greenX – a blockchain-based solution for an alternative REC marketplace

Blockchain Business Development CINTV1803E

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31.10.2019

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Executive Summary

The fast-paced human activity of the past 150 years led to changes in our climate systems hat become more visible every day. Governments, corporations and the civil society are responding to the climate crisis with multiple strategies. Yet, despite all these actions, the concentration GHGs in the atmosphere is increasing (IPCC Report, 2014). By adopting a sector perspective on CO2 emissions, the IPCC Report (2014) shows that Electricity and Heat Production together with Agriculture, Forestry and Other Land Use correspond to almost half of CO2 emissions worldwide. In this context, actors at all levels have seen an economically efficient and viable way to deliver such goals in the broad employment of market-based mechanisms, such as renewable energy certificates (RECs). RECs are market-based instruments that represent one megawatt-hour (MWh) of electricity generated by a renewable energy resource (wind turbine, solar panel etc.). While energy markets are constantly monitored and kept in balance (on a day-, hour- and second-basis), markets for RECs resemble commodity markets whereby RECs are sold and purchased by green energy provider and the interested users. This mismatch calls for a new architecture for REC markets where the coupling between the purchase of the REC and the physical energy consumption is achieved.

In this context, greenX is a blockchain-based platform for an alternative REC marketplace. On the platform, green and black tokens are generated by smart contracts as a result of the company's energy consumption; consequently, a third smart contract regulates the purchase of the certificate in a way to achieve a coupling between the amount and type of energy consumed and the sustainability attribute that the certificate represents. The solution is addressed to RE100, that is a consortium of around 300 companies representing a total of $5.5 trillion aggregate revenue throughout 150 markets globally who have committed to the goal of powering a low carbon economy in the shortest timeframe possible (The Climate Group, 2019). In this context, greenX can be regarded as a transparent and reliable tool that companies can use to achieve their goals of 100% green energy consumption.

The report concludes that greenX has the potential to be a disruptive innovation due to the creation of an alternative market system for an initial niche customer segment – RE 100 companies – that could potentially take over the current mainstream market mechanisms. However, limitations to the potential of disruption were also considered. In particular, the costs and state of development of the technology would correspond to a slowdown in the adoption. Moreover, regulations built around the current system are also a factor to be considered: in fact, policymakers would play a crucial role in supporting or hindering the adoption of a new system.

Introduction

The fast-paced human activity of the past 150 years led to changes in our climate systems hat become more visible every day. Governments, corporations and the civil society are responding to the climate crisis with multiple strategies. Individuals are protesting on streets all around the world with climate movements, corporations are investing on green actions (no matter how 'green' the results of the process are) and governments are pushing more and more environmental conscious agendas. Yet, despite all these actions, the concentration GHGs in the atmosphere is increasing (IPCC Report, 2014). Unprecedented amount of carbon dioxide, methane and nitrous oxide are being released by everyday life activities and captured by the atmosphere causing the dramatic phenomenon of global-scale warming. Extreme sea levels, heavier precipitation events, droughts and biodiversity loss are some of the major results of global warming and all together are leading the planet towards profound and irreversible alterations of human and natural systems (ibid). Based on these changes, limiting climate change has become one of the most urgent challenges of our time. In fact, only a substantial and steady reduction in GHGs emissions will lead us to a more effective adaptation[1] that will support the human species in tackling climate-related issues on the long-run (ibid).

By adopting a sector perspective on CO2 emissions, the IPCC[2] Report (2014) shows that Electricity and Heat Production together with Agriculture, Forestry and Other Land Use correspond to almost half of CO2 emissions worldwide. Of interest is the energy industry since, starting from the Industrial Revolution, energy access and usage has represented a fundamental key to development and economic prosperity (Ritchie and Roser, 2018). For what concerns the sustainability of energy sources through history, renewable energies such as wind, hydro and solar energy were deployed way before fossil fuels were discovered – think about the fact that electricity was first produced in 1876 from a solar cell (Racz, 2018). However, throughout the 20th century, renewable energy implementation was extremely expensive and fossil fuels represented the most competitive energy source. For decades, the whole economic machine has thus heavily relied on fossil fuels to achieve its objectives economic growth and poverty alleviation at the expenses of the environment and the people living on it. A whole production system was built around fossil fuels and long-term, irreversible investments were largely made to seize the opportunities of growth that the sector was offering.

[1] 'Adaptation' is referred to according to IPCC definition of "The process of adjustment to actual or expected climate and its effects" (IPCC Report, 2018).

[2] The Intergovernmental Panel on Climate Change (IPCC) is a UN body established in 1988 with the goal of assessing the science related to climate change in terms of risks and implications, as well as supporting policymakers in the creation of mitigation and adaptation strategies.

However, in recent years, the cost of solar and wind energy production has yet drastically fallen thanks to the fast pace of technological innovation in the field. Renewable energy sources are therefore becoming competitive on the market and this did not go unnoticed. In fact, both the public and private sector have started to heavily invest in in renewables technologies, with solar and wind energy attracting 47% of total investments (Ritchie and Roser, 2017b). In this context, actors in the energy sector play a fundamental role since they represent at the same time one of the greatest polluters and one of the most promising game changers (IRENA, 2018). In fact, while traditional oil and gas companies are responsible for having led to a nearly collapsing planet, the same companies – together with the multitude of green energy producers of any size - are now working on business model innovation and they are investing on the potential to develop and deploy renewable energies on a large scale.

Moreover, to this date, 186 countries have ratified the Paris Agreement of December 2015 committing “to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future” (UNFCCC, n.d.). With the goal of limiting the global temperature rise to below 2°C – or ideally below 1.5°C -, countries started to adopt a variety of measures including more significant deployment of renewable power, energy efficiency, land-use controls such as conservation of forests and grasslands and market-based instruments for emission reduction (ibid). The Paris Agreement further highlights the need for a cohesive action aiming at mitigating and limiting the effects of climate change (IPCC Report, 2018; Sterman, 2015). Actors at all levels have seen an economically efficient and viable way to deliver such goals in the broad employment of market-based mechanisms. Pricing mechanisms for climate change mitigation include a variety of instruments such as carbon taxes, schemes of carbon credit and certifications for the usage of renewable energies. In line with these trends, the market for energy attribute certificates (EACs) boomed in 2018 as a result of an increased use and trade of Guarantees of Origin (GOs), Tradable Instruments for global renewables (TIGRs) and International Renewable Energy Certificates (I-RECs) among others[3] (see Appendix 1). RECs are market-based instruments that represent one megawatt-hour (MWh) of electricity generated by a renewable energy resource (wind turbine, solar panel etc.) (United States Environmental Protection Agency, n.d.). Once any type of energy is produced and immitted into the grid, its origin is lost and it becomes a single flux of electrons travelling around the energy grid (Hsiao, 2018). For this reason, RECs with unique IDs - containing the data on energy unit embedded in the certificate - were born with the aim of tracing and assigning the ownership of green energy produced. In fact, with the purchase of the certificate

[3] GOs, TIGRs and I-RECs are the three international systems for the issuing and tracking of EACs (IRENA, 2018). Throughout the report, for simplicity, we will use the general term ‘Renewable Energy Certificate’ or ‘REC’ to refer to all EACs .

a company can 'take ownership' of the unit embedded in the REC and accordingly make claims of renewable energy use (ibid).

Currently, two types of REC marketplaces exist. On one hand, policies requiring minimum levels of renewable energy in the electricity supplied by service providers - such as state Renewable Electricity Standards (RES) and Renewable Portfolio Standards (RPS) – led to the creation of a REC compliance markets (Holt and Bird, 2005; Hsiao, 2018). In compliance marketplaces, electricity server providers either produce or buy the required number of RECs needed to meet their renewable energy obligations under the policies (Lau and Aga, 2008). On the other hand, voluntary REC markets accommodate the retail, commercial and industrial energy users' demand for green energy. In this case, utilities and renewable energy producers sell RECs to private customers and corporations to support their renewable energy goals (Holt and Bird, 2005; Lau and Aga, 2008).

The Issue

While energy markets are constantly monitored and kept in balance (on a day-, hour- and second-basis), markets for RECs resemble commodity markets whereby RECs are sold and purchased by green energy provider and the interested users (Holt and Bird, 2005). With this mechanism, the sale or purchase of the certificate is decoupled from the physical energy production or consumption (Holt and Bird, 2005; IRENA, 2018). Therefore, certificates are not traded in real-time and purchasers can buy a year-worth of energy credits in a single transaction. This 'mismatch' between the energy consumed by the purchaser and the green energy represented by the certificates gives rise to multiple controversies. On one side, it allows private actors connected to grids with low shares of green energy in the energy mix to purchase green energy shares without altering their existing power contracts (Holt and Bird, 2005; Lau and Ada, 2008). On another hand, MNCs may take advantage of the lack of geographic boundaries in REC trading by buying the number of certificates needed to make their energy consumption worldwide 'greener', regardless of the cleanness of the grid they are attached to (Holt and Bird, 2005; Kashav, 2018). Currently, related claims of renewable energy consumption are thus not backed by facts and companies pioneering in sustainability as well as companies trying to address claims of greenwashing currently lack a vehicle to differentiate their sustainability profile. A new architecture for REC markets is thus needed for the system to function more effectively and achieve the necessary coupling between the purchase of the REC and the physical energy consumption (IRENA, 2018).

The Solution

In this context, greenX was born from the challenge proposed by Vestas - global leader in wind turbine manufacturing – during the Hackathon on Responsible Use of Blockchain Technology organized by CBS PRIME. The challenge consisted of creating a solution for an alternative REC marketplace where the coupling between energy consumption and REC purchases could be achieved. After two days of discussions and iterations, greenX was born as a blockchain-based platform for standardized REC purchases. On the production side, when a renewable energy source produces 1MWh of green energy, 1 REC certificate is created and a related token is released on our blockchain-based platform through a smart contract. Second, on the consumers side, both the energy mix consumed and the hourly energy consumption of the company are detected by smart devices; the data is then transmitted on the blockchain through their application programming interfaces (APIs). Third, smart contracts on greenX will use the data receive to execute several transactions: first, whenever 1 MWh of green electricity is consumed by the company, a first smart contract will generate 1 fungible green token. In the same way, whenever data on consumption and energy mix shows that the company has consumed 1MWh of 'dirty' energy, a second smart contract will generate 1 non-fungible black token. All green and black tokens are then stored on the company's wallets. Fourth, for what concerns the trading layer of the platform, a third smart contract will take care of the matching and exchange of green and black token with REC certificates. The black and the REC certificates will be matched based on the timeframe in which the energy attribute they represent was produced while the green token will essentially represent the 'right' for the company to complete the transaction. As a result of the execution of the last contract, a real-time coupling between real-life energy consumption and REC purchase is achieved and companies can visualize the purchases of the RECs on the platform.

We envisioned Vestas as the driving force behind such a solution, not only because of their resources and market power, but also because of their recent decision to join RE100 – a global corporate initiative that brings together business leaders aiming at accelerating the achievement of a 100% renewable energy consumption (there100.org). Following pressing needs of achieving long-term sustainability on a global scale, firms of all sizes are either creating new value propositions or reformulating old ones considering not only the economic value but also the environmental and social impact of the product or service proposed. In this context, firms around the world are no longer operating autonomously to achieve individualistic goals but rather collaborating with external parties – e.g. joining powers in formal and informal alliances or through consortia (Beattie and Smith, 2013). This is exactly what the RE100 represents: a consortium of around 300 companies representing a total of $5.5 trillion aggregate revenue throughout 150 markets globally who have committed to the goal of powering a low carbon economy in the shortest timeframe possible (The Climate Group, 2019). In this context, our solution can be regarded as a transparent and reliable tool that companies can use to achieve their goals of 100% green energy consumption while enhancing their reputation and branding (Hsiao, 2018). Vestas would be the actor powering the solution and proposing greenX as a platform where RE100 companies could achieve the missing match between purchase of RECs and real-life energy consumption, thus managing to distinguish their sustainability profile and lead the way for a green energy future.

The Innovation

The following section of the report will provide a detailed description of the innovation as well as of how blockchain technology is integrated into our solution. The report will not cover details about APIs connection nor cover the way the blockchain is connected to the prototype. In order to delimit the scope, the paper will describe the innovation and discuss its development.

greenX Platform

GreenX was born as a solution to the problem of mismatching currently present in the REC marketplace. RECs are currently traded in commodity-like markets whereby the certificates are sold and purchased by private entities without the need to consider any connection to their actual physical energy consumption. The lack of coupling between the purchase of the certificate and the energy consumed allows companies to 'clean' their energy profile with a single transaction thus building sustainability profiles that are not matching their real-life actions (i.e. 'greenwashing'). In the case of energy consumption, companies showcase achievements or objectives of 100% renewable energy consumption even though the current functioning of the market is far from supporting them in the actual achievement of that goal (Corradi, 2018). As such, greenX was born as a tool for multinational corporations to pursue their sustainable development goals in a transparent and accountable way. The failure of current REC marketplaces to couple the time and place of energy consumption with the acquisitions of certificates is addressed with the implementation of a blockchain-backed system that provides companies with the opportunity to purchase RECs according to their real-life energy consumption. Moreover, companies will also have access to real-time data regarding their energy consumption as well as the energy mix received. In this way, they can enhance their strategies for sustainable energy management. A detailed explanation of how the platform works will follow.

First, companies can log in or register in the platform and access their private member area. In this case, we chose Coca Cola to exemplify one of the RE100 companies using the platform. Once the logged in, the company will be able to see their profile with information about their renewable energy consumption goals (see appendix 2). The second section is called 'Wallets' (see appendix 3). Here companies have a visual representation of their holdings of green and black tokens as well as to the record of certificates bought. Green and black tokens are the means through which the coupling between energy consumption and REC purchase is achieved. Green tokens are generated whenever 1 MWh of renewable energy is consumed by the company. Black tokens are created accordingly to each MWh of fossil fuel energy recorded by the smart devices. Data on the amount and origin of energy consumed are gathered by connecting the following APIs to the blockchain: smart-me API (for energy consumption) and electrictyMap API (for the energy mix).

Based on the data recorded by the APIs, smart contracts on the blockchain will then create the green and black tokens that will be stored in the company's wallet. Green tokens are fungible tokens representing the right for the company to proceed with the acquisition of the REC: the number of green tokens in the wallet will determine the number of RECs that the company will be allowed to purchase according to our sustainable energy accountability guidelines. On the other hand, black tokens are non-fungible tokens containing the data on 'dirty' energy consumption. These will define the type of REC that will be bought. By visualizing the number of tokens available, the company can have an understanding the status quo of their REC purchases. A third smart contract will provide information about green and black tokens will be matched with the data provided by a REC database attached to the chain. The database is provided by REC issuing bodies and it will integrate on the blockchain the information about REC certificates available on the market[4]. The smart contract is then programmed in a way that it matches the timeframe of the black tokens with the timeframe of the 1MWh of renewable embedded in the multiple RECs. If the match is found and there is availability of green tokens (which permits the purchase), the RECs are purchased and stored in the company's wallet. This level of the solution is the main focus of the report since the innovation brought by greenX

[4] See for example: https://www.rec-registry.gov.au/rec-registry/app/public/about-the-registry

lies in the match between the company's consumption and the purchase of certificates – figure 1 illustrates the mechanism just described.

While the first section is related to the alternative mechanism of purchasing RECs offered by greenX, the last two essentially provide companies with tools for energy management.

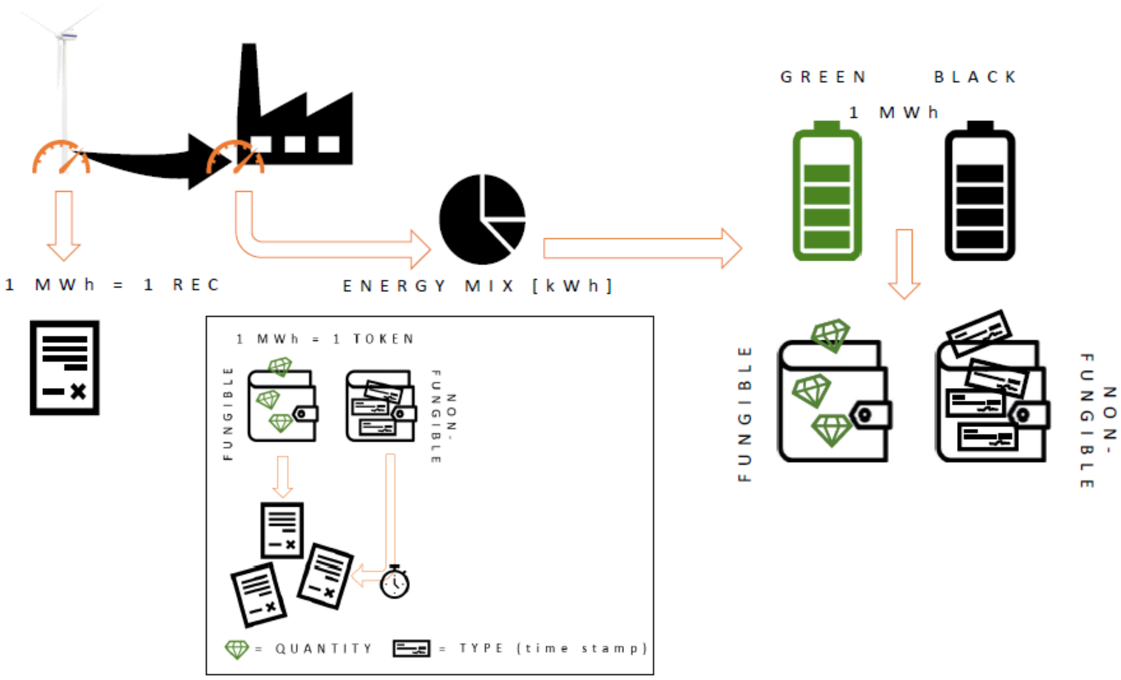

Figure 1. greenX - token generation, storage and trading

In the third section ('Energy Consumption') (see appendix 4), companies have access to their live energy consumption data. Currently, end users of any type do not have live access to the data collected by the smart meters. In fact, these are typically collected by utility companies which then offer end users the possibility to access data on a different day, through different platforms and only allowing them to verify their electricity consumption and without any further management option (smart-me, 2018). On the contrary, on greenX companies can visualize and monitor their energy consumption in real-time, thanks to the connection between our blockchain and smart-me API (further explanation on the API in the next section). On greenX, smart-me data has a two-fold application. On one hand, the data will serve to trigger the smart contracts for the creation of green and black tokens (see 'Wallet' paragraph). On the other, it also serves as a way for the company to visualize and monitor their energy consumption on an hourly, daily, weekly, monthly and yearly basis.

In the fourth and final section of greenX, companies can access data on the energy mix they receive from the grid and that they consume to run their daily operations in that part of the globe ('Energy Mix' section – see appendix 5). In order to include this feature, greenX relies on a second source of data coming from electricityMap API (further explanation on the API in the next section). In a similar way as for the ‘Energy Consumption’ section, the data will be used, on one hand, by the two smart contracts for green and black tokens generation (in combination with data from energy consumption). On the other, it will provide companies with clear information about the origin of the energy consumed so that they can make informed decisions towards the achievement of an actual a 100% consumption of green energy.

greenX on Blockchain

Given that greenX is a platform originally conceived for a consortium of multinational corporations (RE100), the attributes of a permissioned blockchain allow to satisfy requirements of privacy, security and transparency without compromising on the benefits of decentralization and automation from smart contract. While the most famous application of blockchain, Bitcoin, is built on a totally decentralized, freely accessible blockchain (*permissionless* blockchain), multiple blockchain-based projects have started to be built and implemented on *permissioned* blockchains. Permissioned blockchains are essentially private networks in which either a single entity or a consortium of organization gets to decide on how nodes are identified and authenticated as well as assigns permission regarding who can read send and receive transactions (itif.org). One of the advantages of using a permissioned blockchain is that consensus can be reached faster and in an easier way thanks to the limited number of nodes on the network and to the signed contracts governing the relation among entities on the chain (itif.org). Moreover, the absence of miners solving complex computational problems results into a lower energy consumption and faster processes. If considering disadvantages, private blockchains lack the total decentralization, thus transparency and tamper-proof nature of public ones (ibid).

For what concerns the consensus mechanism, greenX runs on Proof of Authority (PoA). PoA can be seen as an ‘optimized Proof of Stake’ that employs the identity of the nodes as a form of stake rather than the actual stake of the nodes in the network (Curran, 2018). Through PoA, nodes reach consensus based on mutual trust, without the need for communication and substantially reducing the computational power needed to validate transactions in the chain (ibid). PoA thus does not involve any mining but rather a process of ‘forging’, i.e. transactions are collected, provided to the other nodes and then validated. The incentive for companies not to act maliciously is related to the fact that their reputation is linked to their identity and none of the companies wished to face reputational damages from misbehaviours in the network (ibid). The main limitation of using PoA is linked to the fact that the greater the number of validators (i.e. companies) on the network, the lower the efficiency and security in the network (ibid). Considering that RE100 gathers around 200 multinationals, we must consider such observation as a potential obstacle to the expansion of greenX platform. Moreover, two assumptions are key for the consensus to work: first, we must assume that RE100 companies, REC issuing bodies and greenX trust each other on the information provided and validated. This leads to the second assumption, i.e. that the smart meters are not hackable.

Figure 2 shows how blockchain elements are combined on greenX. The nodes (i.e. actors labelled 'A') on our blockchain are greenX as a policymaker ('P'), RE100 companies as validators ('V') (companies may also constitute potential contributors to policymaking) and REC issuing bodies. We can say that greenX is operated by the network of RE100 companies as validators under the conditions set by greenX as policymaker. Validators are nodes whose identity is well-known by all the nodes and whose role is to validate transactions and blocks within their own blockchain (Curran, 2018). Policymakers act as governing entities needed to 'establish the rules of the game': in our case, greenX is indeed entrusted with the creation of a policy framework to set and enforce rules governing the legal and economic side of the platform. greenX authority may comprise having veto powers on decisions regarding who can access the blockchain and who can be in fact expelled.

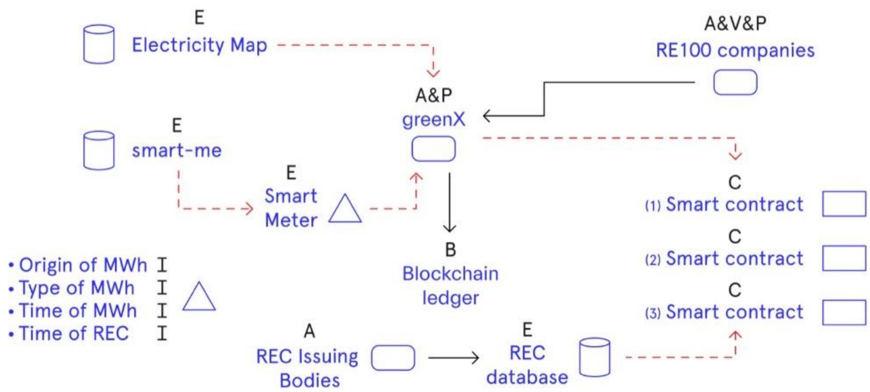

Figure 2. Blockchain-Augmented Rich Picture

Furthermore, the figure shows three different event sources ('E'). First, electrictyMap is an open-source platform created by Tomorrow to display in real-time the origin of electricity generated by each country and its carbon intensity (Corradi, 2016) (see Appendix 7). By using coupled flow equations, Tomorrow is able to determine the physical origin of electricity at every point of the grid; in turn, Tomorrow's AI algorithms manage to estimate the marginal origin of electricity and make forecasts (Tranberg et al., 2019 for more information about the methodology). Thus, as a consequence of integrating real-time electricityMap API, the greenX blockchain receives precise data about measurements and forecasts of the origin, fuel source and carbon intensity of more than 100 countries worldwide. Second, smart-me is technology manufacturer that develops and commercializes devices for sustainable energy management (smart-me, n.d.) ; as part of their product line[5], smart-me produces a module that end users - RE100 companies in our case - can plug into their energy meter in order to capture their real-time energy consumption from all energy sources (smart-me, n.d.). Once the module is inserted into the smart meter, the smart meter connects to the smart-me cloud through simple Wi-Fi connection and proceed with transferring and storing all the data regarding the user's consumption of energy on the cloud (smart-me, n.d.). For what concerns our solution, the data is then transmitted from the cloud to greenX blockchain through the smart meter and used as described above to execute the smart contracts for token creation. The third source of events is the smart meter installed in companies' buildings which functions as blockchain oracle, i.e. as a middle layer that transmits and authenticates events from the real world and pass this information to smart contract, thus triggering their execution (Voshmgir, 2019). Each smart meter will be assigned a specific address and transmit the data to the blockchain thanks to internet connection.

Tokens

According to Mougayar and Buterin (2016), a token is "a unit of value that an organization creates to self-govern its business model, and empower its users to interact with its products, while facilitating the distribution and sharing of rewards and benefits to all of its stakeholders." Tokens are thus digital representation of value which can take two different forms: tokens can be either fungible (i.e. 'value tokens') or non-fungible (i.e. 'digital assets tokens'). While fungible tokens represent identical standards value uniformly accepted (ex. digital currencies or means of exchange), non-fungible tokens embody unique and different types of value (ex. assets or data) (Oxcert, 2018). As a consequence, while fungible tokens can be divided into smaller units and are interchangeable, non-fungible tokens are indivisible and cannot be exchanged for a token of the same type (ibid). As mentioned above, two types of tokens exist on greenX. Green tokens are fungible tokens and are used to define the *number* of RECs that the company is allowed to buy. On the contrary, black tokens are non-fungible and contain pieces of information (data, time, origin) about the energy consumed deriving from fossil fuels. By matching the timeframe of production of the two, black tokens will delineate the *type* of REC that the company will purchase.

Fungible tokens are issued through the ERC-20 standard on the Ethereum blockchain (Oxcert, 2018). The ERC-20 Standard defines a set of six functions that all ERC-20 tokens must comply with. ERC-20 tokens are therefore recognized and identified by other smart contracts thus resulting in all ERC-20 tokens on Ethereum to be exchanged and utilized across different applications such as contracts, wallets or marketplaces (Ethereum Improvement Proposals, n.d.). By using

[5] See Appendix 6.

remix.ethereum.org – an IDA (Integrated Development Environment) to test smart contracts in Solidity – the code for the green token was developed and compiled. Figure 3 shows the section of the code describing the token's characteristics. Appendix 9 shows the full code ready to be compiled. For what concerns black tokens, standard ERC-721 on Ethereum regulated their issuance.

```
function ERC20Token(
    ) {
    balances[msg.sender] = 1000;
    totalSupply = 1000;
    name = "green X green Token";
    decimals = 0;
    symbol = "GXGT";
}
```

Figure 3. Green token's characteristics.

Smart Contracts

First introduced in 1994, a smart contract is described as "a computer program executed in a secure environment that directly controls digital assets" (Szabo, 1996). When Ethereum emerged in 2005, it represented the first blockchain-based smart contract platform thanks to its programming language (Solidity) that would allow both normal transactions (such as Bitcoins' transactions) and transactions among smart contracts (Pan et al., 2018).

Thanks to the presence of three smart contracts on greenX blockchain, green and black tokens are produced, matched with REC data and exchanged for a certificate whenever the programmed conditions for their release are met. As already mentioned, for green and black tokens, the contract is enforced whenever the sensor registers 1 MWh of renewable and fossil energy respectively. After the green and black tokens are matched with the REC certificate, the purchase is accomplished and a new state of the chain is reached showing the updated token balance. Both the green and black tokens will then become inaccessible. In order to make them inaccessible, it is key to set up the logic behind the smart contracts generating the tokens in a way to limit their use to a single transaction. A way to accomplish this would be to include special fields in the smart contract such as a 'use-once' and 'delete-after' clauses. For what concerns the 'use-once', it would imply that "If a match between the black token and a REC is found, only execute the purchase transaction if and only if any green token is available and if and only if the black token has never been used before. If these conditions are not satisfied, then the purchase will not be triggered." On the other hand, the 'delete-after' clause would make sure that the tokens are burnt after the purchase is terminated. In conclusion to the transaction, the block will be closed and stored it on the blockchain to represent a transparent and accessible history of all transactions executed. The new transactions will then be added to the new block containing also the updated balance of tokens.

The Business Model

In order to discuss how greenX will conduct and sustain its business, a Business Model Canvas was created (see Appendix 8).

Customer Segments & Relationship

greenX solution is developed to meet the needs of companies for tools to differentiate their sustainability profile with a real-life coupled purchase of REC certificates. In particular, RE100 companies were chosen as main customer segment due to their public commitment to 100% green energy consumption.

Moreover, the main channels to communicate the value proposition of greenX will consist in the RE100 consortium, specifically in the role of Vestas as leader of the green transition, as well as the platform itself.

Value Proposition

greenX provides RE100 companies with a blockchain-based platform for real-time REC trading on which companies can achieve a match between current energy consumption and purchase of RECs. As a result, greenX constitutes a tool to for RE100 companies to lead the transition to a 100% green energy consumption in a transparent and traceable way.

Key Activities & Partners

The main activities conducted by our company would be those of developing, maintaining and operating the blockchain platform. In particular, the team will be responsible for the creation and implementation of a legal framework to regulate the acceptance/refusal as well as the legal and economic behavior of RE100 companies on the platform.

In terms of business collaborations, greenX relies on four main partnerships. First, Vestas is a key partner as it represents both the initiator of the solution and the main financial supporter. In fact, greenX was born as a result of a challenge launched by the company and it constitutes a sort of agile, blockchain-focused spin-off of the multinational company. Moreover, having Vestas recently joined RE100, the company can strategically leverage their brand and credibility to launch and promote the adoption of the solution among RE100 companies. Moreover, two other key partners are smart-me and electrictyMap because the provision of core data to the blockchain (i.e. real-time information about energy consumption and mix) through smart devices and APIs. The data is 'core' because it constitutes the trigger for the execution of the smart contracts. To conclude, the fourth key partnership is established with REC issuing bodies that will be central in the provision of the database containing the information about emission, registration, trade and surrender of RECs.

Key Resources

For what concerns key resources, greenX is built on financial, technological and human resources. Financial resources represent the funding necessary to develop, maintain, run and promote the platform. On the other hand, technological resources refer to the servers (i.e. computational power) and connectivity fundamental develop the blockchain network. Human capital is constituted by the knowledge, skills and personal attributes of the member of greenX as well as by the experience of external advisors and consultants (specifically playing a key role in the first years of activity).

Cost Structure & Revenue Stream

The cost structure is mainly as result of the costs of developing and running the blockchain, the costs of accessing the different APIs and human capital costs. For what concerns the latter, we are not only referring to salaries but also to cyber-security costs in order to protect the network from potential cyber-attacks. Moreover, costs of creating such platform would be mainly related to the number of nodes on the network and to the number of transactions executed by each node.

The two main ways in which greenX will generate revenues are through a fairly low transaction fee (3% cc) on each REC purchase and a subscription fee based on the size and profit of the company. The payment of the subscription fee will be a criterion that greenX will adopt to accept/refuse the entrance of companies on the platform.

The Development Process

The Creation Process

This is how GreenX began on a rainy Tuesday morning, 24th September 2019, at Copenhagen Business School (CBS) for the Hackathon on Responsible Use of Blockchain Technology by CBS

PRIME. Excited about the topic, my friends and I teamed up to participate to the presentation of the program and the company presentations of the challenges by Oxfam IBIS, IKEA and Vestas. Few hours later, we registered our team for the Vestas' challenge: "How to use an existing, or develop a new, platform/marketplace that enables 24x7 green electricity through reliable Renewable Energy Certificates (RECs) balanced against the time-of-use of electricity in a given geographical area or market" (Vestas, 2019). It's the first time we worked together, as we have different backgrounds going through Sustainable Energy Engineering, Physics and Nanotechnology Engineering, Environmental Development and, myself, Business and Development Studies. However, the common ground and the team main drive was to make a meaningful impact in the transition towards a regenerative sustainable society. And Vestas' challenge seemed the perfect occasion to start.

At this stage, the commitment needed to be translated into organisation of personal effort, expectations, knowledge, resources and time. Luckily, our backbone of trust speeded up the process and allowed us to dig into the challenge soon. We moved together with the other teams to get more information and brainstorm with Jared and Mads, from Ideation and Partnering department of Vestas, in a Q&A session. They explained what Vestas is, leader in Wind turbine, and its long-term strategy of becoming the global leader in sustainable energy solution. Furthermore, they give us a deeper understanding of the mismatch in the RECs markets, underlining the constraints in time and audit of coupling RECs with the companies' real-time consumptions. Particularly, we found appealing the tracking process of renewable energy consumptions and how to improve their traceability in order to be compared with generated RECs, before being traded. Here the initial idea came into play: the creation of a double layered blockchain-based solution matching the tracking of the origin of energy with renewable energy certificates trading. As figure 4 shows, the solution envisioned two layers. First, the green layer would have represented the consumption side. In this case, a first partnership with The Energy Origin (TEO)[6] would have provided transparent and traceable data on the provenance of energy consumed by the nodes of the blockchain. Second, the red layer would have corresponded to the productions side. Here, thanks to a second strategic partnership with C6[7], data about the production of REC would have been access and registered on the blockchain with each REC representing a token. The two layers would have interacted in a way that the blockchain would receive data from both sides and match the type of energy consumed with the purchase of the REC generated in the red layer. However, not completely convinced of passing the buck to possible

[6] A blockchain start-up created by Engie (a French utility company) and operating on the Energy Web Foundation's (EWF) open-source, blockchain platform. More here: https://energyweb.org/portfolio/the-energy-origin-teo-engie/
[7] C6 is a Power Ledger's blockchain-based solution to assess, record and verify the production of RECs. More here: https://www.powerledger.io/product/c6/

partners and presenting a solution partnerships-based, we decide to individually research at home alternative solutions and sleep over it.

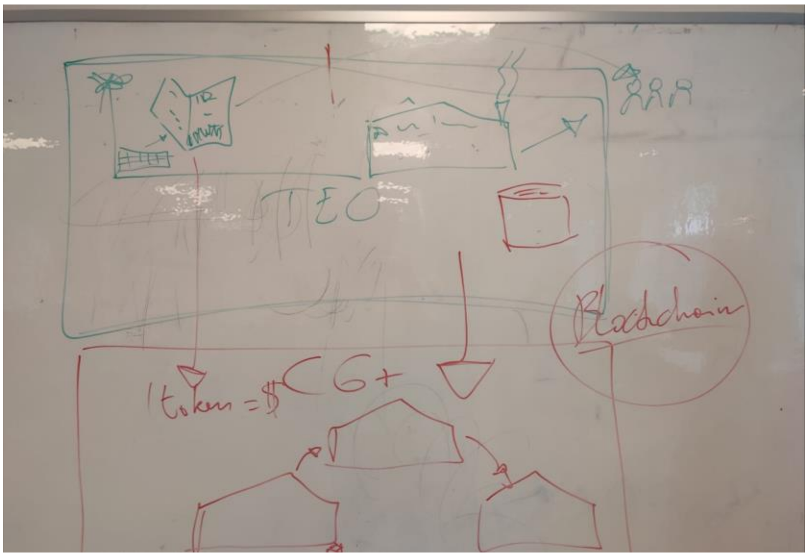

Figure 4. Draft of the first solution.

On the second day, we met and Alice found out that Vestas recently joined RE100, “a global corporate leadership initiative bringing together influential businesses committed to 100% renewable electricity” (there100.org) for a total of around 300 companies operating in a diverse range of sectors. And Vestas is one of the few energy companies, having the vision of becoming global leader in the renewable electricity transition. That set off the light bulb. The business value that a big community of organizations, already committed to seek out a practical technological way to achieve the shared long-term goal, could bring to a trusted company that may create that technology came to our minds. So, now that we had this potentially scalable market, we started to consider RE100 companies as nodes of a multi-layered network defined with specific IDs, as following: each company (ID 0) has at least one site (ID 01) connected to a local energy grid (ID 012) of which energy mix can be retrieved hourly and matched with the real electricity consumption of the company’s site. Thanks to smart devices, we realized that not only we could potentially access those data but that we could connect the APIs to our blockchain platform in a way to use it to execute smart contracts. We started to elaborate then on how to actually achieve the matching between the given consumption and the purchase of the certificates. The solution that we develop and presented is the one represented in figure 1. Vestas appreciated the innovative idea of creating an alternative REC marketplace and they were impressed with the potential that blockchain technology has in solving the issue of the mismatching currently affecting the way RECs are traded. In conclusion, we were awarded with the first prize and decided to take this exam as a point of departure to further develop and explore the solution.

Process Modelling with Soft System Methodology

According to Checkland (2000), organizations are "open systems that interact with their environment" (p.45). As such, the complexity of the problems that an organization face increases when including individuals, groups and the external environment in the picture. Soft systems methodology (SSM) is the result of 10 years of research conducted by Peter Checkland at the University of Lancaster during which he studied how complex situations are analysed and solved by individuals and groups with different views acting within the dynamic framework of an organization (Checkland, 2000). As a result, SSM was developed as an organizational approach to business process modelling used by organizations to deal with the complexities of acknowledging individual's thoughts and their influence in problem-solving and change management (Checkland, 2000). The approach evolved during the years across multiple research programs, papers and articles and it is outside of the scope of this report to analyse it. Instead, this section aims at highlighting the relevance that modelling played in defining and building our solution. Specifically, we used the CATWOE model, that is a model developed by a David Smyth while working at Checkland's department. Models, from Checkland's view (2000, p.26), can be regarded as "an intellectual devices — whose role is to help structure an exploration of the problem situation being addressed". In fact, we used the CATWOE to explore the core purpose of our solution as well as to resonate on the values laying behind. Moreover, the creation of the so-called 'rich-picture' of the system allowed us to then understand how to integrate blockchain in the envisioned solution (see figure 2). Figure 5 shows the CATWOE model for greenX.

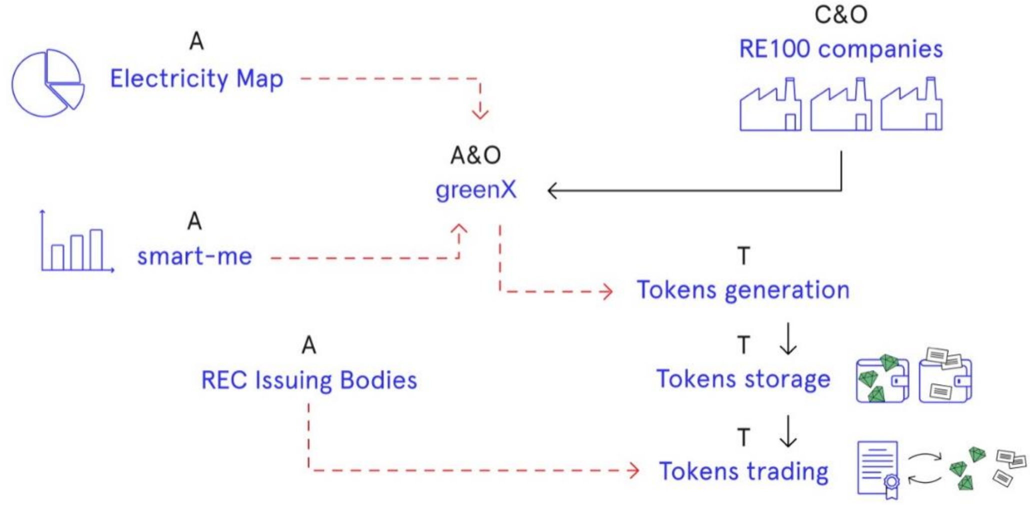

Figure 5. greenX CATWOE model

In CATWOE model, 'T' represents transformation process whereby inputs are being transformed into outputs (Bergvall-Kåreborn et al., 2004). As for greenX, the core business processes (i.e. the three 'T's) are token generation, token storage and token trading. Within these processes, while inputs are represented by the electricity and REC data gathered from smart-me, electricityMap and the REC database, the outpsut corresponds to the match of the data and the consequent purchase of the REC certificate. In order for the transformation process 'T' to assume meaning, a worldview 'W' also needs to be defined (ibid). As for greenX, customers ('C') – i.e. those affected by the system -, actors ('A') – i.e. those performing the activities – and owners ('O') – i.e. those in control of the system – share similar ideas and beliefs. They are all working to support an inclusive and sustainable development and more specifically, to accelerate the transition towards a 100% renewable energy consumption. To conclude, environmental constraints 'E' include outer elements of the system affecting the functioning of the system itself (ibid). Regulations, challenges to adopt a new technology as well as technical complexities of blockchain technologies are constraints that greenX may face. More in regards of limitations is discussed in the 'Evaluation and Assessment' section of the report.

In Support of greenX

While developing the solution, we found multiple evidences supporting the adoption of an alternative, blockchain-backed REC marketplace. First, according to the International Renewable Energy Agency, in 2017, almost 62% of the renewable electricity consumed by companies was purchased through unbundled RECs (IRENA, 2018). This fact highlights the willingness of companies to consume higher shares of renewable energy, whether through direct consumption from the grid or indirectly through the purchase of certificates. Nevertheless, as long as the energy attribute of RECs is unbudled from the actual energy consumption of the company, companies do not have the tools to realistically achieve a 100% green energy profile. A huge potential thus exists to strengthen corporate sustainable energy commitments by providing alternatives to the current system, such as the alternative marketplace for RECs proposed by greenX. To this extent, among the recommendations on how to scale up corporate sourcing of renewables, IRENA suggests that it is key to "support an effective system for issuing and tracking of energy attribute certificates, enabling companies to make credible renewable electricity use claims" (IRENA, 2018, p.13). greenX uses blockchain as a tool to achieve real-life coupling of purchase of REC and energy consumption thus providing companies with an instrument to sustain such claims. In fact, thanks to the presence of green and black tokens to 'regulate' the purchase of RECs, companies are allowed to buy only a limited number of certificates that may not be enough to cover all their fossil fuel energy consumption. As a consequence, they would be pushed towards the creation and implementation of a broader sustainability strategy in order to reach their emission reduction targets: for instance, they could implement in-setting practices[8] or reformulate their investment strategies by taking into greater consideration the type of energy they would receive from the grid of the country they are investing in.

Second, the report from IRENA (2018) highlights the need for a "transparent tracking system [that] clarifies origin and ownership" of RECs (IRENA, 2018, p.13). At the same time, also Power Ledger CEO criticized the opacity of REC marketplace, calling for increased efficiency, security and transparency (McDonald, 2019). GreenX answers these calls by taking advantage of blockchain technology to create a tamper-proof, traceable and transparent records of RECs attributes and ownership thus contributing to increased soundness and coordination of the system (Hasse et al., 2016; Hsiao, 2018). To this extent, the different sections on the platform ('Wallets', 'Energy Consumption' and 'Energy Mix') serve both for companies and the outer public as a way to access to key information on energy consumption and sustainability profiles.

Third, using blockchain to create an alternative REC marketplace also allows to face some of the inefficiencies that are currently in place. In fact, as a consequence of the existing great variety of RECs available in the market (RECs, I-RECs, GOs and so on), experts in the sector have highlighted issues related to double-spending. Double-spending implies that a REC holder sells the same certificate to more than one person or entity (Holt and Bird, 2005; Hsiao, 2018): this illicit behavior of sellers is tackled on greenX thanks to the use of cryptography and decentralized consensus on transactions (IRENA, 2019). In fact, each certificate has its own encrypted ID that is matched with that of the black tokens during trading. Once the purchase is accomplished, the black token is burnt and the REC ID is stored in the company's wallet. As a result, not only double-spending issues are solved but the system also constitutes a way for companies and auditors to verify its soundness.

Evaluation and Assessment

Can greenX be considered a disruptive technology? And if yes, what kind of issues evolve around such consideration? According to disruptive innovation theory introduced by Christensen (1997), a technological innovation is considered to be disruptive when it contributes to the transformation and creation of new markets that offer new functionalities and thus may disrupt existing market dynamics. Blockchain technology application in the energy sectors has already been described as disruptive due to its core nature of full decentralization and to the creation of a new, peer-to-peer market system (Hasse et al., 2016). To this extent, the creation of an alternative REC marketplace based on the

[8] See here for more about 'insetting': https://www.theguardian.com/sustainable-business/2015/jan/09/carbon-offsetting-insetting-supply-chain

attributes of blockchain could lead greenX to be categorized as a disruptive innovation. If the system reaches a broad adoption, it has the potential to 'disrupt existing market dynamics' due to the introduction of 'new functionalities', i.e. the coupling mechanism between REC purchase and energy consumption.

Moreover, disruptive technologies have been discussed in terms of creating new values with respect to mainstream technologies (Christensen, 1997). In these regards, greenX represents a platform through which companies can pursue their environmental bottom-line and their commitment to an inclusive sustainable development. In fact, RE100 companies can achieve a broader impact thanks to the coupling mechanism enabled by the blockchain and smart contracts. Our platform can thus be seen as generating new values that go beyond efficiencies related to the economic performance of firms. To this extent, RE100 companies will be provided with a transparent and effective tool to sustain claims of renewable energy consumption, thus distinguishing their sustainability profile thanks to the creation of more consistent green identities supported by the technology.

One more point in Christensen's theory (1997) includes the consideration that as soon as the innovation will be introduced, it will serve a niche customer segment willing to embrace the 'non-standard' attributes of the technology. Again, greenX could fit in this description as RE100 companies can be identified as niche customer segment that would first adopt the alternative REC marketplace. The blockchain-enabled coupling between the energy attribute of the REC and energy consumed represents the 'non-standard' trait that distinguished the technology and provides an incentive for companies to adopt the new solution.

For the reasons discussed above, greenX could thus be seen as having the potential to disrupt the market for renewable energy certificates; yet, in line with Christensen's view, the potential disruption would only occur once the blockchain-based marketplace would displace the current mainstream market. As a consequence, the report will now discuss the solution in terms of limitations for mainstream adoption. For this purpose, Sterman (2013) discusses radical disruption and the creation of new industries built on sustainable products, services and operations considering obstacles and challenges to adopt such solutions. In Sterman's perspective, transitions to new markets has a history of 'path dependence, false starts and delays' (ibid, p.21). In this context, when analysing the creation of an alternative, blockchain-based marketplace, we have to acknowledge that even though the problem of the mismatch has been widely recognized, costs and the state of (im)maturity of greenX technology (versus the maturity of traditional REC marketplaces) may be factors that slow down the adoption. In fact, due to the current sizes of the REC marketplace and the regulation that has been developed around it, it may take a long time before energy producers, companies and government decide to invest in alternative solutions. For what concerns companies, unethical behaviours on their side is also a potential limit to the disruptive potential of the platform. In fact, companies may take advantage of the coupling provided by greenX between energy consumption and purchase of RECs as transparency-provider tool to build CSR reports while, on the other hand, they may still continue to purchase the remaining RECs on traditional markets (instead of investing in alternative offsetting strategies). In regard to governments, resistance may also be found in providing regulative support and frameworks to the new solution. In fact, current REC markets are already regulated in most parts of the world and governments may rather keep the status quo then engaging and supporting a new technology whose potential is disruptive yet still need to be fully understood and explored.

This intuition is confirmed by the study of Lacity and Khan (2019) which explain that blockchain solutions that involve multiple organizations have an intrinsic challenging nature. For what concerns the regulative environment, they explain that policymakers are still in the process of understanding blockchain technology and how to create a policy environment around the variety of application arising (ibid). To this extent, they suggest that a proactive approach of blockchain companies seem to be the most effective way to facilitate the process of technology integration and adoption (ibid).

Results & Impact

GreenX allows related claims of renewable energy consumption to be backed by the reality of facts, providing a coupling between the purchase of the REC and the physical energy consumption with regards of the cleanness of the grid they are attached to. A first impact thus comes at the corporate level, since RE100 companies will be able to achieve an increased transparency and traceability in their operations in a way that supports their commitment to an economy based on renewable energy consumption. Thanks to the alternative configuration of the REC marketplace proposed by greenX, corporations can now limit practices of greenwashing and implement sustainability strategies that differentiate their profiles in face of competitors. Given that REC certificates will be matched with the actual energy consumption profile, companies will be able to support sustainability claims in a more transparent and truthful way.

Due to the limitation on the number of certificates which the company can buy, the system would also force companies to find other methods to become truly sustainable. Examples could be to implement in-setting practices or changes in their business model in a way to increase the eco-efficiency of their operations and reduce their CO2 emissions. Moreover, multinational corporations will also be incentivized to relocate in countries with a greener electricity mix. The re-shaping of sustainability strategies towards a more concrete impact on the reality can be regarded as a second major impact of adoption greenX as alternative REC marketplace. To better understand the potential results of such adoption, let’s take the example of a RE100 company on greenX such as the BMW

Group[9] considering Poland as destination for a future investment. Among other considerations, Poland may be an attractive investment for the labour-intensive operations of the company since the country is characterized with one of the cheapest labour costs in Europe[10]. Yet, around 82% of Poland's electricity is produced from coal: from greenX perspective, this means that BMW Group's operations in Poland will generate mainly black tokens and only few green ones. According to how the current REC marketplace works, BMW could still purchase a number of RECs sufficient to cover their entire dirty energy consumption. In contrast, the adoption of greenX as an alternative marketplace would imply that BMW can only buy as many RECs as the (little) amount green tokens. Considering their commitment to source more than two thirds of electricity from renewables by 2020, BMW will then have to re-direct the investment towards countries with a 'greener' energy mix.

This example shows a third potential impact that the adoption of greenX may have beyond the sphere of the private sector. In fact, if corporations start to direct their investments towards countries with higher share of renewable energy in their gird, governments will be in turn pushed to increase the number of policies aimed at attracting renewable energy investments in the country. Moreover, if governments create higher incentives for renewable energy projects, renewable energy producers will also be motivated in expanding their business in country that may be currently result not attractive due to a non-supportive policy environment. These dynamics represent the creation of a potential green incentive loop that would further strengthen the transition to a renewable energy economy.

Furthermore, on the operations side, companies could also become more efficient in their energy management practices. In fact, with the current system in place, corporations may incur overhead costs related to tracking and reporting their renewable energy targets as well as related to the purchase of RECs through intermediaries. As a blockchain-enabled solution, greenX offers an entirely automated process REC trading and a transparent and accessible platform for energy management. As such, the adoption of the platform has the potential of leading to a reduction in operational costs and an increased operational efficiency.

Future developments

As a main future development of greenX, we envision renewable energy producers to join the network and become nodes of the platform. In this way, data from renewable energy production would be directly included in the system and used to produce REC with precise timestamps thanks to blockchain technology.

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[9] A German automobile, motorcylce and engine manufacturer with global operations.
[10] https://www.thefirstnews.com/article/polish-labour-costs-still-under-half-of-eu-average-new-figures-show-5559

Currently, RECs are described as an electronic document and every step of a their lifecycle (creation, transfer, trade and cancellation) is recorded in an electronic platform. However, the process of recording is cumbersome since it is carried out manually by each stakeholder who inserts data from its database to the electronic platform at all levels of the process (Flexidao.com, n.d.). Furthermore, the current REC chain involves multiple and different parties, making the auditing process slow and expensive, with corrections of mistakes extremely onerous. Moreover, RECs are not issued with the charging and discharging of electric batteries or small-scale photovoltaics and the current system do not allow kWh granularity (Flexidao.com, n.d.).

The blockchain enabled system would enable increased transparency for the consumer, kWh granularity, the integration of storage and distributed generation and - most importantly - hourly-bundled certificates with price fluctuations following renewable energy supply. Furthermore, the system would also allow the issuing of certificates from small-scale energy producers, and this would have tremendous impact especially in developing countries, where small size installations do not have their energy production certified.

Conclusion

To achieve the targets of the Paris Agreement and contain the alterations in climate and human systems, a stronger and more effective strategy supporting climate action is needed at all levels (IPCC 2018). The report considered the role of the private sector in creating and implementing solutions to tackle climate change. In particular, the solution discussed addresses RE100 companies, a global consortium of business leaders that committed to 100% renewable energy consumption in the shortest timeframe possible. These companies currently support this commitment mainly through the purchase of RECs to testify their consumption of renewable energy (IRENA, 2018).

The problem is represented by the mismatching within the REC marketplace that makes the efforts of these companies being regarded as 'greenwashing' due to their lack of tie to the real world. The report thus introduced the reader to an alternative, blockchain-enabled REC marketplace, greenX. Briefly, green and black tokens are generated by smart contracts as a result of the company's energy consumption and third smart contract regulate the purchase of the certificate in a way to achieve a coupling between the amount and type of energy consumed and the sustainability attribute that the certificate represents. Such mechanism allows greenX to position as a provider for RE100 corporations of a tool through which increase the credibility and transparency of their green energy use claims.

After presenting the solution, the business model canvas helped in assessing the business case for greenX while the development process described the journey behind the ideation of the platform. In particular, the report shows how soft system methodology was chosen as approach to business process modelling. A CATWOE model was developed and facilitated the identification of the main actors, transformation processes and external factors affecting the creation of the solution. The use of CATWOE was not only beneficial in terms of exploring the core purpose and values of the innovation but also to understand how to integrate blockchain technology within the solution. Moreover, the added-value of using blockchain technology was discussed. First, the attributes of blockchain permit to create an effective system for issuing and tracking of RECs that allow companies to hold credible claims of green energy consumption. Second, using blockchain leads to the foundation of a tamper-proof, traceable and transparent records of RECs attributes thus increasing efficiency, security and transparency in the system. As a consequence, blockchain also allows to tackle issues such as double-spending thanks to cryptography and decentralized consensus mechanism.

For what concerns the evaluation of the solution proposed, the report concluded that greenX has the potential to be a disruptive innovation due to the creation of an alternative market system for an initial niche customer segment – RE 100 companies – that could potentially take over the current mainstream market mechanisms. However, limitations to the potential of disruption were also considered. In particular, the costs and state of development of the technology would correspond to a slowdown in the adoption. Moreover, regulations built around the current system are also a factor to be considered: in fact, policymakers would play a crucial role in supporting or hindering the adoption of a new system. Last, the main impacts of the technology were analysed. These include tackling greenwashing thanks to an increased transparency and traceability of operations; the creation of a positive incentive loop involving corporations, governments and renewable energy producers; and the generation of greater efficiencies for companies in their energy management processes.

In conclusion, the solution has the potential to be valid and effective in the creation of an alternative REC marketplace, yet limitations on adoption and development represent new challenges and calls for further research.

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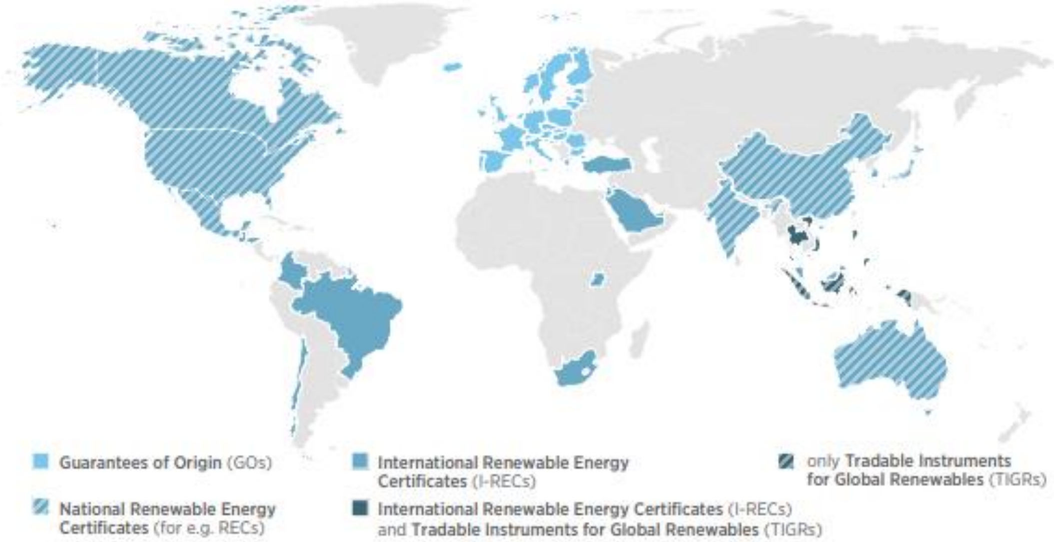
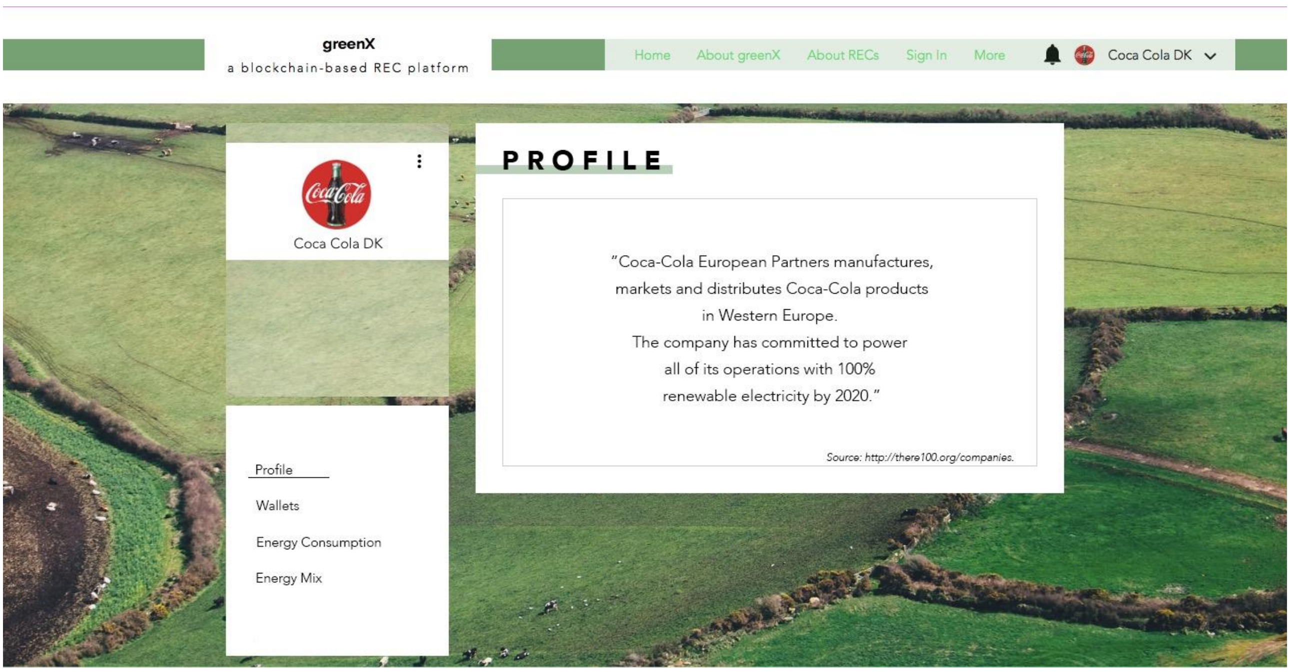
Appendix

Appendix 1. Global overview of energy attribute certificates (EACs) systems.

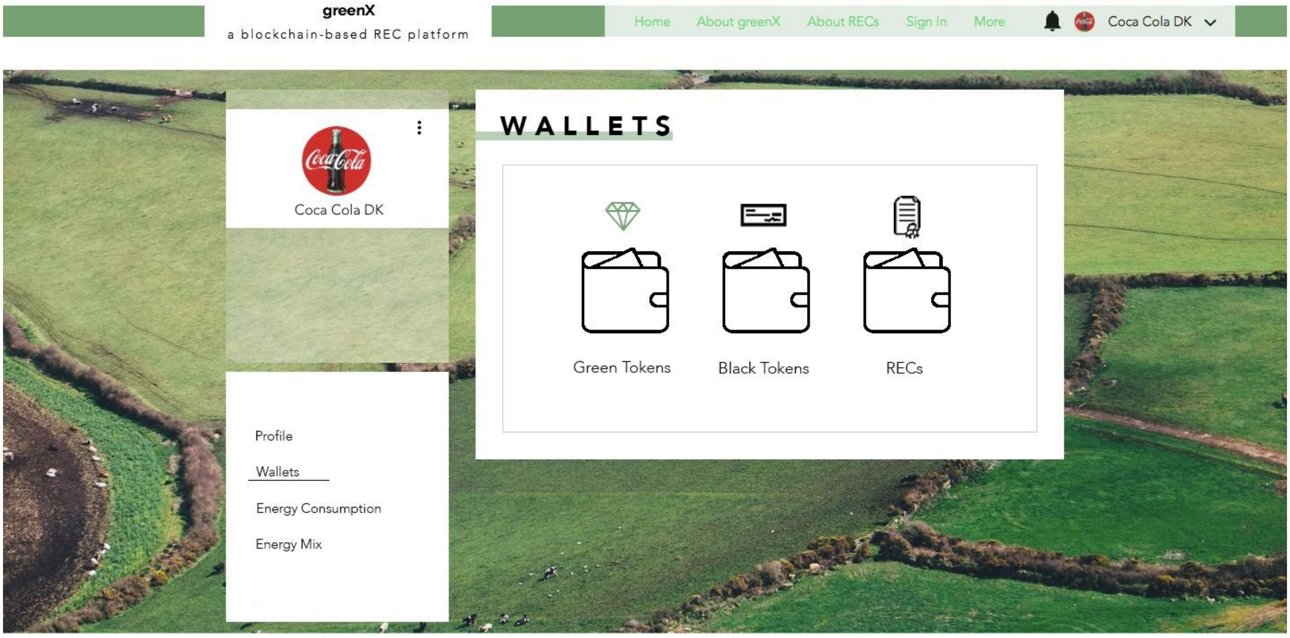


Source: IRENA (2018)

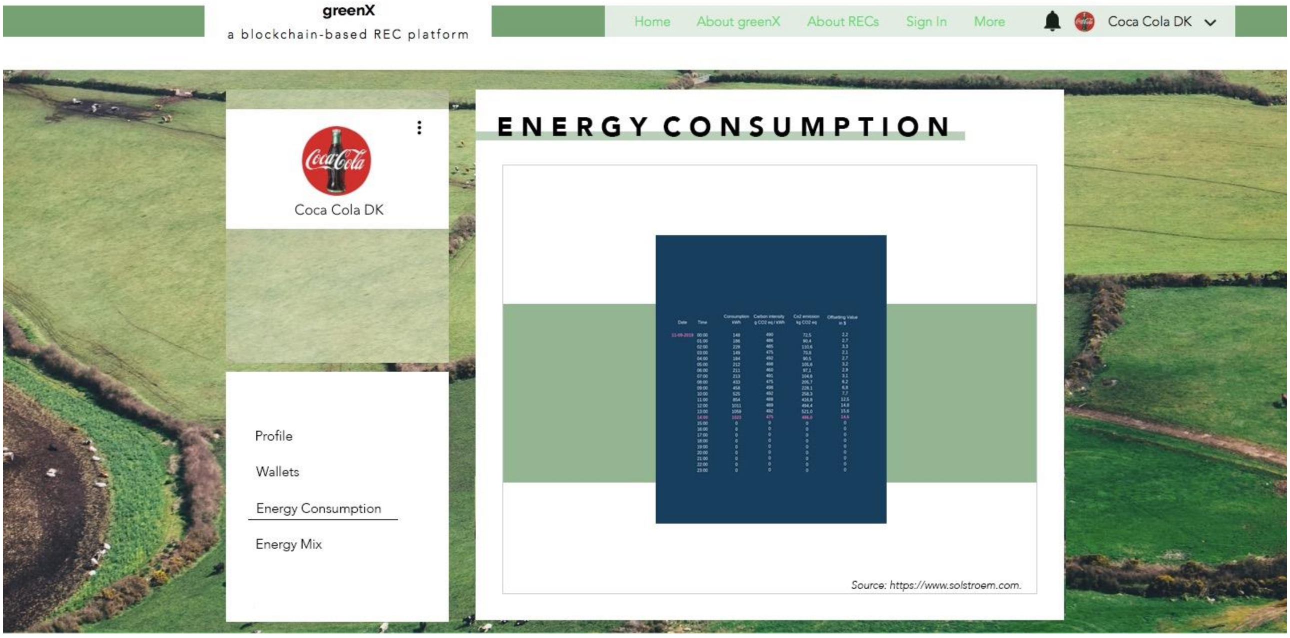
Appendix 2. 'Profile' section on greenX.



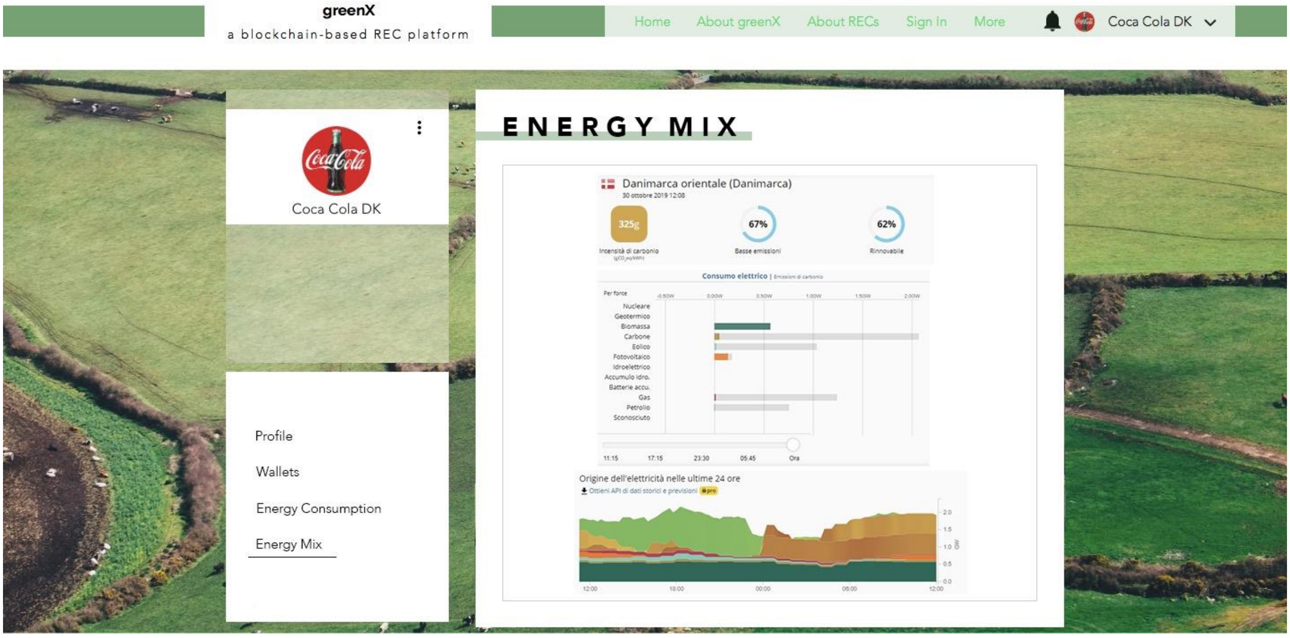
Appendix 3. ‘Wallets’ section on greenX.



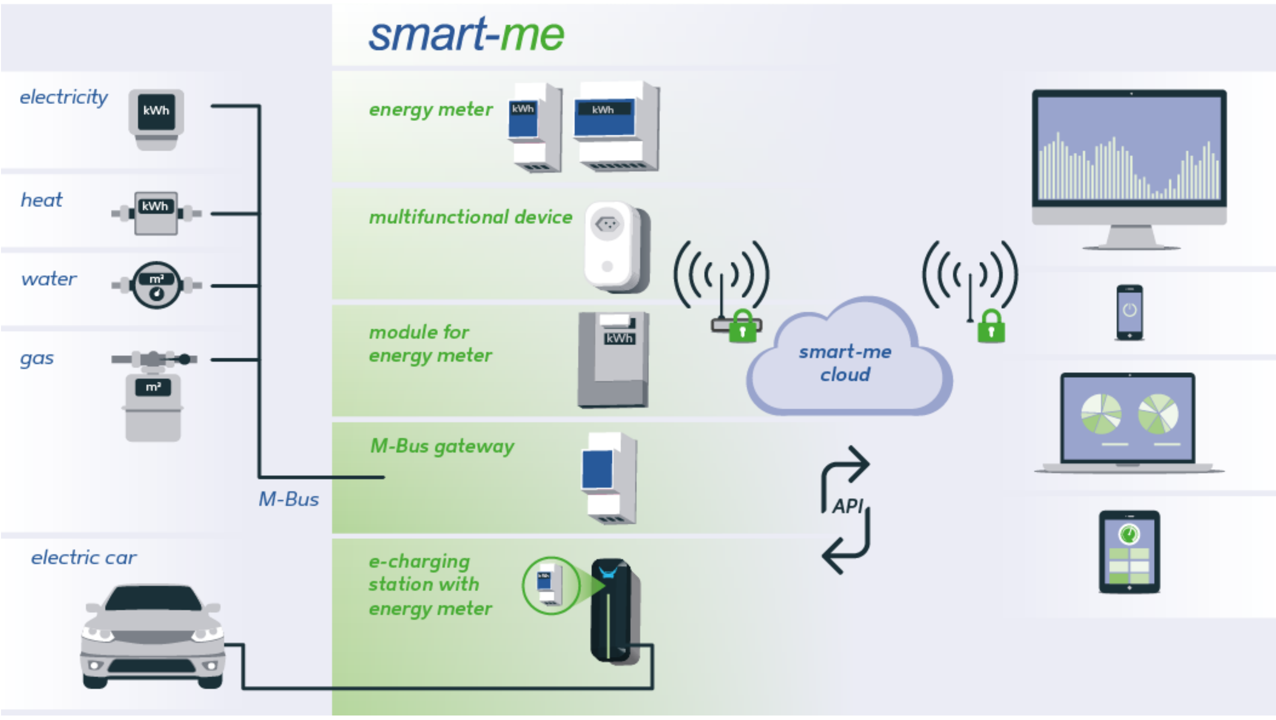
Appendix 4. ‘Energy Consumption section on greenX.



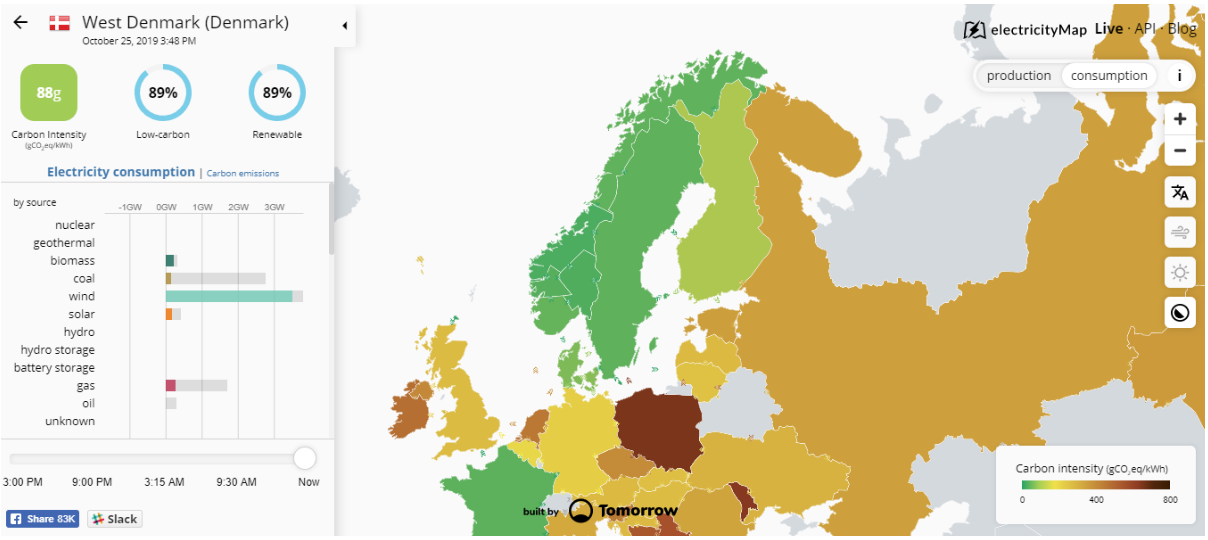
Appendix 5. 'Energy Mix' section on greenX.



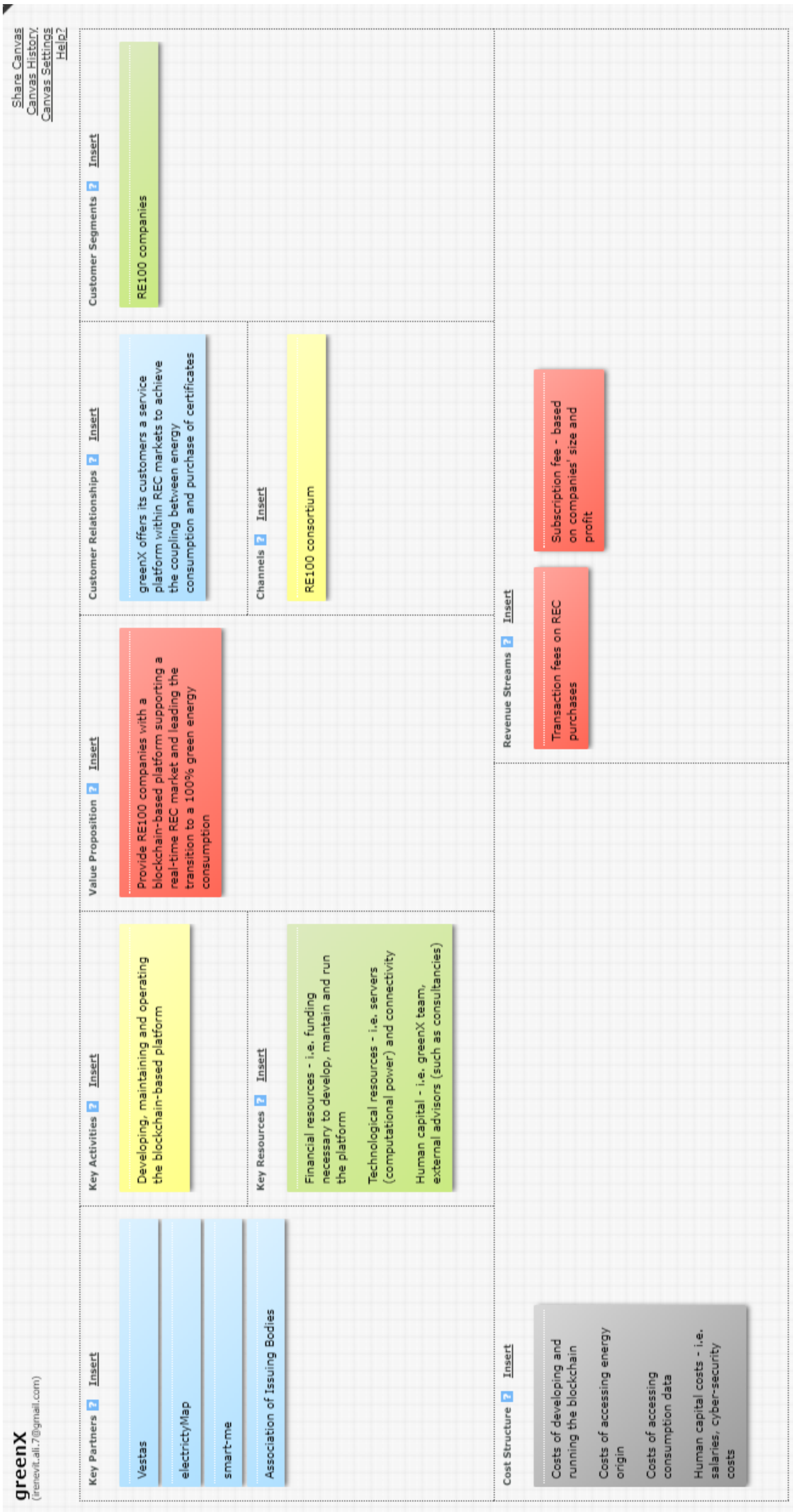
Appendix 6. smart-me products and solution



Appendix 7. electrictyMap – West Denmark



Appendix 8. Business Model Canvas



Appendix 9. Green token's code.

```
pragma solidity ^0.4.20;

contract Token {

    function totalSupply() constant returns (uint256 supply) {}

    function balanceOf(address _owner) constant returns (uint256 balance) {}

    function transfer(address _to, uint256 _value) returns (bool success) {}

    function transferFrom(address _from, address _to, uint256 _value) returns (bool success) {}

    function approve(address _spender, uint256 _value) returns (bool success) {}

    function allowance(address _owner, address _spender) constant returns (uint256 remaining) {}

    event Transfer(address indexed _from, address indexed _to, uint256 _value);

    event Approval(address indexed _owner, address indexed _spender, uint256 _value);

}
contract StandardToken is Token {

    function transfer(address _to, uint256 _value) returns (bool success) {

        if (balances[msg.sender] >= _value && _value > 0) {

            balances[msg.sender] -= _value;

            balances[_to] += _value;

            Transfer(msg.sender, _to, _value);

            return true;

        } else { return false; }

    }

  function transferFrom(address _from, address _to, uint256 _value) returns (bool success) {

      if (balances[_from] >= _value && allowed[_from][msg.sender] >= _value && _value > 0) {

          balances[_to] += _value;

          balances[_from] -= _value;

          allowed[_from][msg.sender] -= _value;

          Transfer(_from, _to, _value);

          return true;

      } else { return false; }

  }
```

```
function balanceOf(address _owner) constant returns (uint256 balance) {
    return balances[_owner];
}

function approve(address _spender, uint256 _value) returns (bool success) {
    allowed[msg.sender][_spender] = _value;
    Approval(msg.sender, _spender, _value);
    return true;
}

function allowance(address _owner, address _spender) constant returns (uint256 remaining) {
  return allowed[_owner][_spender];
}
```

```
    mapping (address => uint256) balances;
    mapping (address => mapping (address => uint256)) allowed;
    uint256 public totalSupply;
}

contract ERC20Token is StandardToken {

    function () {
        throw;
    }

    string public name;
    uint8 public decimals;
    string public symbol;
    string public version = 'H1.0';
```

```
    function ERC20Token(
        ) {
        balances[msg.sender] = 1000;
        totalSupply = 1000;
        name = "green X green Token";
        decimals = 0;
        symbol = "GXGT";
    }

    function approveAndCall(address _spender, uint256 _value, bytes _extraData) returns (bool success) {
        allowed[msg.sender][_spender] = _value;
        Approval(msg.sender, _spender, _value);

        if(!_spender.call(bytes4(bytes32(sha3("receiveApproval(address,uint256,address,bytes)"))), msg.sender, _value, this, _extraData)) { throw; }
        return true;
    }
}
```