Policy paper for ‘Blockchain Economics and Radical Markets’

A new radical market combining hypermodern and classical building blocks

How to increase renewable energy investment by creating a new radical market, driven by blockchain.

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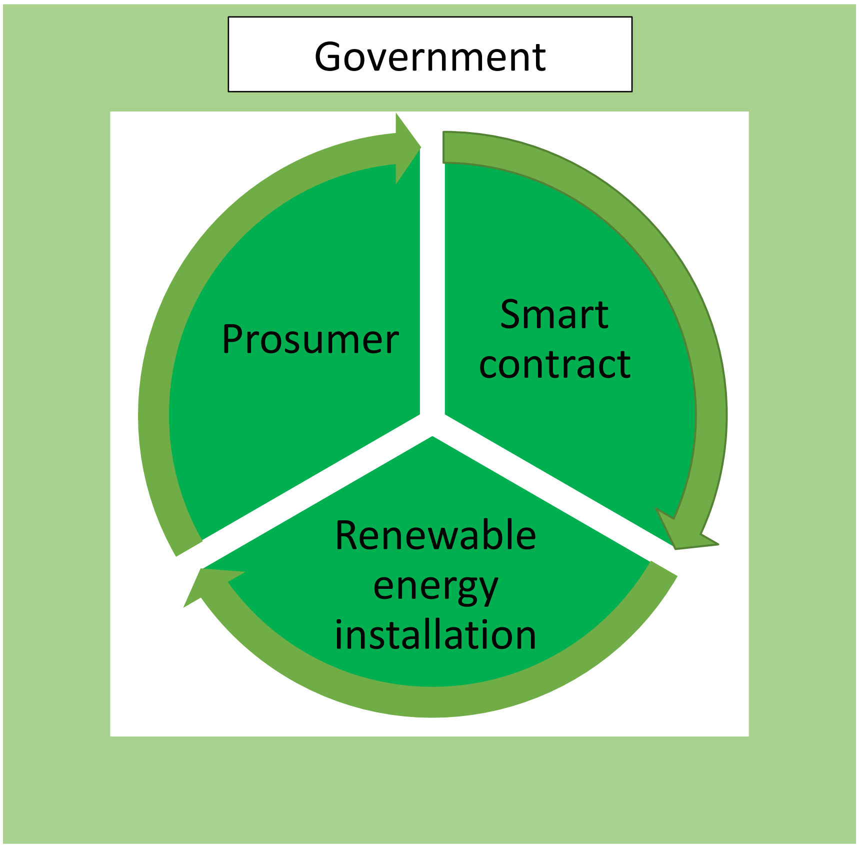
Abstract:

The world is heading towards a dangerous future with man-made climate change accelerating every year. Part of the solution for stopping this trend is to change the electricity generation sources from fossil fuels to renewable energy. This paper proposes a solution to accelerate the production of renewable energy, by introducing a new radical market that will increase the total investment. Blockchain technology and crowd sourcing ideas are combined to make the new electricity market: More efficient, more democratised, and more stable. The new market increases the investment by giving normal consumers the chance to buy into the new power production facilities. This opens another investment pool that has not been utilised earlier, increasing the total investment. An additional advantage with this finance model is that you eliminate the monetary risk for both the consumers and the contractors of the power installations by changing the transfer between them, to a capital cost. The contractor does not have to worry about differing energy prices, since he/she only receives a set amount for construction and maintenance. The consumer also pays for the electricity in a one time lump sum and receives a given percentage of power independently of the power prices. This angle, and many others, are discussed in the paper, giving a thorough review of the subject and a powerful idea for change. Underneath you see a figure showing the cycle between the three elements of the market, as well as the government setting the frame for the market through regulation and guarantees.



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1. Introduction:

In this paper I will introduce smart contracts driven by blockchain technology and a new market idea, inspired by the radical markets movement. These will be combined to create an efficient new solution to the relationship between consumers and producers in the energy market. The need for an increase in renewable energy generation to meet the climate crisis is well known.

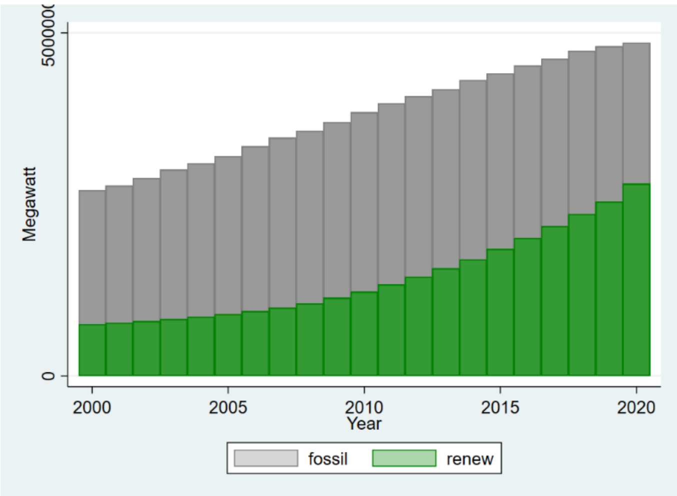

Figure 1: Bar chart over change in installed electric capacity

In the graph to the left you see the development of electricity production between fossil fuels and renewable energy. The bars are not stacked, and show that even though the production from renewable energy is rising, the production from fossil fuels is doing the same. It is therefore still far from enough to stop global warming.

To meet this challenge, I propose a new renewable energy market to speed up the production of clean power to outcompete fossil fuels. This market is designed to push consumers into investing in renewable energy sources directly and thereby increasing the overall investment by a large margin. In the new system the risk is minimised for both the contractors of the power production installations and the consumers. This comes from the change of transfer between these two, from power cost to capital cost. Renewable power sources often cause controversies since the local population usually does not benefit much directly. With this new approach local community invest in the installations themselves and after personally profiting, they will likely be more positive to increased levels of renewable power generation in their local area. To make the market better, more efficient, and more democratic it is controlled through smart contracts, through the Ethereum blockchain. This paper is setup to fit many different levels of previous knowledge. You can skip the subjects where you are already well informed, or focus on some areas that are more interesting to you. I will start in chapter 2 by explaining the background of Blockchain technology and smart contracts in general terms. Chapter 3 will explain the radical market idea and how this paper fits within this narrative and most importantly, why this solution is important. Chapter 4 contains the main part of this paper where the solution is outlined and the steps to get there are discussed. If you have great knowledge of the surrounding themes, this is the only chapter you need. Chapter 5 finishes with discussing similar solutions and the way forward. Chapter 6 concludes the paper and there is also an appendix further discussing the statistical analysis used in chapter 2.

2. How blockchain technology and smart contracts are efficient

The technology enabling the efficiency in this new market is called blockchain technology. Simply explained, it is built up as a decentralized information system where everyone has the exact facts and therefore nobody can dispute them without also controlling the entire market. Most of the economic research around blockchain is focused on Bitcoin and the economic repercussions of the new monetary form that this creates (Böhme et al., 2015), or a general overview over the blockchain technology (Catalini and Gans, 2019). Using cryptocurrencies discussed in these papers can be part of the solution outlined in this paper. It is, however, not a vital part and will therefore not be further discussed.

2.1 Smart contracts:

The blockchain technology is in rapid development and covers many different areas. One of these are the smart contracts. These contracts separate themselves from normal contracts by being programmable and automatically being enforced through code. If a certain goal is reached, you are not dependent on the opposite part being willing to fulfil their end of the deal. It is automatically done as the parameters of the deal are made. They can also make a more efficient workflow, as they can automatically trigger the next step of the deal when the initial step is concluded. These types of contracts are immediately usefulness in e.g. finance, but can also have many other use cases (IBM, 2020).

Smart contracts are also older then Blockchain itself and refer to a contract where the terms are strictly parametrical and cannot be disputed. This was first coined by Nick Szabo in 1994. He described them as computer operated contracts that could be executed without human intervention. They are written into code and are executed automatically through this code (Lipton and Levi, 2018;Frankenfield, 2021). Smart contracts function by setting the execution steps where if “x” happens then “y” is executed. Developers are already working on making the smart contracts more advanced. They are stringing more steps together to be able to initiate a list of steps within one contract and creating agile contracts which can satisfy different outcomes. Currently the cost of such transactions in the Ethereum Blockchain is prohibitive of very complex contracts and microtransactions (Lipton and Levi, 2018). Smart contract market is already established within certain industries and the monetary size is projected to reach over 300 million USD within a couple of years (Kenneth Research, 2021;Valuates Report, 2021).

The smart contract reaches this by eliminating the need to trust the intermediary which controls the contract (Bottoni et al., 2020). The Ethereum blockchain is the by far the leading platform for smart contracts where all types of transactions require a smart contract. The whole blockchain system is built around them (Almasoud et al., 2020). A smart contract in this sense is simply a program that runs on the Ethereum blockchain where the range spans from simple transactions to complicated scripts. Tokens which are digital assets can be built on top of the Ethereum smart contract network. This make the divide between the asset and the contract clearer as well as making the programming of the smart contract itself more transparent (Ameer Rosic, 2020;Wesley, 2021).

2.2 Weaknesses of smart contracts

Smart contracts also have their downsides. They are harder to create than text-based contracts and even more so harder to amend or terminate(Lipton and Levi, 2018). This results in a larger transaction fee for changing the original plan or fixing mistakes, which can result in errors and inefficiencies being left in. The heightened rigidity in the smart contract system makes small errors impossible to overlook, which makes the system vulnerable to errors. Writing a smart contract is also more costly as you cannot leave anything in the contract ambiguous. All eventualities must be covered. With a normal text contract, you can stop improving it as the diminishing returns of a negotiation can make the completing a contract one hundred percent, unprofitable. This is currently not possible for smart contracts. There is at the moment, work being done to create smart contracts that are more easily changeable to solve this issue. This reduces the valuable simplicity of the smart contract as it is this and ease of execution that makes it useful (Lipton and Levi, 2018).

2.3 Ethereum Blockchain

The Ethereum Blockchain is the most popular blockchain overall (Joanna Ossinger, 2020; Matthew Leising and Olga Kharif, 2020). It is used for many applications, but mainly smart contracts. It is a whole platform of different features, also covering crypto-currencies where it competes with Bitcoin. For the most part however, Ethereum and Bitcoin mainly does not compete since they serve different purposes. Bitcoin is digital gold while Ethereum is a network of different computers and computer codes which can be used in variety of ways. This Ethereum network, driven at the forefront by the smart contract concept, has fostered many similar ideas and led to the development of a wide range of independent platforms with smart contract capabilities (Spychiger et al., 2021). Smart contracts are therefore only a part of the Ethereum

Blockchain. The smart contract uses the ability of the internalised code in the Blockchain to create this decentralised contract network.

2.4 A more energy efficient blockchain in the future

There are ongoing efforts to make blockchain technology more energy efficient and thereby more environmentally friendly. This is done by reducing the redundancy in the system where every transaction is saved in every single block as soon as a new block is made (Neudecker and Hartenstein, 2018). In the paper by Petri et al. (2020), they find that the use of blockchain, and specifically Ethereum, is beneficial for use from energy communities. Additionally, it also fits well with renewable energy, where the surplus can be registered through the blockchain.

Another factor that can make the future of energy through blockchain more efficient is demand side management (DSM). DSM is used as an alternative to controlling the output of the power producers. When you use e.g. wind power, the power output is highly variable and cannot be changed without losing total output. To combat this inefficiency, you can use DSM to alter the consumption of the power to when the energy is readily available. An example of this could be a washing machine that only runs when the power is cheap or storing thermal energy when the power is cheap and then spreading it out. With demand side management used efficiently, it can control and balance the demand for energy, compared to the supply. This can be an integral part of the new modern smart grid system. Previously, shaping the energy demand through technology change was considered the only option to manage the high peaks of power consumption. It has now been proved that it is not the only solution and plenty of other mechanisms can also play their role in DSM (K. Wang, 2018). One of these is through a token, which will be explained in more detail as a part of the proposal of this paper in chapter 4.

3. The radical idea of a decentralised cooperative energy network

This paper proposes a new market that is not only more efficient, but also has the chance to improve society. It uses new disruptive technology combined with disruptive ideas. It is therefore a new radical market.

3.1 More renewable energy investment is still needed

The need for increased investment in renewable energy generation is already known. This need is however still not met with action and the rate of renewable energy investment is even falling in some time periods (Frankfurt School-UNEP Centre/BNEF, 2020;Benjamin Wehrmann, 2020;Blake Matich, 2019). To get a deeper understanding of the development of the investments in renewable energy compared to fossil fuels, I have made a statistical calculation to be able to compare the two better. The data is taken from the *Public Investment Database 2020* from International Renewable Energy Agencies (2020). This maps all the installed capacity of electricity coming from the different sources each year from 2000 to 2020. To get a more detailed view of the statistical work behind the numbers, please read appendix 1.

Power generation type	Change per year	Standard deviation of change
Renewable 2000-2020	103	0.2
Fossil fuels 2000-2020	114	0.4
Renewable 2010-2020	156	0.2
Fossil fuels 2010-2020	104	0.1

Table 1: Overview of power generation change in Giga Watt

The numbers in table 1 above, shows the development of how the increase in the two fields have changed over the 20 years and how much variation there has been during this time. It compares these numbers with the same numbers from the last 10 years to show how the trend line has changed in this period. The regressions used in this paper reveal the different trend lines within the two time periods. We see how the fossil fuels trend lines are similar while the renewable power trend lines are significantly different. Even though it is good news that renewable energy is capturing market shares, the total electric power production emissions are still steadily rising. The higher growth in renewable power generation is therefore only covering the higher growth of power generation in general and must still be increased by a lot to start to shrink the total emissions from electrical power generation. When you compare the numbers, you can see that it is getting better, but not fast enough to be able to reach the agreed upon goal of limiting the global temperature increase to 1.5 degrees from the Paris agreement (United Nations/Framework Convention on Climate Change, 2015). Even if we see a higher growth in the renewable sector, the growth in the fossil fuel industry is staying high (Bloomberg, 2019;Fiona Harvey, 2014;Benjamin Storrow, 2018).

3.2 Fighting inequality with new technology

Today's inequality is mostly driven by the divide between income from work and income from wealth (Piketty and Goldhammer, 2014, p. 92). By nudging normal consumers to save up to invest in their own power generation, you can offset this imbalance by making the working class take a larger share of the capital returns then they are today (Thaler and Sunstein, 2008, p. 77). This can in the long run help stagger the increasing wealth inequality, given that the returns on capital continue to be as important as they are today. For this to come true, the investors must mainly be working- and middle-class people. Given an investment environment where long term stability is the focus, not the absolute profit, this is possible. It is still very uncertain who will invest and government intervention, to secure a redistributive effect, may be preferable.

3.3 How this radical market differs from other radical markets

The radical market theory over property, proposed by Posner and Weyl (2018, p. 30), argues that a different kind of property ownership is needed. The theory links the ownership of property to monopoly as only the owner controls the production on the given land and cannot be outcompeted by competitors on the same land. This theory crashes with article 17.1 of the universal declaration of human rights: “Everyone has the right to own property alone as well as in association with others” (United Nations, 1948). My theory uses peoples seeking for possession and control over the supply of necessities to increase renewable energy investment. It does not deny the prospect of the original theory, but rather uses one of its counterpoints to power its cause. This will differ around the world as different cultures have different ownership cultures. One example is that the homeownership rate in Norway is at around 80%, while the homeownership in Switzerland is around 40% (Statista, 2021). Since these countries have similar GDP and geography, it is natural to believe that the difference does not come from economic reasons. The difference will most likely affect the success of the introduction in the two different countries since they have a difference in the general ratio between ownership and renting. This ratio should therefore be a guide to see where the implementation will be easiest and can be used among other factors like GDP, suitability for REI and strength of government.

4. Creating an efficient new radical market through blockchain

The new blockchain driven investment energy market is a bold change from the status quo. It combines ideas of common ownership, decentralisation, and democratisation with the new blockchain technology of smart contracts. Each of these parts are not unique and have already been tried out and implemented in many ways. It is the combination of all these that makes this a new radical market. To make this as understandable as possible, I will introduce two different concepts first, REI and prosumer.

REI is an abbreviation of renewable energy installation. It is the physical part of this proposal and how it functions is vital to the success of the market implementation. The term is kept vague to give room for many different types of installations. In the early stages the installations will most likely be solar powered as these are the least capital intensive, and most reliable and stable power sources. As the market grows larger it will also encapsulate other power sources, such as wind and hydropower, to give it more diversity and enable households to balance their power supply between different sources.

Prosumer is a term made up of consumer and producer combined. It describes the new type of energy consumer within these networks who both buy and sell power to and from the networks. Even though the smart contract holders in this new market do not produce the power from their homes, I will still refer to them as prosumers since they own their own decentralised power source and control what is done with the power it produces.

4.1 The goals of the new market

The new market has four main parts: The contractors who produce the REI in return for the initial investments, the prosumers that invest in and receive the electricity, the smart contract which acts as the glue and binds the parts together, and the government which facilitates the market through the smart contracts. All this must be knitted together to create a functioning new market. The new market also needs a purpose. As previously mentioned in the introduction, the new energy market, proposed in this paper, has several goals. It should increase the investment into renewable energy installation as well as making the energy market more efficient and democratic. Having the power to implement a new market also relies on outcompeting the existing market. The competitive advantage stems mainly from the new technology of smart contracts within blockchain, but also from the stability of the set financial costs. The technology is already here, but not yet matured enough to be implemented in the thought of way.

Before going deeper into the idea, I want to make the caveat that this system is heavily dependent on a trusted and competent local and state government. It is possible to create a similar market without government intervention, but you then run the risk of high amounts of fraud, non-optimal placements of installations and even more inequality than what you started with. Opposite of the goal of the original idea. This system is therefore not suitable for most developing countries where the institutions and governmental stability are not strong enough. I will go deeper into the alternative projects, that already exist for these countries, that are already running in the part 5.2.

4.2 Integrating blockchain into the energy market

There are already companies trying to implement blockchain technology into wholesale electricity distribution and thereby connecting the consumer with the grid (see subchapter 5.2 and 5.3). Blockchain combined with smart devices enables consumers to trade and purchase energy directly from the supplier instead of the retailers. These retailers are seen as the driving source of inefficiency in the electricity market. Retailers own very little of the grid infrastructure. Instead, they only manage services that blockchain technology can fully replace, like billing and monitoring electricity usage. Blockchain-based platforms can reduce costs by around 40% compared to the current retailer driven market. By connecting consumers directly to the power grid, blockchain technology and specifically Ethereum, allows users to buy energy from the grid at a lower cost. The result is a fairer and more stable energy market that is more efficient and has lower electricity costs.

4.3 Example of a hypothetical REI from start to finish

This example will go through the process of how an REI is created and recycled, in what should be normal circumstances. It will also cover possible deviations.

The contractor applies for an REI building permit in a place of their choosing or chooses one of the plots that have already been given by the government. This permit needs to satisfy several environmental and local community standards. When this is completed, the contractor can fill out the smart contract outlined below and offer it to the market. The prosumers can then buy the contract, and when the order is filled the contractor will start the construction of the REI, following the rules set by the permit, and possible terms set in the smart contract. The fulfilment of the order could also be flexible where the contractor could build solar panels amounting to the number of smart contracts that have been sold given that the permit allows such flexibility. When the REI is finished the prosumers start receiving their power and the contractor goes over to a maintenance role outlined in the smart contract. This goes on for the given life cycle of the REI. When the REI has left the end of its lifespan it is sold to a new contractor. The price the contractor pays goes to the smart contract holder. In a situation where the REI is still well functioning and has a lot of life left this price will be relatively high. The contractor will do necessary repair and then sell new smart contracts for the same REI. This cycling makes sure that the contractors have a clear time span where the plant must be maintained. There is however a problem with a lack of incentive for longevity of the REI from the side of the contractors, which will be discussed in subchapter 4.6.

4.4 Setup of the smart contract

As seen above there are many parameters that need to be outlined in the contract. The smart contract initially works as a contract between the contractor and the prosumer, where the permit given by the state is also attached. When the REI is finished, the smart contract works as a certificate connected to the power grid that gives the REI authorization to send the power to the prosumer through the grid. In this instance, the smart contract should be designed with a contractual hold on a given percentage of output from the REI. The prosumer can then choose between consuming the electricity instantly or selling it on the market through an automatic auction. If it is consumed, there will also be a cost calculated with the electricity's travel from the REI to the prosumer, that must be added to the transaction. The process of consuming or selling can be automated, depending on the consumer needing it or not. The contract will also have time limits for how long it can be on market while not being fulfilled, and how much time the contractor can use to finish the new. To allow greater financial flexibility for the prosumer, these contracts will also be transferable and could be sold in the same way as a normal stock.

4.5 Technical setup of the smart contract

The smart contract will be utilised in the new radical market as a complete contract between the involved parties as well as the asset which gives the right to the power transfer. The asset will be represented by a token which will handle the correct distribution of the electricity outputted from the REI. It is therefore split into two parts, where the smart contract itself handles the contract obligations between the prosumer and contractor, while the token acts as the right for your percentage of power. If there is extra electricity generated that cannot be used, it will also need a system to sell this power to the market. To execute the sale of an amount of overshoot power generated from the REI, it is possible to use the new distributed ledger technology (DLT). The ledger is a digital system for recording the transactions, where each transaction is stored multiple times. The distributed ledgers have no central data storage or administration functionality. It is based on a transaction technology that has no cycles and therefore has far lower transaction fees compared to both traditional technology and blockchain technology. This system is called direct acyclic graph (DAG). Klein and Stummer (2021) goes deeper into this technology and what supports it, also giving more background. Even though this is not blockchain technology, it still relies on many of the same aspects where some proof-of-work and the reference of earlier transactions are required to prove authenticity. It is however more efficient, and it could therefore be a good applicant for an overshoot power market system.

Since the smart contracts will be mostly identical within the different REIs, and very similar between them, the cost of making them will be dramatically reduced. This lowers the worry discussed in subchapter 2.2. When the market has matured, there will also be possibilities to create bundled smart contracts. Vendors or private persons could sell bundled smart contracts consisting of parts of different REI contracts to create a more balanced product where the different renewable energy sources balance each other out and make the output more stable. A bundled smart contract as described here would work very similarly to how a wide index fund in the finance world works today.

4.6 Longevity of the REI

When the contractor does not receive any of the potential profits from a well-built and long lasting REI, they have no incentive to make them long lasting. To avoid this problem there will be built in bonuses for the contractors connected to the sale of the contracts that are sold after the period of a given contractor is over. How this bonus is scaled must be balanced between the wish for longevity and the extra profit of the prosumers. When the prosumers profit from longevity they will also seek contractors where that can show that they build long lasting REIs. The size of the bonus must therefore not necessarily be that large to achieve the goal of a very long lasting REI.

When it comes to an REI like a hydro powerplant, the solution could either be to have a more environmentally friendly powerplant which does not regulate the water height and the power production is given by the rain or the timing of the production could be decided by a board voted on by the prosumers. A hydro powerplant will in both ways be a good power production hedge especially for sun power and will therefore be very lucrative.

4.7 Where to locate the REIs

The location for both the renewable energy installation and the prosumer is important, as the basis of the smart contract is that the power goes straight from the REI (renewable energy installation) to the prosumer. The prosumer can decide to sell it or consume it, depending on the circumstances. If it is over a large distance, it could even be efficient for the prosumer to sell all the power locally, where the REI is, and buy the power they consume from closer sources. The stable energy goal is still reached as they buy and sell in the same market. This means that the REIs should ideally be close to the prosumers to work most efficiently, and at least within the same grid, whether that is national or regional depending on the country. Going away from this severs the direct link between the REI and the prosumer which enables them to consume their own energy and be more independent of the entire grid depending on the distance. If this is no longer the goal a simple direct investment into an REI would be better. There are similar solutions to this outlined in subchapter 5.3.

4.8 Handling the inherent risk within the market

The proposed market is a two part market split into contractors and prosumers. One of the most important purposes is that the contractor does not assume any energy price risk. This will make the contractors job much more straight forward, as the income is set in advance. The only risk element for them is changes in the prices of their costs, like materials and wages. This is partly offset by having a very efficient and quick market, giving little time for the prices to change. Other than this there is potential to internalise material costs and wage costs into the smart contract parameters which can pivot the costs of the contract. This would however most likely be counterproductive as it would make the contracts more unstable and harder to trade. A solution here would either be that the contractors simply take this risk or that they buy insurance separately.

4.9 The role of the government and insurance in case of bankruptcy

The government sets the framework for how the market is created, and how it is regulated. To avoid half built projects halted by bankruptcies and make sure that the REI are built on suitable locations it is important with a strong state. To make the system work, the framework needs to be agile enough to be able to service different types of installations in all sizes, as well as rigid enough to be very dependable for the everyone involved. A free market where all contractors are certified creates an efficient market and safety for the investors, in this case the prosumers. The certification will have to include a demand for a backup plan in case of a bankruptcy. This could be an insurance which covers potential bankruptcy. The insurance would pay the cost of having a different contractor finish the contract, making the market as self sufficient as possible without frequent government intervention. The insurance increases the start up costs of the market, as a new insurance product will always be more expensive than an existing one. It therefore increases the need for start up subsidies. To make sure that the contractors do not use the bankruptcy insurance as a tool the certification will have a onetime fixed cost. This does, however, increase the starting cost of the contractors and can therefore decrease competition. These two factors will need to be measured up to each other when deciding the size of the certification cost. Upholding the integrity of the market and allowing bankruptcies also gives higher competition, which again makes it cheaper and more efficient. This helps limit the negative effect of the insurance and certification cost. As renewable energy is already cheap, the return on investment is likely to be high. This makes the inherent competitiveness of the market stronger, since the return on the base product, the REI, is high (Jillian Ambrose, 2021; Victoria Masterson, 2021). The goal of the new market is not to make the prosumers or contractors money, but this will increase the interest in the market and thereby the competition. The stabilisation of energy costs and the reduction of risk will make it a more robust market, while at the same time making it cheaper for the consumer.

4.10 Privacy concern

Since the payment system relies on how much power the prosumer uses, there is a privacy concern as to how much power a household uses, and when it uses it. This can be solved through a noise-based privacy preserving method to conceal the trading distribution trends. It works by hiding the sensitive data within lots of other data to make it hard to pick out what is what. This method is shown in the paper from Gai et al. (2019), where you can read more clearly how this can be incorporated. It is demonstrated to work, but has not been shown to be able to handle large scale usage. It is, however, a common privacy management style, and fit to be tailored to different areas, like the one this paper proposes.

4.11 Effective use of the blockchain to reach the goal

A potential solution to the direct secure energy trading with Blockchain through Industrial Internet of Things (IIoT), is proposed by Hou et al. (2019). It uses a method which enables buyers or sellers to access power loads by using locally available energy storage. As in the privacy method, the scalability of this solution is also uncertain. The number of nodes that are tested is low, and it is not certain that a large scale application of this will have the same outcome. For a closer look at how this method works, please see the cited paper by Hou et al., (2019).

A bonus feature of this new role of the consumer is that it can lead to a more adaptable market. A prosumer has a special interest in tailoring their consumption to mirror their production. This is an efficient demand side management technique to reduce the peak-to-average ratio of energy consumption from the grid, which, in the long run, can contribute to reduce fuel waste and greenhouse gas emission. Load control and management plays an important role in demand side management, which is a vital part of changing the energy market from fossil to renewable (Wang et al., 2018). Modern demand side management must also be more flexible and possible to change at will. Since the prosumers have greater knowledge over their own power production and given power price, they are more likely to decrease their consumption when the output of power is low. The reason here being that they have more to gain from lowering their power consumption during high prices, than normal consumers.

5. Further research and alternative use cases.

The radical market outlined in this paper has the power to increase the investment into renewable energy sources, make the production more democratic, and create a market which is much more responsive to the consumer as it is entirely prosumer driven. It uses the power of the market to allocate where and how much to build, the government's power to regulate and control, and the blockchain technology to make it efficient and able to outcompete the current system. For a radical solution to be implemented it is vital that it is better than the old system, as there are lots of latencies built into most conservative societies which resists change.

5.1 Alternative solution

An alternative to my suggestion is to use a normal market and sell the power individually through a specialized auction, as termed in the (Hassan et al. 2021) paper Optimizing Blockchain Based Smart Grid Auctions: A Green Revolution. This could also be implemented through blockchain with smart contracts, although these contracts would be much simpler, and just specify a sale of a specified amount of power. It could also contain a more advanced auction style where the function of this is contained within the smart contract. Then the smart contract itself could contain the participants in the auction to safe measure it and to avoid manipulation.

5.2 Solving the same problem in developing countries

This solution is not suitable for the developing countries as discussed in the previous part. There are however already some companies who are trying to solve this issue. Sunexchange are building renewable energy installations, by seeking investments from mostly small capital. Sunexchange is offering shares in solar farms in Africa, against capital gains and good conscience. They are currently building in South Africa, with money gathered from western nations. They also accept investment through bitcoin (Sunexchange, 2020;Jake Bright, 2020).

5.3 Direct investment into renewable energy installations

Solstice is closer to my project. They are letting people buy a share of a solar farm close to themselves and getting the power directly as a dividend of that investment. This is more streamlined, as Solstice is building the solar farms themselves (Solstice, 2021). There is no new market, just a business which offers a similar product through a single company. This does not need a strong government in the same sense, but also does not give the same advantages. There are also projects utilizing P2P hubs off grid to help make solar panels profitable and displace the fossil fuel generators. This is on a much smaller scale but can achieve some of the same results in developing countries as what this paper tries to achieve in developed ones.

6. Conclusion:

The world is in dire need for more investment into renewable energy. Even though the production is rising, it is not increasing fast enough as the use of fossil fuels in electrical power generation is steadily rising world-wide. The sketch created in this paper for a new radical market, powered by blockchain technology, can be part of the solution. It can radically change the sale of electricity, as well as the investments to create it, and the different ways the market interacts. Doing this, the new market will increase the growth of the production in renewable energy, nudge working-class people to invest, and create an energy market that is more democratic and stable. Another reason this market is superior to the existing one, is the new risk structure that the new market brings. The contractor of the renewable power installations does not need to account for the fluctuating energy price, since they are paid in a lump sum at the start of the contract. The consumer also does not need to worry about the changing prices, as they have guaranteed a certain part of the power output of the renewable energy installations, irrespective of the energy price. The movement of risk increases the efficiency of the market, by making it more competitive through lover entry costs, originating from lower risks. Moving on to the government's involvement in the new market, setting the framework. The electrical energy market is a complex system where the government is heavily involved through both regulation and management. The new radical market solution that this paper puts forth does not try to change this aspect, but rather change everything around it. It is also possible that government subsidy will be necessary to get the market started. There are some parts of the market that can easily be transformed, and other parts that are very change resistant. Setting this idea into life, the goal is not to convert the entire market over one year, but to gradually change parts of it making the market more competitive and efficient. The retail power companies are replaced by smart contracts which contain all necessary information for a secure transaction. The electrical power producers are replaced, or forced to change, into contractors working directly for the energy consumers. A change of this magnitude makes it a hard process, with many roadblocks that must be passed. The most vital one is the further development of the smart contract. It is in its current form possible to use to create the radical new market, but still has high transaction fees and is a very unknown technology for the public. This makes the desired transition less favourable and difficult to advertise, making it harder to implement. This radical new idea is ideally implemented from within a government, as a free market only controlled by the framework given through the smart contracts. If the market itself is not successful, I hope that it can be used to inspire you, the reader, to use the ideas and solutions outlined to steer the world towards a better and greener future.

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Appendix 1: Data analysis explanation

To best capture the development of electrical generation from fossil fuels and renewable energy, I have used a dataset from IRENA (International Renewable Energy Agency), and regressed the power source on the time. The dataset was built up of very many different types of energy generation, where each was marked either renewable or fossil fuels. To get a clear picture I added all the different sources together into renewable and fossil fuels, as it is this difference that is the important one.

Table 2: Regression of development of renewable energy

	renew
Yearsmallnumber	102624.3***
	(235.6)
_cons	398995.3***
	(2880.9)
N	25196

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Regression of development of fossil energy

	fossil
Yearsmallnumber	113711.1***
	(43.90)
_cons	2676558.4***
	(418.3)
N	25196

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Regression of development of renewable energy 2010-2020

	renew
Yearsmallnumber	155790.4***
	(190.8)
_cons	-429948.9***
	(2895.6)
N	15243

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Regression of development of fossil energy 2010-2020

	fossil
Yearsmallnumber	103963.0***
	(84.62)
_cons	2834602.7***
	(1201.4)
N	15243

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The regressions are used to find the growth coefficient of the two different dependent variables, over the different regressions over the independent time variable of years. The data from table 2 and 3 come from the entire interval between 2000 and 2020, while table 4 and 5 account for the years from 2010 to 2020. This is to see the difference in the development between these two periods. The reason for not splitting it into two equal parts, but one as a part of the other was to highlight that there is a general increased growth. Not just a stronger growth after a specific time. Moving on to the specifics of the regression. I have used robust standard errors, as the structure and shape of the standard errors are unknown, and are therefore better represented by such robust standard errors. The regression is not panel data since there are more than one time observation, per given year, per variable. In this instance, where we are just looking for the trend line and are not investigating the correlation or causality, a simple OLS holds. The p-value is not very important in this regression, as we do not really wonder if there is a specific hypothesis that is fulfilled. It does however show that the growth is stable and clearly positive from year to year for both power sources. The number of observations, N, are high because each observation is an independent powerplant outputting electricity. The smaller N in table 4 and 5 comes from the fact that all the observations from before 2010 are omitted.