs for these mechanisms and a business case to bring them to market.

7.1. Blockchain implementation

The solution proposed in this section is driven by the main purpose of boosting investments in the energy transition. It is argued that the crowd can be further empowered as the fuel for the transition by liberating them from centralized financial institutions for the financing of renewable energy projects, thereby continuing the trend of decentralization in the energy market to include financing as well. This entails reforming the crowdfinancing market by removing intermediaries from the crowdfinancing and trading processes, so that crowdinvestors (demand) and project initiators (supply) do not need to rely on and pay the costs of third parties to achieve and settle financial agreements or trade the securities acquired through those agreements. Instead, smart contracts facilitate these processes autonomously based on functionalities previously agreed upon by the parties involved.

In the analysis of the financing market for renewable energy projects a financing gap was identified for small and risky projects (see sub-section 3.3.2), but the use case of crowdfinancing goes beyond a mere alternative source of capital, as it can be used as a tool to increase the support of and/or share the financial benefits with (local) inhabitants as well. The potential of crowdfinancing in view of the current types of energy projects is summarized in Appendix E, which show a diverse set of potential use cases, all with their own specific characteristics. Thus, designing a one-fits-all crowdfinancing mechanism is not likely to satisfy market needs nor allow for new business models to emerge; instead, a crowdfinancing platform should create an ecosystem where demand and supply can meet and the parameters of the crowdfinancing mechanisms (e.g. capital structures, control rights, funding targets) can be defined for each specific project.

Nevertheless, a distinction can still be made between low risk and high risk projects, regardless of their size. In this thesis low risk projects refer to initiatives for the development of renewable energy with proven technologies, clear business plans and reasonable guarantees (e.g. production installations as collateral); while high risk projects refer to initiatives with unproven technologies, unestablished market players and/or questionable business plans. These assumptions are made for the purpose of this research, but are in no way intended as a representation of the current market's perception of risk.

The following sub-sections will deal with the design process of the crowdfinancing mechanisms for these two types of projects.

7.1.1. Design requirements

This sub-section provides and answer to research question 3.b by formulating design requirements for the crowdfinancing mechanisms based on the theoretical analysis and the pilot study.

7.1.1.1. Functional requirements

In order to arrive at design requirements a stakeholder analysis was performed for the crowdfinancing process based on the theoretical analysis and the results of the pilot study. The stakeholder analysis entails a description of each stakeholder's interests, problem perceptions and (where applicable) functional/performance requirements for the crowdfinancing process (see Appendix F). The resulting list of functional requirements is shown below:

1. Project initiator can assume the responsibilities of the platform or outsource to another third party
2. Local inhabitants are given priority to invest
3. Secondary markets are available
4. Investors' financial information is not public record
5. Investors can exercise their voting power (if applicable) from distance
6. Investors can cut losses in failing projects
7. Transactions are traceable to individual investors
8. Investor funds are not held by the platform

7.1.1.2. Performance requirements

The following performance requirement was deduced from the stakeholder analysis:

1. Cost efficiency: (1) low brokerage fees relative to existing crowdfinancing platforms, (2) low administrative costs relative to existing crowdfinancing platforms and, (3) low interest rates relative to bank financing

Additionally, the decentralization of the crowdfinancing and trading processes requires the underlying blockchain protocols to meet certain performance requirements in order to be effective solutions. These requirements are:

2. Accessibility: the mechanisms are accessible everywhere, to everyone with an internet connection
3. Reliability: the mechanisms are online 24-7
4. Security: the mechanisms are secure from attacks from outside (e.g. sibyl attacks[11])
5. Immutability: Transactions are final and tamperproof
6. Speed: Transactions are confirmed within reasonable times (say 5 minutes)
7. Scalability: the mechanism is able to handle hundreds of transactions within hours (the average crowdfinanced renewable energy project has 120 investors [ASN Bank, 2019] and is sometimes financed within hours [AFM, n.d.-d]).

7.1.2. Conceptual designs

7.1.2.1. General design choices

In view of the design requirements formulated in previous sections, the following design choices were made for the blockchain-based crowdfinancing mechanisms for both low risk and high risk projects:

- *The crowdfinancing mechanisms organized around a platform:* The platform is a common place for supply and demand to meet, but the investing process could take place through the project initiator's website or even directly from each participant's wallet. However, there is added value in having one entity matching supply and demand, thereby reducing/eliminating marketing costs for the projects; the market seems to value this, as 90% of all crowdfinancing for sustainable projects takes place on platforms (ASN Bank, 2019) even given the high brokerage fees (see sub-section 3.3.1.1)
- *Antea Group as platform owner:* Writing a smart contract could be done by a number of capable parties, but writing the right contract, taking into consideration the activities and risks related to the development of a renewable energy project, is best done by the party that is already managing the project for the project initiator.

[11] A Sybil attack is an attempt to control a peer network by creating multiple fake identities. To outside observers, these fake identities appear to be unique users (Coincentral, 2018)

- *A Know-your-customer (KYC) check as pre-requisite for participation:* In order to comply with regulation anyone investing/trading in a security should be identifiable.

7.1.2.2. Design choices for low risk projects

For low risk projects the main use case of blockchain technology is the issuance of securities and trading thereof on secondary markets, while also reducing the administration costs related to the record keeping and reporting of unusual transactions to the Dutch Financial Action Task Force (AFM). Appendix G.1 shows the conceptual design for the blockchain-based crowdfinancing mechanism for low risk projects, including a detailed description of the investing process; a simplified extract thereof is shown in *figure 19*.

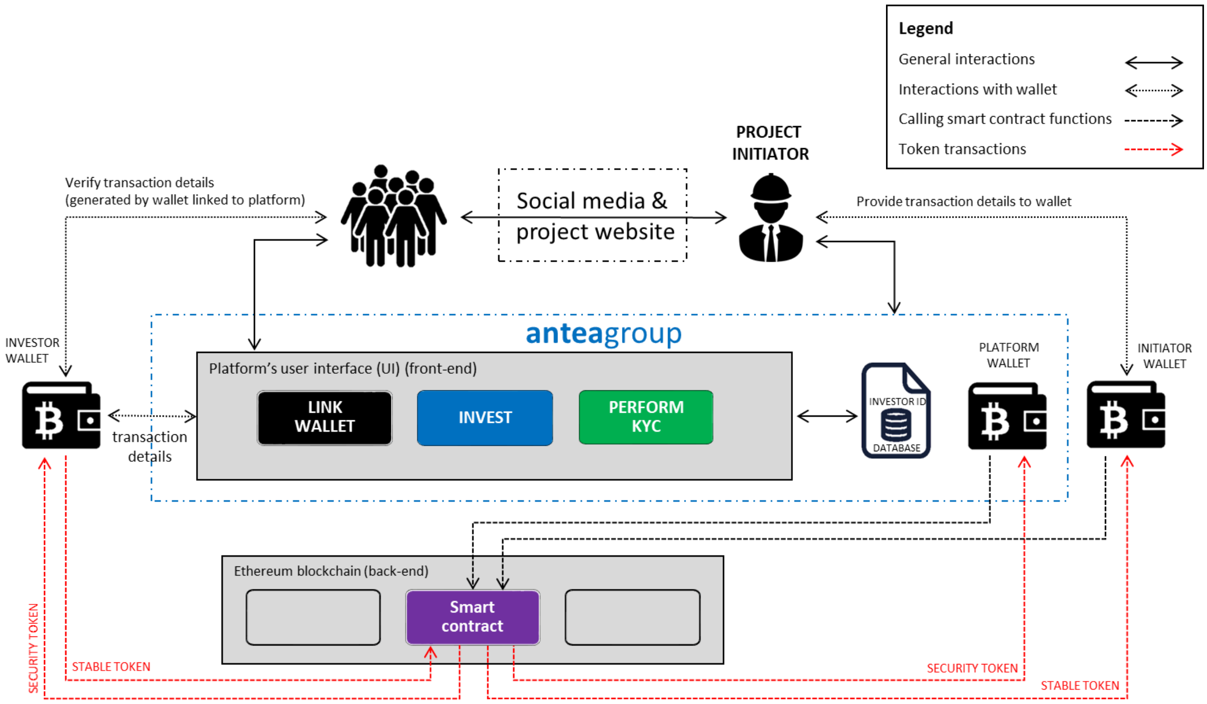

Figure 19 (extract of Appendix G.1): Conceptual design of the crowdfinancing mechanism for low risk projects

This crowdfinancing mechanism facilitates the issuance of security tokens in exchange for stable tokens, which can later be withdrawn by the project initiator once the funding target has been reached. The trading of the securities issued could then take place on any of the decentralized exchanges available.

The platform is only a user-friendly front-end for crowdinvestors to easily interact with the smart contract and perform KYC to get their wallet addresses approved. In case of bankruptcy or unavailability of the platform, it is possible to interact with the smart contract directly (e.g. providing transaction inputs from the wallet) or through other websites serving as a front end; the project initiator can also delegate the power to whitelist addresses to another party that would take over the KYC checks for new investors/traders.

The payout back to investors would take place directly between the project initiator and the whitelisted addresses, preferably by means of batch transactions, in order to avoid unnecessary capital pools.

7.1.2.3. Design choices for high risk projects

The crowdfinancing mechanism for high risk projects has the same characteristics as the one for low risk projects, but with extra functionalities. Namely, the use case is extended to the management of funds by locking investor contributions in the smart contract according to the planning of the project, thereby creating a DAO and finally addressing the limitations of current crowdfinancing models with regards to *investor distrust* and *adverse selection* without increasing intermediation and regulatory oversight, i.e. costs. Appendix G.2 shows the conceptual design of the blockchain-based crowdfinancing mechanism for high risk projects, including a detailed description of the investing process; a simplified extract thereof is shown in *figure 20*.

With this crowdfinancing mechanism investors have more control and oversight over the

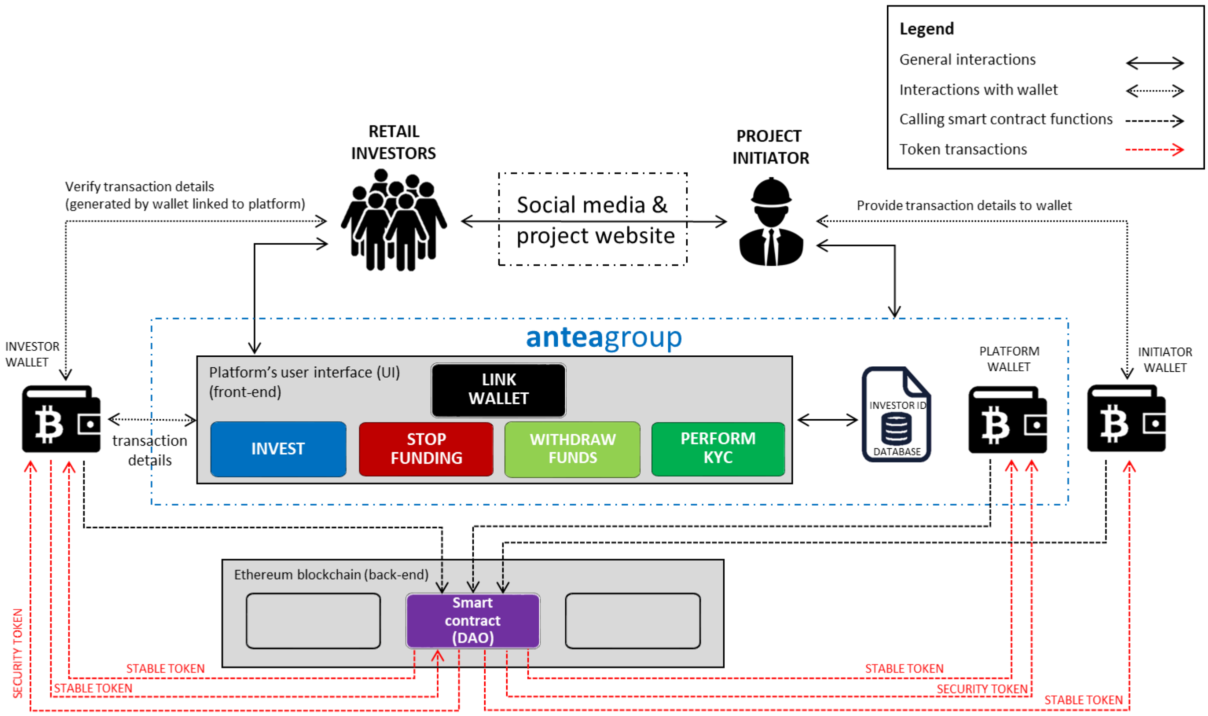

Figure 20 (extract of Appendix G.2): Conceptual design of the crowdfinancing mechanism for high risk projects

project initiator's use of funds. If they lose trust in the project initiator, they can vote to stop the funding of the project; after 51% – this is an arbitrary number – of all investors have voted, the remaining funds in the contract can be withdrawn. This reduces the capital that is being risked by crowdinvestors, by so doing reducing the required trust in the project initiator and the potential consequences of adverse selection.

7.1.3. Brief to the developer

The smart contract for low risk projects only holds stable tokens during the fundraising campaign and its single function thereafter is the execution of transactions initiated through decentralized exchanges. The security tokens issued are required to conform to the ERC-20 standard in order to facilitate easy integration with third party applications. A model of the way in which the smart contract is envisioned to function is laid out in Appendix H.1 by means of a flow chart. This model was not developed by a programmer.

The application for high risk projects entails the creation of a DAO where project funds remain locked after the fundraising campaign and are released throughout project development according to a planning. The funds should be locked in an immutable proxy contract and another application contract should contain the application logic. The ERC-20 standard requirement also applies. A model of the way in which the smart contract is envisioned to function is laid out in Appendix H.2 by means of a flow chart. This model was not developed by a programmer.

7.2. Business case

7.2.1. Problem description

The production of energy from renewable sources in the Netherlands was at the end of 2018 less than 8% of the total energy consumption (CBS, 2019-a), while meeting the long-term temperature goals of the Paris Agreement is estimated to require additional investments upwards of € 10 billion per year starting in 2020 (van der Geest, 2017). The continued reliance on centralized financial institutions seems unlikely to address this investment gap, as the banking sector's share of the financing market continues to decrease (CBS, 2018) and the early phases of infrastructure project development do not fit the investment preferences of other institutional investors (e.g. pension funds and insurance companies) due to the high risks of default (Ehler, 2014). There is thus a growing need to boost investments in the energy transition by attracting non-institutional investors by means of by example, crowdfinancing.

An analysis of the energy market (see section 3.3) shows that there is high demand from crowdinvestors for renewable energy projects and that project initiators of risky and/or small projects (up to € 1 Million) are making use of crowdfinancing as an alternative source of funding, absent access to bank financing. Additionally, interviews with relevant market parties (see chapter 5) revealed that the bigger projects – these constitute the bulk of the market – are having difficulties with permits and opposition from the public (e.g. public interest groups, NIMBY movements). The market is signaling a move towards (financial) citizen participation in order to increase support from the public, since they bear the costs of the energy transition but do not benefit from the generation of profits. However, the brokerage fees on the existing crowdfinancing platforms are too high for a project generating average market returns, especially when secondary markets are provided. These high costs of intermediation are thus a bottleneck for further growth of the crowdfinancing market.

In conclusion, there is a need for improved crowdfinancing mechanisms for the matching of demand and supply and the creation of secondary markets with lower costs of intermediation, for the sake of lowering the barriers to entry for crowdfinancing and facilitating citizen participation.

7.2.2. Project scope

The proposed solution to the high costs of intermediation with existing crowdfinancing practices entails the removal of intermediaries from the crowdfinancing process by means of blockchain-based crowdfinancing mechanisms, distinctively designed for high and low risk projects, with Antea Group as the facilitator of the process (see section 7.1). Smart contracts deployed on a public blockchain would facilitate the entire crowdfinancing process autonomously, from investment to pay-out of rent/dividend back to investors, and a non-essential front-end (website/app) would make the process user friendly. Besides writing the smart contracts beforehand for the project initiators, Antea Group's sole role in the process would be that of verifying investors' ID documents and granting them permission to interact with the smart contracts by whitelisting their addresses.

By using a public blockchain existing infrastructure is leveraged for cryptocurrency on- and off-ramping, trading of securities on decentralized exchanges and access to mature storage solutions, thereby reducing investment costs and allowing secondary markets to arise organically.

7.2.3. Added value

These mechanisms can be used by Antea Group primarily as a tool for stakeholder managers to reduce community risks by stimulating support from the public for the bigger projects, by allowing them to participate financially and potentially become agents of the projects as well. This can give Antea Group a competitive advantage in the market, as the company will be offering an innovative, (cost-) efficient and inclusive financing mechanism to potential clients. Additionally, this tool for facilitating citizen participation can allow Antea Group to come more often (and sooner) to the negotiation table, thereby increasing the company's share of an expanding renewable energy market. Lastly, the reduced brokerage fees and increased liquidity allows more projects to take place and more investors to participate, thereby contributing to the company's positive image in light of its contributions to the energy transition.

7.2.4. Investment and payoff

The costs of the crowdfinancing mechanisms depend upon the way in which they are brought to market. Appendix I shows and overview of the different possibilities based on 2 general variants and a summarizing extract thereof is shown in *table 2*. The second variant has a high risk of additional costs due to the possible requirement of a license to underwrite the issuance of securities.

Cost category	Variant 1: Investing through the project initiator's website	Variant 2: Investing through Antea Group's platform
Investment costs [risk of additional costs]	€ 1.000 - €2.000 [€ 2.000]	€ 6.000 - € 12.000 [€ 50.000]
Fixed costs (per year)	€ 5.500 - € 11.000	€ 3.500 - € 7.000
Variable costs (per project)	€ 150 - € 1.500	€ 1.000 - € 2.000

Table 2 (extract of Appendix I): Direct cost estimation of the crowdfinancing mechanisms.

Regarding the payoff, investments in renewable energy production in the Netherlands are projected to be around € 5 billion in 2020 alone and continue to increase thereafter (ECN, 2017). By making the conservative assumption that the engineering costs for all project phases until delivery are 15% of the capital investments (Horvat & partners, 2018), of which 10% entails project margins for the engineering firm, the potential size of the market for Antea Group can be estimated to start at € 75 million per year in 2020. Assuming that variant 2 is used at full cost for 10 crowdfinanced renewable energy projects per year, which individually raise on average € 400.000 (ASN bank, 2019), Antea Group would only have to capture 0.12% of the market the first year in order to cover the costs of the tool if offered for free; transferring the costs to the project initiators would result in 2.2% in brokerage fees, which is well below similar alternatives currently available in the financing market (see sub-section 3.3.1).

7.2.5. Deployment

Given the innovative nature of these crowdfinancing mechanisms and the uncertainties regarding the costs of compliance with regulation, it is advised to start with low risk projects crowdfinanced through the project initiators' websites (variant 1). This approach will result in the lowest investment costs for Antea Group, while limiting risk exposure and allowing the company to gain experience in the process before making bigger financial commitments.

7.2.6. Risks and limitations

The most important risk is the potential cost of compliance with regulation. In January 2020 the EU's Fifth Anti-Money Laundering Directive (5AML) will be implemented in The Netherlands, which among other things compels exchanges and wallet providers to report unusual transactions (Charco & Dique, n.d.), similar to the requirements for crowdfinancing platforms that underwrite the issuance of securities bought with traditional fiat currencies. The crowdfinancing mechanisms proposed were designed in such a way that no anonymous transactions of securities are possible, but if 5AML ends up requiring an assessment of the origin of the stable tokens initially used to invest in the projects, it remains unclear how such an assessment could be performed and what the related costs would be; namely, cryptocurrency transactions are at the very least pseudo-anonymous, so determining the origin of funds can be an extensive and costly process, if at all possible.

On the other hand, bringing blockchain technology to the masses can be a complicated process given the mindset changes required from the end-users (see sub-section 2.2.2.2). After all, since the average retail investor in the Netherlands is 52 years old (AFM, 2017), the adoption of the technology might not take place as fast as desired.

7.3. Verification

The proposed solution was confronted with the design requirements for an ideal crowdfinancing process (see Appendix J). All requirements were met, besides the following:

1. With low risk projects adverse selection, lack of trust and exclusive corporate governance were not assumed to be a problem, so crowdinvestors do not have control over the project funds.

2. It is currently impossible to compete with bank financing in terms of interest rates, even with zero brokerage fees, so crowdfinancing is still not financially attractive for the bigger projects.

3. The DAO smart contracts for high risk projects are only safe against known attacks, so security might be compromised if new attacks are successful before the application contract can be updated.

7.4. Validation

The following assumptions were presented to the panel of experts for feedback:

1. The proposed solution is smart enough, i.e. it fulfills its intended purpose
2. The proposed solution is attractive for crowdinvestors

3. The proposed solution is attractive for potential project initiators
4. The short-term exposure to the risks associated with stable tokens are acceptable
5. Blockchain technology is suitable for compliance with laws and regulations
6. The complexity of using blockchain technology is compensated by the benefits

The feedback comments from the panel members and corresponding responses are processed in Appendix K. The following conclusions can be extracted from the validation meetings:

1. There was skepticism among all panel members about the effectiveness of increasing support from local communities for the bigger projects through financial citizen participation. It was argued that there are more effective ways to increase support (e.g. by financial compensation for the entire community) and that public engagement is not improved by making a financial transaction. This feedback contradicts literature findings on the reduction of community risks with (civic) crowdfunding (see sub-section 2.1.2.2) and the findings from the pilot study (see section 5.2).

I think that the criticism was centered around the valid assumption that opposition from a group of local citizens (e.g. NIMBY movements) is unlikely to be reduced by co-investing, but it failed to take into account that opposition is only effective if it is unmatched by support; namely, crowdfinancing would stimulate YIMBY movements to emerge that would frustrate the actions of the opposition. Additionally, adding more costs to project development is counterproductive in general for the energy transition; instead, the solution proposed in this thesis would allow more projects to take place by sharing risks (investment) and benefits (return on investment) without extra costs to the projects.

2. Providing financing solutions to project initiators is not part of Antea Group's business model and is an unconventional approach for consultancy and engineering firms. It remains unclear whether this is a good business strategy.

3. Conflicts of interests invalidate the use case of crowdfinancing for projects where the municipality is the project initiator. This is not an issue if project development is outsourced to another party through concessions.

4. Social exclusion can be a problem for appealing to local inhabitants, given the complexity of blockchain technology.

8. Discussion

The results indicate that there is a positive business case for a consultancy and engineering firm such as Antea Group to develop blockchain-based crowdfinancing mechanisms for renewable energy projects in the Dutch energy market. The proposed blockchain implementations allow an arguably new market for crowdfinancing to emerge by reducing brokerage fees, facilitating the organic establishment of secondary markets and addressing the inherent limitations of current crowdfinancing models regarding lack of trust, exclusive corporate governance and adverse selection that might restrict the potential of crowdfinancing to give a boost to the energy transition.

These improvements of the crowdfinancing model are beneficial for risky and small projects that do not have access to bank financing, thereby further empowering the crowd to be the fuel of the transition. However, it remains unclear whether crowdfinancing would be an effective tool to increase support from local inhabitants for the bigger projects, since this was invalidated by a panel of experts.

Additionally, the relatively high complexity of blockchain technology and the required individual responsibilities to its users might be a bottleneck for adoption and the cause of social exclusion with local inhabitants.

Lastly, there is high uncertainty regarding the legal status of a platform that facilitates blockchain-based crowdfinancing. Although the crowdfinancing mechanisms proposed in this master's thesis rely on existing third party wallets and exchanges, the platform itself could be classified by the authorities as equivalent to an investment bank (in Dutch: *beleggingsonderneming*) due to its role in "underwriting the issuance of securities" and would therefore still have to comply with Wwft regulation (AFM, n.d.-a) and bear the related costs. But since the entire crowdfinancing process is facilitated by an autonomous smart contract, while the platform only provides a user-friendly experience and has no control whatsoever of the blockchain/smart contract protocols on top of which it operates, it is difficult to place the platform within existing regulatory frameworks.

Limitations

Extant literature suggests that crowdinvestors are driven by a community logic (Vismara, 2019) and the crowdfinancing market continues to show high demand for new (renewable energy) projects (AFM, n.d.-d), but it is unclear the extent to which such high demand is explained by crowdinvestors' benevolent intentions. After all, the fact that interest rates are currently well below inflation rates suggest that crowdinvestors might be more driven by financial rewards than assumed.

Also, the interviews conducted in the pilot study did not include interviewees from energy cooperatives. Since their initiatives are often not eligible for bank financing, regardless of project risk, their perspectives related to the financing market would have been of added value.

Lastly, the fact that the effectiveness of crowdfinancing to increase support for a project from local communities was invalidated by a small panel of experts reduces the reliability of the validation results. The findings should be re-submitted for validation in the future if an engineering and consultancy firm, or any other interested party, is considering utilizing crowdfinancing as a tool to reduce community risks for a project.

9. Conclusions and recommendations

The main research question of this master's thesis was *how can blockchain-based crowdfinancing be implemented to finance renewable energy projects in The Netherlands*. Based on an analysis of the energy market, a supplementing pilot study and qualitative desk research on reference smart contract applications, blockchain-based crowdfinancing mechanisms were designed and a business case for the implementation thereof was produced. The resulting practical plan provides engineering and consultancy firms with a tool to further empower the crowd as the fuel for the energy transition, while increasing their share of an expanding renewable energy market. The degree to which this gives a boost to the transition remains unclear due to a lack of consensus on whether crowdfinancing truly increases support for the bigger projects, since they currently make up most of the energy market.

During this research I expected to find that the low share of renewables was due to a lack of funding, but instead I found that the bottleneck was a lack of support for project development, arguably due to the unequal distribution of the costs and benefits with local communities. Given the rapid growth of crowdfinancing and energy cooperatives, coupled with a liberalized energy market, I also expected to find that the crowd was utilizing favorable market conditions to produce energy and accumulate wealth; instead, I found that cooperatives are booming in spite of current market conditions, i.e. financing projects at relatively high costs of capital and often working with a subsidy system (SDE+) geared towards the bigger market players.

Recommendations for further research

In this research two different smart contracts were designed, one for the mere automation of the crowdfinancing process and another also for the creation of a DAO in charge of project funds. In the latter case the funds are locked in an escrow contract according to a planning, but project development often does not conform to the initial planning, even more so with high risk projects. There is thus more in-depth research necessary in order to define a risk management-based approach for the design of the DAO.

Additionally, the use of DAOs was proposed in this research as a way to mitigate the impact of the adverse selection problem, but recent empirical studies on crowdfunding platforms' best practices shed light on financial performance as a function of project ownership structure. According to Walthoff-Borm, Vanacker & Collewaert (2018) firms with a nominee shareholder structure in equity crowdfunding show better financial performance than firms with a direct shareholder structure. Blockchain technology also allows the delegation of power to other addresses (market participants), which presents possibilities for the creation of ecosystems where unsophisticated crowdinvestors could delegate certain control rights to professional investors so they can act in their behalf. Such mechanisms could decrease the likelihood of adverse selection, rather than mitigate its impact; hence, there is a research gap with regards to the delegation of control rights in blockchain-based crowdfinancing that needs to be filled.

Finally, exclusive corporate governance is a limitation of current crowdfinancing models that was not addressed extensively in this research. The proposed DAO for high risk projects does improve the degree of control that crowdinvestors would have over a project, but this is restricted to the management of funds only. Depending on the voting rights that crowdinvestors might have in a project and/or company, additional tools might be required in order to facilitate the exercise of their rights to participate in additional corporate governance processes.

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List of appendices