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BlockChain Technology for Energy Transition

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Abstract

In this chapter, we provide a framework for assessing the relevance and impact of BlockChain technologies for enabling the energy transition from both the production and consumption sides of the equation. We will assess the issues and current solutions to understand how BlockChain combined with Smart Contracting could be best adapted and combined to serve energy transition objectives. The assessment is taken from both the technology and business models perspectives.

Our framework is designed as a guide for the adoption and deployment of BlockChain and Smart Contract solutions in the energy sector for common and new use cases by taking the perspective of multiple stakeholders such as consumers (either private and industrial), producers, operators and investors in microgrids, DSOs and TSOs. Moreover, we will include aspects related to regulation and policies.

The proposed framework and assessment methodology are the synthesis of a study realized in Switzerland where several representatives of multiple stakeholders have been consulted via interviews and a workshop held in mid-2019.

Keywords

Energy Transition, Business Models, Smart Contracts, BlockChain, microgrids, use cases, market analysis.

1 Introduction

The Energy Industry in a profound transition due to new regulations and technology advancements. This transition is motivated by the following factors:

- Diversity of energy sources
- New and different places of energy production
- Emerging opportunity of producing energy for self-consumption and for selling it to other consumers
- Energy storage technology
- Information and Computing Technology

These important changes provide new opportunities for the players in the energy industry at different levels. New business will emerge based on the possibility for energy production, distribution and trading.

Moreover, policy makers are concerned with the Climate Change induced by un-optimized energy production/distribution/consumption. Therefore, new constraints are already in place to deal with this global issue.

Information Technology is crucial in the evolution of the market of the energy because of mainly two factors:

1. Intensive Data Production and Data Accessibility
2. Distributed Computing advances, which allow the design of complex systems.

The BlockChain (BC) and Smart Contracts (SC) technologies (Schneider et al. 2016) (Swan, 2015; Wright & De Filipi, 2015) are extremely relevant for the second factor (and indirectly for the first one) because it enables the “Internet of Value”. With these two (strictly related) technologies, it is (and will be) possible to build systems where not only information is exchanged but also assets. BC and SC are expected to disrupt the traditional financial systems but also every system where any kind of goods or commodities are exchanged and traded.

Currently, most of deployments of BC and SC have been done in financial system (e.g. cryptocurrencies like BitCoin and investment like Initial Coin Offering (ICO)). In the Energy Market, however the adoption of those two technologies seems still to be slower. Among several reasons, we can certainly affirm that two are very important:

1. Regulations of the energy market: the government bodies, at different levels, from local to global, have developed a complex regulatory system, which is also influenced by different lobbies.
2. Complexity of the energy market. With “complexity” we mostly refer to the variety of stakeholders with different and often conflicting interests, but also to the intrinsic complexity of the energy distribution networks.

Nevertheless, the enabling power of these new technologies is such that they are going to be adopted by the players in this industry, maybe in an anarchic way. BC and SC have the potential of enabling the full decentralization in the management of power networks to the point that energy consumers and energy producers will be able to do business without intermediaries.

There are also big expectations from those technologies, based often on a misunderstanding of their features. In particular, the constraints imposed by the existing grid infrastructure cannot be ignored and must be considered in the design of energy trading overlay. However, the existence of those constraints can be the opportunity of developing new *Business Models* that were unconceivable when these technologies were not available.

Information and Communication technologies are usually innovation enablers. In the context of the evolution of the energy market towards SmartGrids, the BlockChain and Smart Contracts technologies can contribute to this evolution provided that new business models for energy trading are developed and implemented correctly. These models should also take into due account important factors such as the *environment*, the *society*, and most importantly the *market*. In this paper, we are aimed at better understanding the role of these technologies for enabling innovative business models for the Energy Market towards the so-called “Energy Transition”. Moreover, we provide with a framework and a methodology for eliciting relevant business opportunities by considering the constraints imposed by existing (and future) regulation as well as the needs of the participating stakeholders.

2 What is “Energy Transition”?

Energy transition currently represents one of the central issues of the beginning of the 21st century. As such, the concept is not precisely defined as it encompasses a broad array of policies aiming at reducing the contribution of non-renewable or, at least, *GreenHouse Ga*s (GHG)-emitting energy sources at regional, national and transnational levels, along with fostering energy efficiency measures, e.g. in the industrial and residential sectors. The stated overall objective consists in decreasing global environmental impact of energy generation and consumption, with the main driver being the drastic decrease of carbon dioxide emissions in the atmosphere (at the EU level, see for example the 2nd Report on the State of the Energy Union (EU, 2017)).

While seemingly homogeneous in the political and civic discourse, such policies differ vastly from one country to the other, in particular regarding the inclusion or exclusion of certain renewable technologies - such as biomass or geothermal (Geels et al., 2016; Hultman et al., 2012). The potential role of nuclear energy within energy transition schemes is also widely debated since its non-renewable nature and the associated cumbersome waste treatment are put in perspective with respect to very limited impacts in terms of both GHG and fine particles emissions (Michaelides et al., 2020; Gralla et al., 2017). Indeed, nuclear energy represents a major heterogeneity factor between countries and policies related to energy transition.

On the demand-side, energy transition underpins more “usual” energy efficiency measures such as buildings retrofitting or low-consumption electric appliances but also a certain number of more fundamental evolutions, e.g. in the industrial or mobility sectors. Indeed, industry is rather swiftly moving towards production approaches inspired by circular economy, that include valorization of waste streams, or lifecycle analyses in the choice of materials and processes (Brunner et al., 2017). In the mobility sector, the penetration of electric vehicles – despite the debate regarding their environmental impact depending on the origin of the power and the battery typologies – has been faster than any prediction, while hydrogen is expected to strongly impact the heavy-duty transport sector already in the short term, not to mention LNG for both road and maritime freight (Pietzker et al., 2014). Hence, the need for innovative policy frameworks and business models constitute a major endeavor, to accompany and foster such structural changes.

2.1 Business Models in the Energy Sector

The linear value chain (centralized generation to end customers) is expected to become an "energy cloud" where the system will be more sustainable, highly digitalized, and dynamic.

So far, the current business models in the energy market are centralized. Burger and Luke (2016), show that the most common structure is that of "brokerage", which is mostly based on a central entity that governs the transactional system as shown in **Error! Reference source not found.**.

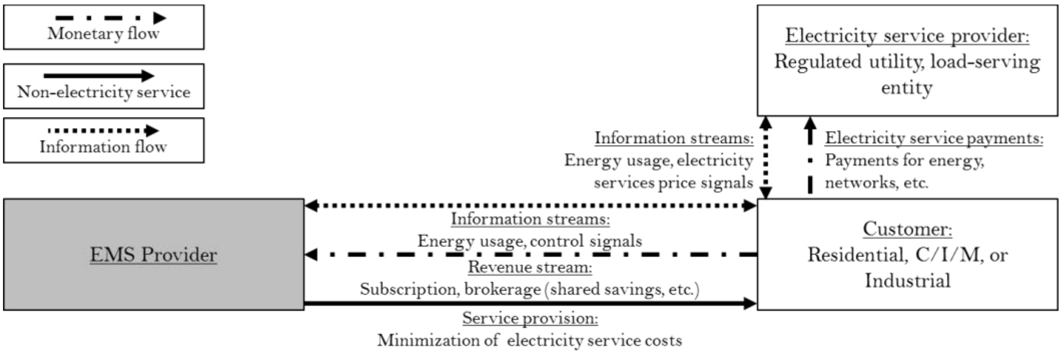


Figure 1. Generic energy management service business model structure from (Burger and Luke. 2016).

In the specific case of renewable energies (e.g. solar power) shown in Figure 2, the business models are currently substantially the same as in distribution of energy produced in power plant. The main reason is because the business transactions are managed by the energy grid operators.

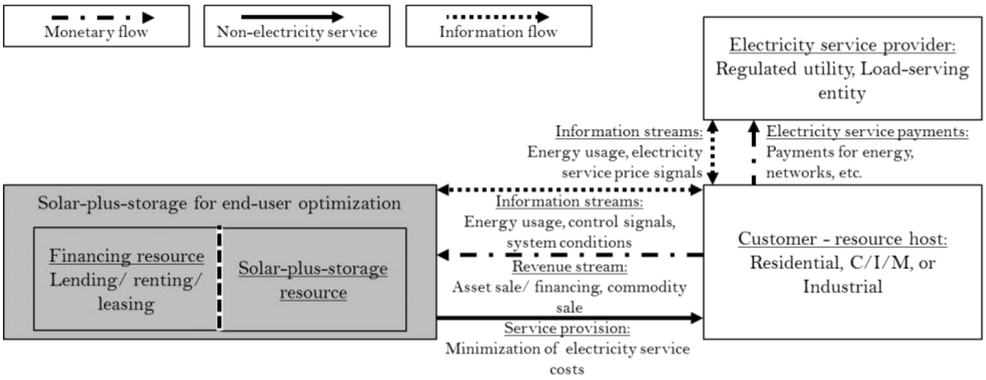


Figure 2. Generic solar-plus-storage for end-user optimization business model structure from (Burger and Luke. 2016).

Until now, innovative companies in the energy industry have focused mostly on grid management by integrating in a seamless way different sources of energy with the traditional grids by providing "smart" devices such as *smart meters*. The surplus of locally energy produced is typically "re-injected" into the grid and distributed to other consumers. The entity in charge of the distribution grid is also in charge of the billing and decides the prices. Prices are not traded among producers and consumers.

2.2 New Business Models for Energy Transition

It is clearly shown in the management literature that a company's business model can be disrupted by changes in the external environment, thus opening new opportunities for new business model design among start-ups and new entrants as well stimulate some level of business model reconfiguration among incumbents (Christensen et al 2015).

The diffusion of new technologies can also be spurred or supported by the catalyst of business model innovation by overcoming both internal and external barriers. The diffusion of sustainable innovations in particular has been linked to the implementation of innovative business models (Boons and Lüdeke-Freund, 2013). One can also imagine that business models that involve a network of players, creating a *value network effect*, can stimulate investments and diffusion of technologies that are particularly key to creating a successful complex innovation ecosystem. However, especially incumbents in an industry like the energy industry that have implemented for a long time the same entrenched business model that is even protected by regulations in place today in most developed countries, may struggle to trust untraditional players that could create the right environment for such network value creation.

Complex *value creation* and *value monetization* among different *stakeholders* needs to be better analyzed in such *value chain networks* (Ricciotti 2020). Service providers find other sources of value creation in B2B business opportunities, such as functionality, durability, reduced complexity, and attributes that might have been overlooked.

Even though incumbents are hesitant to significantly move away from their formerly reliable business models, today the energy sector is experiencing a profound transformation. While this transformation may occur more rapidly in the developing world where regulations do not protect large market players, and where many markets are still untapped by existing incumbents, this transformation is slowly happening even in the developed world despite the protection of the existing market in these countries.

This transformation is supported by multiple factors including:

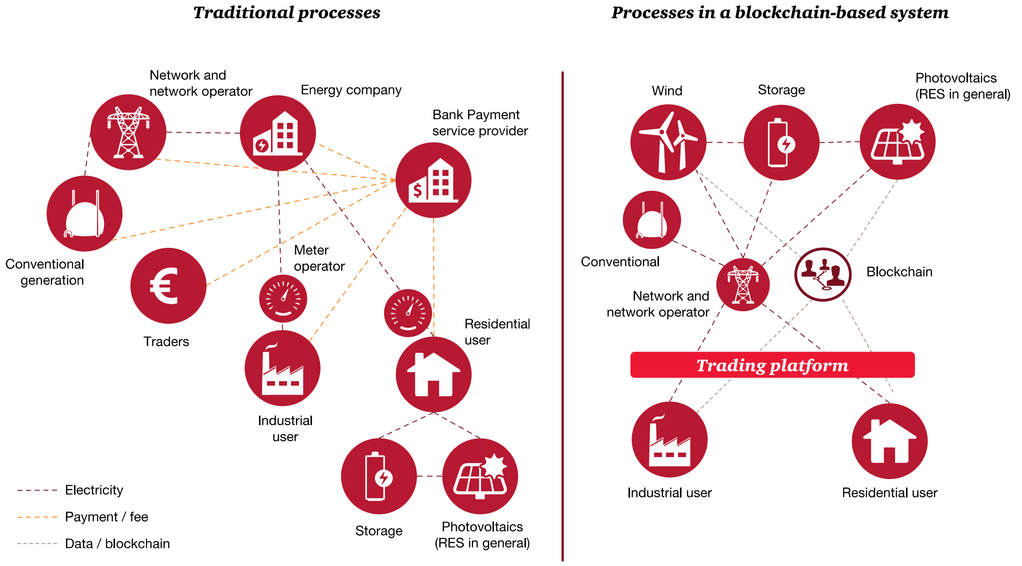
1) many emerging technologies have already achieved critical mass, or it is on the immediate horizon;
2) innovative technologies are responding well to demand for novel energy products and services, that is has augmented overs the last years;
3) economically viable business models are increasingly in competition with the traditional business models of the sector, which drive in turn incumbents to consider business model reconfiguration themselves.

According to (Navigant, Energy Cloud 4.0, 2018), new energy cloud platforms such as Transportation-to-Grid (T2G), Building-to-Grid (B2G), and Smart Cities that are more centered on the customer needs will increasingly emerge. In addition to this energy carriers will become increasingly interconnected. Other such applications will allow the transformation to be felt beyond the power grid. Finally, it will impact not only the way we live and work and move around, but also the way we use materials, produce goods and transport them, as well as existing business models around services.

Monitoring benefits accrued to different actors may be needed or capturing value from different actors could be needed (including from public sources) to compensate the enterprise or consumers for the "purchase" of such value which previously was ignored by the existing business model paradigms in the energy sector.

3 BlockChain and Smart Contracts in the Energy Sector

According to the Pw&C report on BlockChain technologies in the energy domain (WEO, 2015), the highest potential resides in the local renewable energy trading market. So far, the existing regulation is not adapted to the possibility of fully distributed energy systems (Microgrids or Smartgrids) where its governance is not centralized. Nowadays, apart from some episodic case, the business models for microgrids do not yet leverage the BC and SC technology.


Traditional processes

Processes in a blockchain-based system

Figure 3. Transformation of the Energy Market structure due to decentralization (WEO 2015).

The challenges ahead for BC and SC technologies in the Energy Market are multiple especially in the context of energy transition. However, the possible disruptions might lead towards a truly liberalized and optimized market where the blocking factors in adopting renewable energies can be removed.

For BC and SC technologies it is also fundamental to understand not only the technical aspects but also their impact in the existing systems, especially when the industry is extremely articulated and complex like the energy one.

The « use cases » proposed by Pw&C cover not only the obvious "billing" case, but also other important aspects of the energy management such as:

- **Contracting** and enforcement of contractual terms;
- **Compliance** with existing regulations;
- **Transparency** in the transaction but also in data exchange and processing;
- **Resilience** of the network, which becomes very critical in a fully distributed one;
- **Liberalization** of the energy market with the creation of different interconnected "marketplaces" for energy trading.

Figure 3 compares the traditional structure of the energy market with that which might emerge from the adoption of BC and SC technologies. The removal of “clearing-hoses” and the introduction of “trading platforms” are key elements of this disruption.

3.1 Types of applications of BlockChain and Smart Contracts in the Energy Sector

We present in this section a summary of specific use cases in the energy industry where BlockChain is being applied or has interesting potential to transform the industry more details are available in (Bürer et al. 2019) and (Strupeit & Palm 2016).

3.1.1 Case 1. For utilities that want to remain competitive and attract new customers in a liberalized market:

Utilities and national grid operators are embracing the BlockChain technology in order to become prepared for the market liberalization. In some cases, they are aimed at optimizing operations (Hesse, 2016). In other cases like for Tokyo Electric Power Co. the goal is to play a stronger role in peer-to-peer microgrids (Christopher Martin, BNEF, 2018).

3.1.2 Case 2. For utilities that want to use BlockChain to better manage the Grid.

Several initiative such as that of Omega Grid in Burlington, Vermont are geared towards deploying BC technology for managing supply and demand in a more optimized way. They starts with micro-grids, but the final objective is that of dealing with the entire grid (Christopher Martin, BNEF, 2018).

3.1.3 Case3. For virtual transmission --- and a move away from the usual players

IBM together with batteries manufacturer Sonnen GmbH are trying to deploy home batteries to store the surplus electricity produced in wind farms, thus eliminating the need of expensive power line infrastructure to be bear by the Germany TSO Tennet (Martin, 2018).

3.1.4 Case3. For peer-to-peer distributed energy trading businesses

Peer-to-peer distributed energy trading (P2P DET) is probably the most developed application of BlockChain (Martin, 2018). Several cases of BC-enabled microgrids are being deployed world-wide since the first peer-to-peer energy trade system of solar power in Brooklyn, New York, in 2016.

BlockChain technology allows for the automatic matching of energy demand and supply via an online platform. Thus, homeowners who produce energy, most of the time through photovoltaic modules (PV modules), can sell their excess production to private individuals and households, usually located in the same geographical area. These transactions are validated and executed through smart contracts in the BlockChain. This kind of trading is called “peer-to-peer”, since prosumers and consumers exchange energy directly between them without a middleman such as the utility company who manage the electrical grid.

Mengelkamp et al. (2018) make a distinction between a virtual grid and a physical grid. The virtual grid is the information and communication network powered by BlockChain which connects all participants. The physical grid is the actual power distribution network. As for the physical grid, a P2P DET system uses either the main utility grid or their own microgrid (Gui & MacGill, 2018). A microgrid is also called “smart grid” because it is powered by digital communication technology which assists grid management.

Scholars (Abdella & Shuaib, 2018; Pouttu et al., 2017; Zhang et al., 2017) describe P2P DET architecture as typically composed of three levels:

1. The *microgrid*, which includes the prosumers, as well as the power generating and storage units.
2. The trading of energy happens among microgrids within the same power distribution network (the cel)l.
3. The energy trading can also occur between cells, namely at the *distribution system* level.

Moreover, energy can be exchanged not only on each of these three levels but also across levels (e.g. a prosumer in Migrogrid 1/Cell A selling his surplus energy to Cell B) (Abdella & Shuaib, 2018; Pouttu et al., 2017). However, this architecture is only a theoretical representation. Apart from the first level, the distribution network and the distribution system level have not been implemented so far (Abdella & Shuaib, 2018).

One point to clarify is whether the P2P DET system can be viewed as decentralized or distributed. It seems that there is no real consensus about this conceptual distinction in the literature (Gui & MacGill 2018).

Conversely, other scholars think that a distributed system allows for a greater freedom of its users than a decentralized system. In this perspective, the electricity and information flows go from the prosumers to the microgrid in decentralized systems while in a distributed system, they circulate directly between prosumers (*Figure 4*; Ahl et al., 2019).

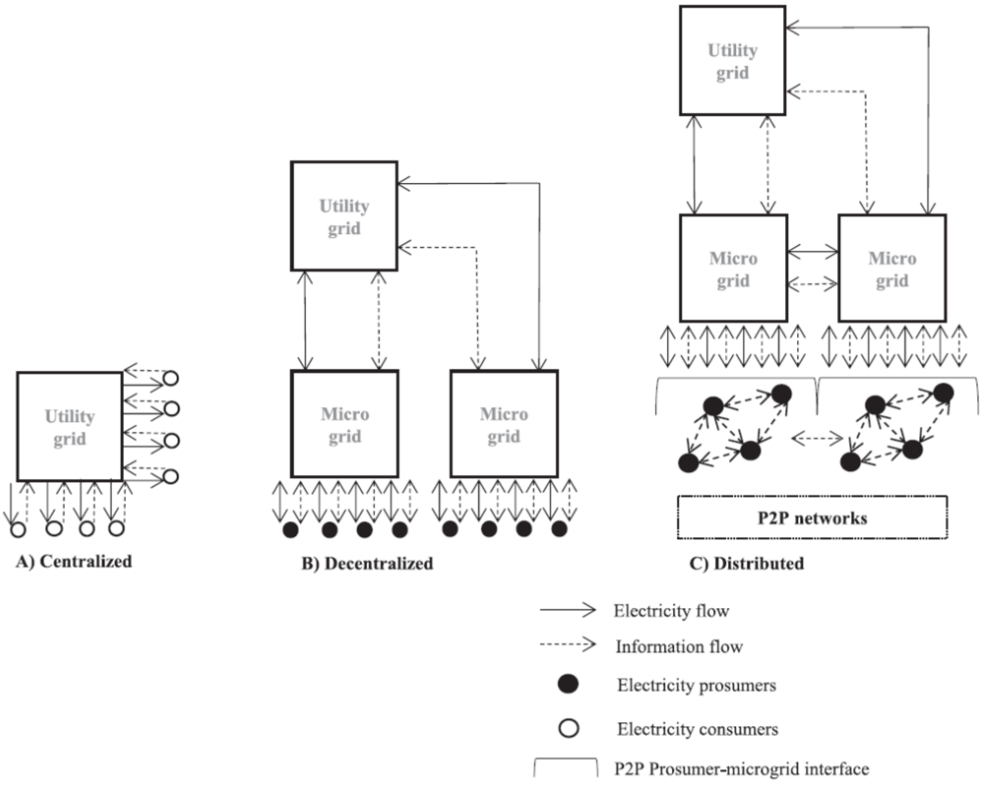


Figure 4 Comparison between different types of power grids (Ahl et al. 2019).

This perspective is more in line with some classic approaches such as Baran's diagram in the field of communication systems. As *Figure 5* shows, a decentralized system is like a polycentric system while in a distributed system, there are no central points at all and each node is connected with all the others, whether directly or indirectly.

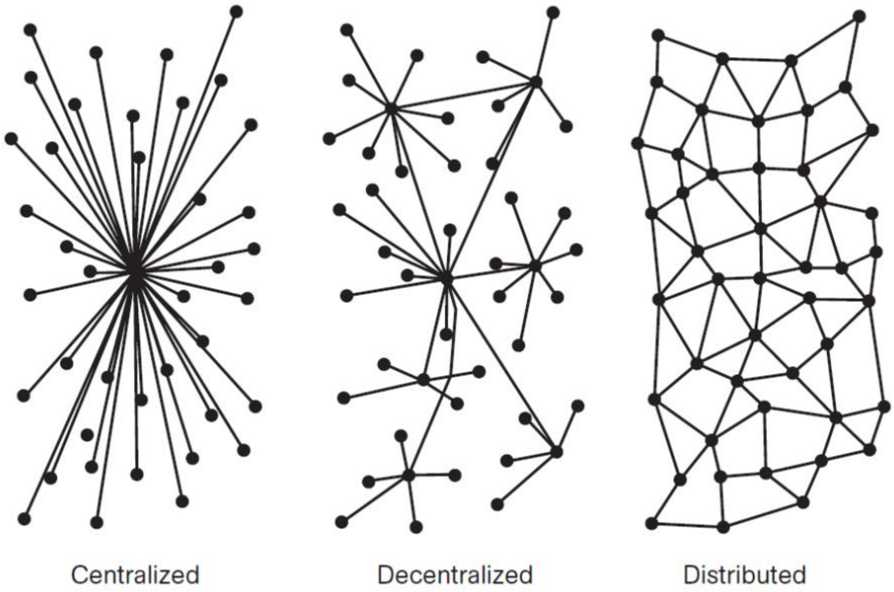


Figure 5. Representations of centralized, decentralized, and distributed communications networks (Baran, 1964 in Gochenour, 2006).

A distributed system corresponds more to a peer-to-peer trading system, where prosumers exchange energy directly between them. Consequently, we will use the term “peer-to-peer distributed energy trading” (P2P DET) in the following sections.

3.2 New Business Models enabled by BlockChain in the Energy Market

The Energy Market will certainly be affected by the diffusion of the BlockChain technology especially concerning the financing models, the contracting and the billing models. We examine in this section the opportunities for each model. A more in-depth analysis of new business models enabled by BlockChain technology are presented in (Bürer et al., 2019).

3.2.1 Transforming the financing models

The financial sector is likely to be influenced significantly by BlockChain technologies in the future, and thus new opportunities will emerge for new financing models relevant to the energy sector. Guaranteeing financial transactions and backing them against the BlockChain, and other use cases in the financial sector, is increasingly being embraced by innovative financial companies and could significantly impact the business models of most traditional financial institutions. Examples of new financing models based BlockChain are discussed in (Higginson, M, et al., 2017).

3.2.2 Transforming carbon management in the energy sector

The world of managing carbon emissions can also be transformed by BlockChain technologies. In a report by Infosys, 2018, the BlockChain solution is laid out. It can be used as a tool to provide companies with readily available information for carbon emission calculations which is accurate, reliable, and standardized. Transparency in supply chain induced by a BlockChain system would be crucial for enabling trust and accountability in the carbon ecosystem. (Infosys, 2018).

3.2.3 Real-time management of the grid infrastructure

BlockChain together with Internet of Object (IoT) technology has the potential of enabling the real-time efficient management of grids infrastructures. Additionally, the intrinsic security and privacy of BlockChain would help preventing fraudulent situations (Higginson, M, et al., 2017).

3.2.4 Management of charging stations for electric vehicles

BlockChain can facilitate the adoption of electric vehicles by providing seamless integration of the several components of the charging infrastructure. As for example, the project BlockCharge, launched by Innogy, a German utility company, enables owners of electric vehicles to pay smaller transaction fees for charging their vehicles by using a “Smart Plug” connected to a Ethereum wallet (Stöcker, 2016).

3.2.5 The peer-to-peer distributed energy trading model

Pouttu et al. (2018) have elaborated a theoretical and complex P2P trading model introducing a number of new actors and roles. Aside from the existing energy supplier (DSOs and TSOs), new actors and roles emerge like:

- the “Microgrid Trader”, who manages the commercial operations of the microgrid and trades energy with other microgrids;
- the “Aggregator”, which is the interface between several microgrids and the energy suppliers;
- the “P2P-Trading Platform Operator” who provides information, matches energy supply and demand, and possibly optimizes demand response at the cell level.

These roles will be certainly enabled by BlockChain and Smart Contracts technologies because the need of transparency and embedded intelligence in the management of the transactions.

3.3 Risks and issues related to BlockChain and Smart Contracts

Block chain involves several risks that have to be carefully considered before promoted for system wide implementation, and in particular for the delivery of energy. As for BlockChain technologies, in general, some standard risk considerations are discussed in (Deloitte, 2017).

BlockChain is also the platform for Smart Contracts. Smart contracts can potentially allow for an infinite number of use cases and potentially beneficial outcomes for sustainability and a distributed income generation from new technologies such as renewables on household rooftops. However, there are risks to smart contracts as well. The type of risk are mostly arising from the correspondence with physical contracts and from security-related risks in the algorithmic execution of the code in the smart contracts (Deloitte, 2017).

Technological superiority does not suffice, especially in the energy market. The risks associated with, or even just perceived to be associated with, BlockChain and its characteristics including anonymity which allowed it to develop for the cryptocurrency market, may be indeed the characteristics that block its development. Meanwhile, BlockChain is already transforming the financial industry and this alone will at least impact the financing models that apply to the energy sector. When BlockChain applications are increasingly applied in a secure and reliable way outside of the financial sector, it is possible that the energy sector will follow closely behind. But as discussed before the energy sector business models are difficult to change in most countries of the developed world today partly because of the protection created by regulatory frameworks created to protect consumers and industry which requires reliable electricity distribution and management.

Companies will face risks in their businesses when they must face completely new ways of doing business if they adopt BlockChain for more than superficial data management. They will have to decide on what business models they want, which partners they want to associate themselves with and rely on, and whether they are ready to manage a completely different business model such as one which is platform-based, or omni-channel based, and even if they want to apply BlockChain technologies to a product-based business model. BlockChain network governance will be key to manage the risks associated with mainstream use of BlockChain in any system, like the energy system.

3.3.1 BlockChain technologies impact in power distribution grids

As discussed in detail in (Bürer et al. 2018;2019), BlockChain technology might facilitate the penetration on the energy market of *renewable intermittent energy sources* (RIES). However, a major source of risk is represented by a potential imbalance to the power grid. If not carefully managed, the massive penetration of RIES and therefore their connection to existing power grid infrastructure might potentially cause transient overvoltages and crossing of current limits. The BlockChain system for RIES infrastructure need to be integrated with the power grid in a safe way in order to avoid disruptions of the power distribution grids. Additionally, the deployment of BlockChain solutions for RIES need to take into account key factors such as precise regulation of contracting, precise estimations of CAPEX and OPEX costs and their fair distribution among the whole energy ecosystem.

4 The Framework

In this section we present the outline of a framework and a methodology for guiding the adoption of BlockChain and Smart Contract technology in the energy sector for enabling the Energy Transition goals.

Our framework is a blend of several methodologies in order to be adapted to the specific application to the Energy Market. We are taking it from the well-known Osterwalder and Pigneur's Business Model Canvas (Osterwalder et al., 2010). To illustrate the framework and the methodology we discuss two use cases that were elicited during a multi-stakeholders Design Thinking workshop held in Switzerland in 2019, in which several local actors in the energy sector were invited.

4.1 The Business model canvas

The business model concept "*was originally used to communicate complex business ideas to potential investors within a short time frame*" (Geissdoerfer, Vladimirova, & Evans, 2018). Since then, the concept has developed into a tool not only for communicating the financial viability of a business project but also for "*analysis, comparison and performance assessment, management, and innovation*" (Bocken et al., 2014). A business model is particularly central to the firm competitive strategy. It helps defining the main characteristics of the goods or services proposed by the firm, the targeted market, the costs and revenues, the firm differentiation from the competition in terms of value proposition, and its integration in the value network. In certain circumstances, business models may play a fundamental role for the diffusion of new and sustainable technologies (Strupeit & Palm, 2016) as they help overcoming internal barriers generated by the organizational culture and corporate governance (business rules, behavioral norms, performance indicators, and other control mechanisms) as well external barriers (high capital intensity, decision makers' reluctance to disruptive innovation) (Boons & Lüdeke-Freund, 2013). As such, according to (Wainstein & Bumpus, 2016), "business models innovation dynamics are key drivers in accelerating the low carbon power system transition". Since the end of the 1990s, the business model approach has grown in popularity with the development of E-commerce and new ways of earning a profit through web-based products and services. The rise of sustainable technologies may have similar effects (Boons & Lüdeke-Freund, 2013). Nowadays, a widely adopted template in business and academia is the Business model canvas (BMC) proposed by Osterwalder et al. (2010). The BMC describes the essential types of "value" related to products or services, namely the *value proposition*, the *value creation*, and the *value capture*.

First, the **value proposition** dimension refers to the nature of the product or services delivered to the targeted *customer segments* and the type of *customer relationship*.

The **customer segments** are of different types: mass market (one large group of customers with broadly similar needs and problems), niche market (specific, specialized customer segments), segmented (market segments with slightly different needs and problems), diversified (unrelated customer segments with very different needs and problems), multi-sided platforms or multi-sided markets (two or more interdependent customer segments).

Customer relationships connect the company with its customer segments. Their purposes are mainly customer acquisition and retention, sales-boosting.

The second general dimension of the BMC deals with *value creation* and *value delivery*. It describes the **key activities**, the **key resources** needed to produce the goods or services, the **key partners** in the production process and the distribution **channels,** i.e. direct (e.g. online sales) or indirect (e.g. stores), company-owned or partner-owned (e.g. wholesaler).

The *value capture* is the last general dimension of the BMC. It concerns the way the firm can turn part of the delivered value into economic profits, by considering its business costs and revenues.

Revenue streams are generated in several ways. The most common are asset sale, usage fees (pay-as-you-go), subscription fees, lending, renting and leasing, licensing fees, brokerage fees, and finally, advertising fees. These different revenue streams are subjects to different types of pricing mechanisms, such as fixed pricing or dynamic pricing. Dynamic pricing can depend on several factors such as product features, customer segment, volume, market conditions, negotiation, time of purchase, inventory status and supply and demand, or competitive bidding ("auctions"). The *revenue streams structure* represents what is usually referred as the "business model" in the classic management literature.

The **cost structure** is the remaining component of the business model canvas. Cost-driven business models aim at minimizing costs through, namely maximum automation and extensive outsourcing, and at proposing low prices (e.g. low-cost airline companies). Conversely, value-driven business models focus less on costs and more on the value (e.g. high-end goods and service).

With the standard Business Model Canvas we are able to represent and possibly design multi-party businesses with intricate relationships between different value propositions delivered to different customer segments through various channels and with a complex revenue streams architecture where it is not always the case that who benefits from the delivered value proposition is the one who pays for it. Also, there is some intangible value that is created through the business that cannot be matched by revenue streams, being this value delivered over a long term to someone who is not necessary part of a targeted customer segment.

This might be the case in the energy market and specifically in this delicate phase of energy transition where we need to take into due account the social and environmental value generated from the adoption of renewable energy sources. If we stick with ordinary business models where only tangible, often short-term value transfer is considered, we lose a large part of the picture. For instance, those partners who would help in building the grid infrastructure for renewable energy might be moved by environmental concerns rather than the pursuit of profits.

Being aware of this aspect, we could consider extending the Business Model Canvas with other components to incorporate those aspects by adopting a more sophisticated business model framework such as that of (Joyce & Paquin, 2016) called the Three Layers Business Model Canvas (TLBMC) where in addition to the economic layer, the environmental and social layer have been added. When taken together, the three layers of the TLBMC provide a comprehensive insight into the economic, environmental and social values created by the business.

For the purpose of the framework and the methodology, we decided to keep it simple and stick with the most intuitive framework of the Business Model Canvas. We went a step further and decided to simplify and focus it on essential elements that are relevant to the energy market. As shown in figure 6, we used a version of the Business Model Canvas where we took away the Customer Relationships, the Key Resources and Key Activities from the original canvas. The main reason was to let the participants to the workshop to focus on the core aspects of the business model.

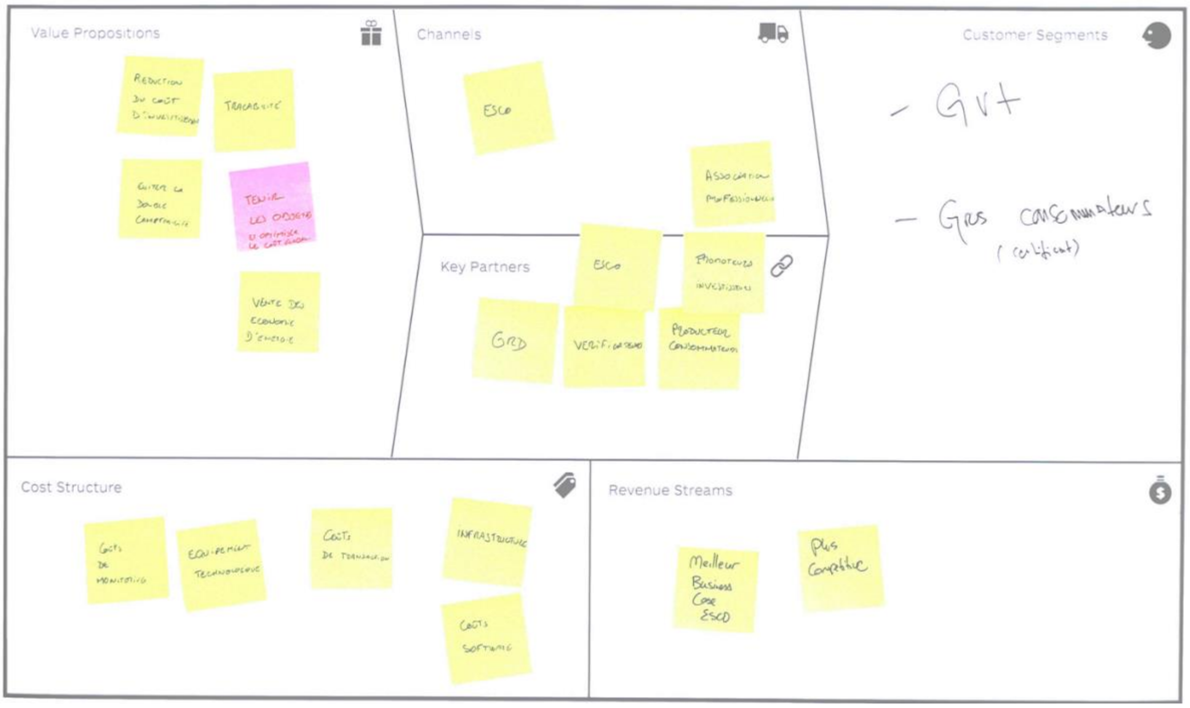


Figure 6. Simplified Business Model Canvas

4.2 The Use Case selection

Before presenting the canvas to the participants, we created two teams and asked them to select a relevant use case based on two main challenges in energy transition described in table 1.

Global Context	Liberalization of the energy market and new opportunities within the context of strong decentralization of energy. Currently, new sources of renewable energy are heavily subsidized around the world, but these subsidies are slowly disappearing. It will be necessary to have systems capable of accurately accounting for renewable energy production at multiple and dispersed production sites. Existing certification systems need to be improved if the system evolves towards a completely free market space, and also, ultimately, if the market evolves towards a scenario of total market liberalization for all segments (commercial and residential).
Local context	In the current market context, there is now an option supported by a new regulatory framework for microgrids for Swiss investors - the possibility of grouping together consumers or prosumers of renewable energy and gaining autonomy. This could apply to *microgrids* or eco-villages development projects, but also to different types of projects such as social or normal residential housing (new or existing projects), industrial parks, business parks, etc. Until now, these developments have been less attractive due to regulatory limitations on energy. Now new business models are possible, and new technologies like smart grid or microgrid control technologies can allow optimization and integration with external power grids, thus providing a more interesting investment story for these developments.

Table 1. Use case description

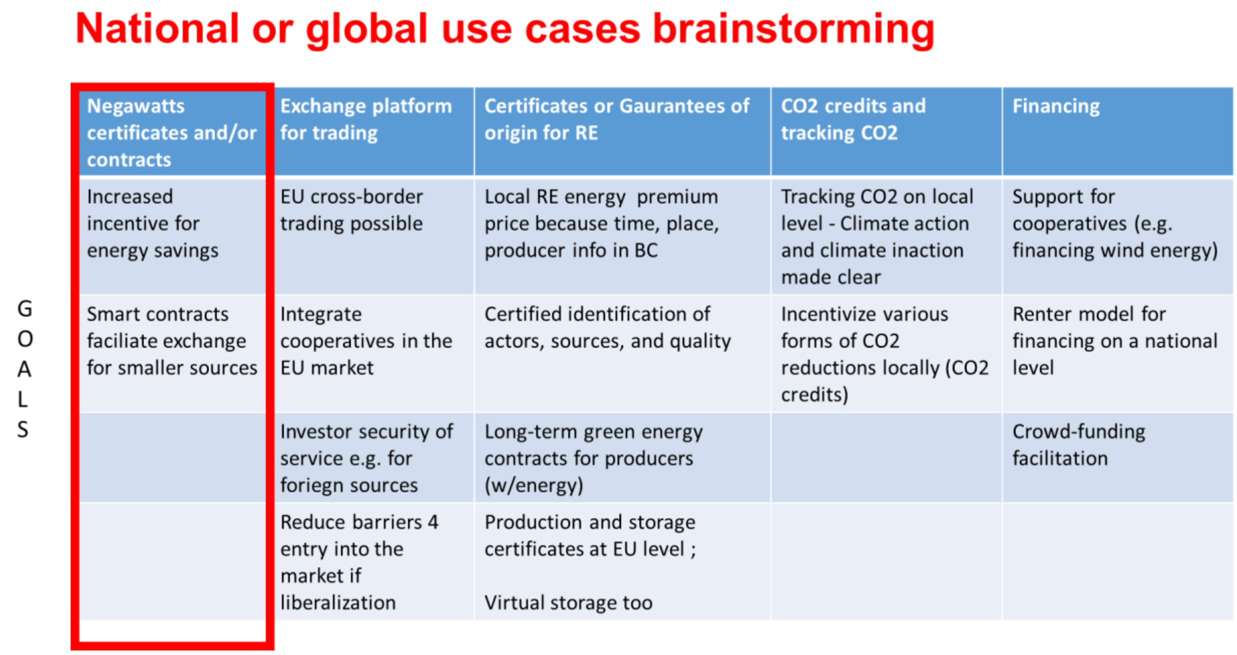
During the brainstorming, it should be noted that the moderators asked participants to think about the applications where BlockChain and smart contracting was needed for the given contexts. Therefore, a focus was put on where BlockChain could add value to the objectives laid out by some of the participants.

4.2.1 The use case for the Global Context: "Negawatt"

The workshop was seen by participants as a rare opportunity to think about uses for BlockChain that have not already been hashed-out and where value to society could lie. It was clear that from the brainstorming session of the Global Context group that the trading of guarantees of origin for green energy received more votes, however the group discussed after the voting and decided that such green certificate trading had been explored more, but there were opportunities for Negawatt trading facilitated by BlockChain which had not been explored enough. They therefore chose this use case in the end for the following steps, because after the discussion they viewed it as having higher value added by the group if solutions could be found to make the trading of Negawatts via BlockChain a reality.

Furthermore, the group interpreted the goal of this step as primarily looking for where BlockChain could add the highest value to the given goals, and it seemed that BlockChain and Smart Contracting could offer higher value to Negawatt trading than it could to the existing system of guarantees of origin or green certificate trading systems that already exist around the world under different policy initiatives and private-sector led voluntary programs.

The proposals are summarized in Figure 8 and also grouped according two dimensions, namely Technology Added Value and Society Needs in Figure 9.

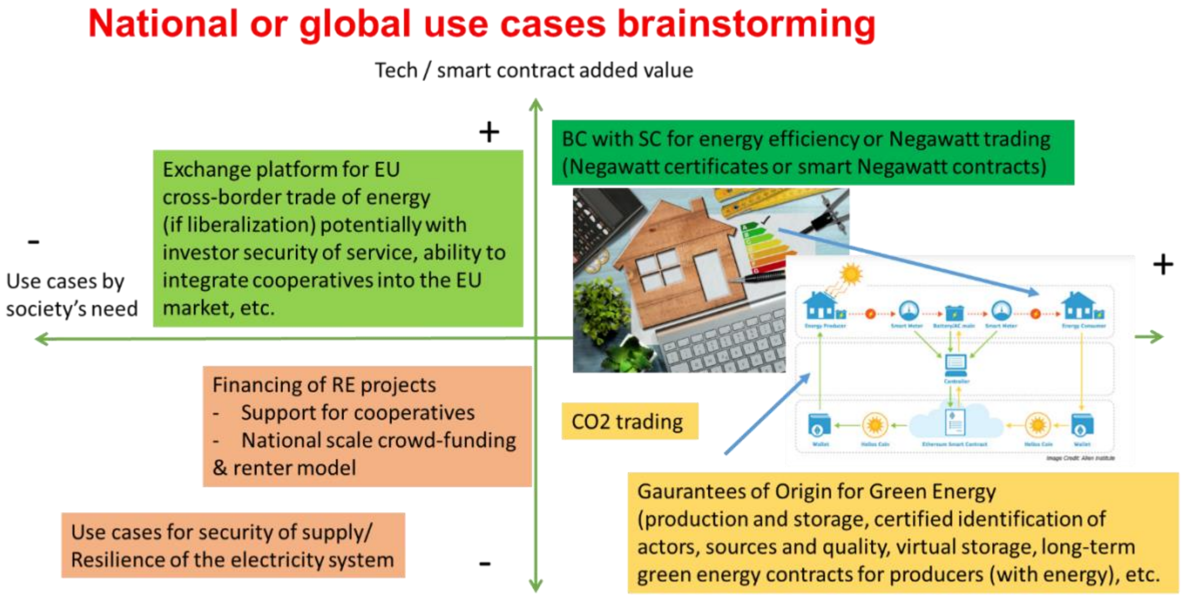


National or global use cases brainstorming

GOALS

Negawatts certificates and/or contracts	Exchange platform for trading	Certificates or Gaurantees of origin for RE	CO2 credits and tracking CO2	Financing
Increased incentive for energy savings	EU cross-border trading possible	Local RE energy premium price because time, place, producer info in BC	Tracking CO2 on local level - Climate action and climate inaction made clear	Support for cooperatives (e.g. financing wind energy)
Smart contracts faciliate exchange for smaller sources	Integrate cooperatives in the EU market	Certified identification of actors, sources, and quality	Incentivize various forms of CO2 reductions locally (CO2 credits)	Renter model for financing on a national level
	Investor security of service e.g. for foriegn sources	Long-term green energy contracts for producers (w/energy)		Crowd-funding facilitation
	Reduce barriers 4 entry into the market if liberalization	Production and storage certificates at EU level ; Virtual storage too		

Figure 8: Results of the global use case brainstorming with the selected case



National or global use cases brainstorming

Tech / smart contract added value

Use cases by society's need

Exchange platform for EU cross-border trade of energy (if liberalization) potentially with investor security of service, ability to integrate cooperatives into the EU market, etc.

BC with SC for energy efficiency or Negawatt trading (Negawatt certificates or smart Negawatt contracts)

Financing of RE projects
- Support for cooperatives
- National scale crowd-funding & renter model

CO2 trading

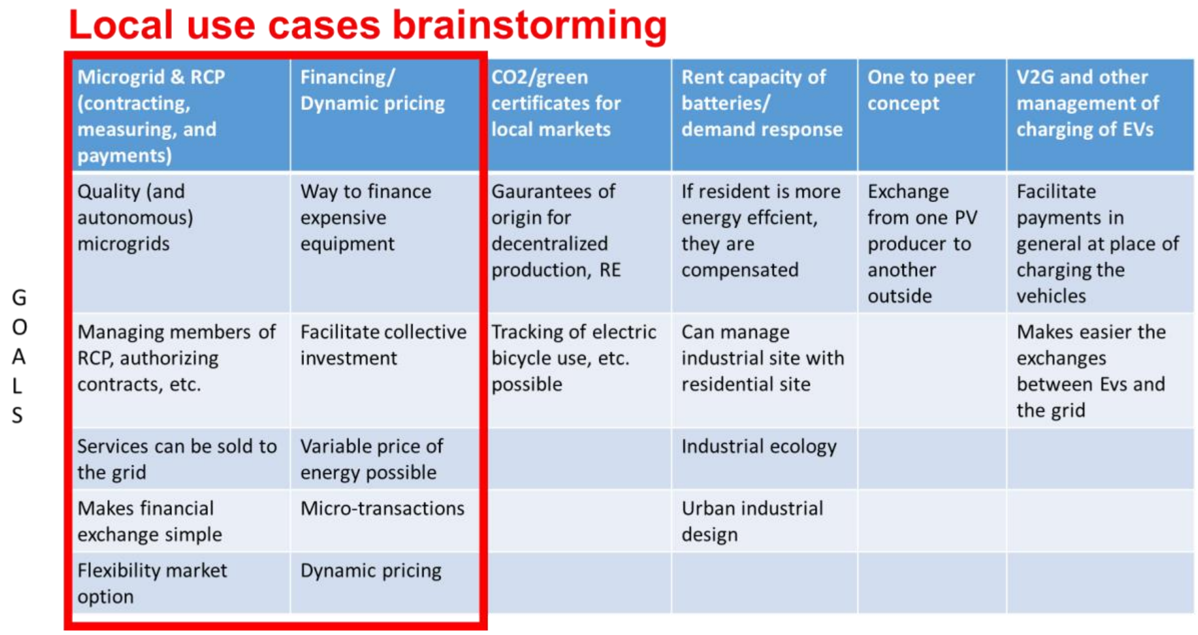
Use cases for security of supply/ Resilience of the electricity system

Gaurantees of Origin for Green Energy (production and storage, certified identification of actors, sources and quality, virtual storage, long-term green energy contracts for producers (with energy), etc.

Figure 9: Global use cases brainstorming grouped by society's need or by technology value added

4.2.2 The use case for Local Context: "Dynamic Pricing for Microgrids"

The selection of the use case for the local context was easier as there was already a strong consensus on the fact that BlockChain would be the enabling technology for peer-to-peer energy trading in microgrids. However, some new elements were added because of the interaction between representatives of different actors in the energy market. For example, DSO representatives would argue that revenue streams could also come from selling microgrid management services or from selling collected data to companies for different purposes. Figure 10 summarizes the proposals and Figure 11 provide the grouping of the proposal according to Technology Value Added and Society Needs dimensions.



Local use cases brainstorming

Microgrid & RCP (contracting, measuring, and payments)	Financing/ Dynamic pricing	CO2/green certificates for local markets	Rent capacity of batteries/ demand response	One to peer concept	V2G and other management of charging of EVs
Quality (and autonomous) microgrids	Way to finance expensive equipment	Gaurantees of origin for decentralized production, RE	If resident is more energy effcient, they are compensated	Exchange from one PV producer to another outside	Facilitate payments in general at place of charging the vehicles
Managing members of RCP, authorizing contracts, etc.	Facilitate collective investment	Tracking of electric bicycle use, etc. possible	Can manage industrial site with residential site		Makes easier the exchanges between Evs and the grid
Services can be sold to the grid	Variable price of energy possible		Industrial ecology		
Makes financial exchange simple	Micro-transactions		Urban industrial design		
Flexibility market option	Dynamic pricing				

Figure 10. Results of the local use case brainstorming with the selected (merged) case

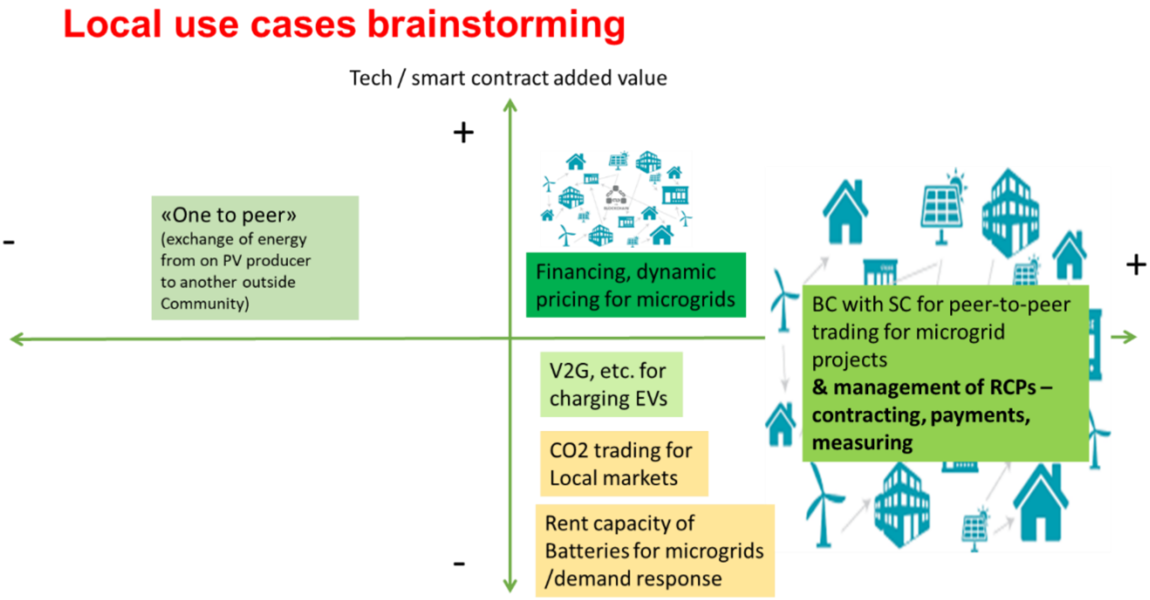


Figure 11: Local use cases brainstorming grouped by society's need or by technology value added

4.3 Impact Analysis of the two selected use-cases

After the workshop, our team grouped the various use cases into categories as per two key criteria:

1) the usefulness of the technology towards the issue at hand or the value-added potential from the technology proposed, compared to other technological options, and

2) the importance of the case to society (although this depends on the perspective one has about what transition scenario is most likely to offer benefits to society).

From this analysis, we see part of the reason why the groups chose the use cases that followed into the ideation and prototype steps which will be explained in the following chapters.

If we consider different perspectives about what is important to society, we can understand the value of each chosen use case compared to the other.

Figure 13: Comparing chosen use cases under the perspective of a decentralized energy transition

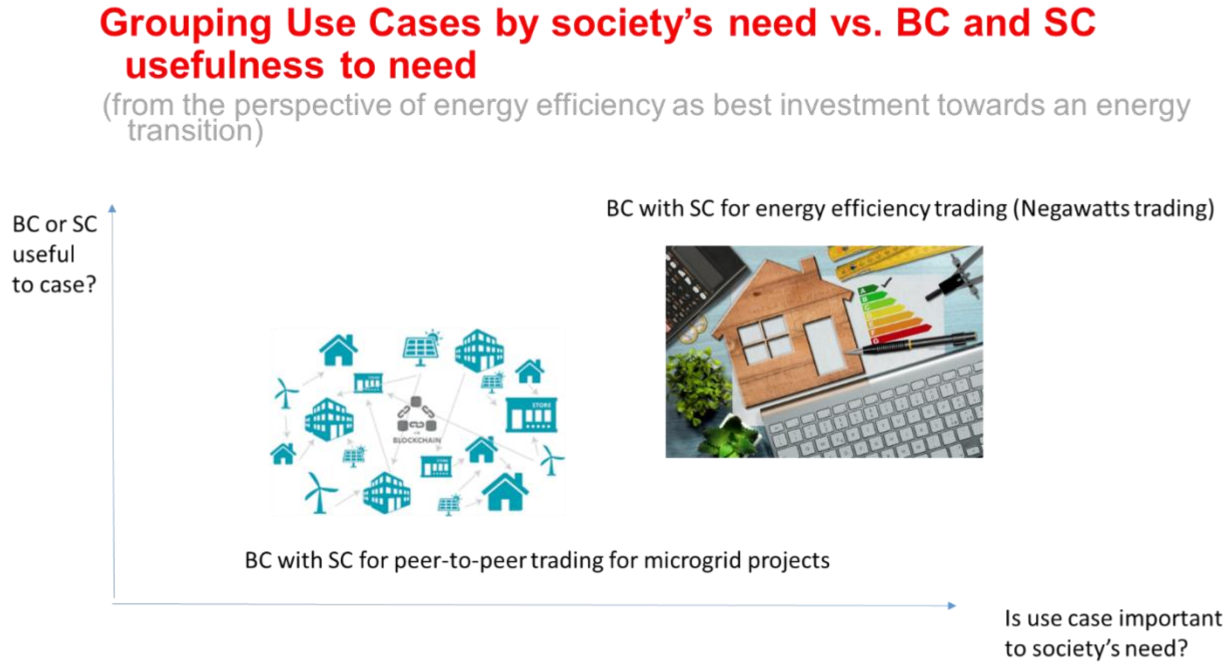


Figure 14: Comparing chosen use cases under the perspective of energy efficiency as key to the energy transition

4.4 The Business Models for the use cases

Although we used a simplified version of the Business Model Canvas, we elaborated a complete canvas with the (obvious) missing elements. We also elaborated the links between the different business model parties in terms of value exchanged and the corresponding revenue streams.

4.4.1 The "Negawatt" Business Model

This business model allows for tokens to be created each time a certain amount of energy savings is produced and traceable, using smart meters, or other sensors. When enough tokens are generated (for example 20 tokens) then the tokens can be spent on an investment in Renewable Energy infrastructure (approved by new rules supporting this business model). Such a business model would assume that there is a *supporting policy framework*:

a) a policy that requires energy savings to be generated by at least large consumers (and perhaps also smaller consumers like residential building owners) and
b) a policy that provides the eligibility for tokens to be spent on renewable energy projects even if this is a voluntary policy invented by an industry group.

This means for example that the tokens generated and sold can only be used for certain types of renewable energy projects that are considered favorable for the region or considered to provide higher value than others which are happening anyway. An example is solar or wind energy projects versus hydro energy projects. The rules must be defined to ensure a high value for the market created (not to water down the value and create a market used only for green-washing purposes).

Another point one can add is the ability for entities to save or bank their tokens for future use, in the case that they are concerned about not meeting future energy saving targets themselves or have concerns about the price or value of tokens rising. This latter case would only be relevant if there was a possibility to trade energy savings generated on another market (like the white certificate market) and if energy savings generated could be banked and used in the future - allowing energy consumers to meet their future energy reduction targets with energy savings produced in the past (or allowing them to meet their current targets with energy savings produced by other entities).

Another option is that an *Energy Services COmpany* (ESCO) could sell energy savings (tokens) to the government allowing for some tokens to be buried, so to speak, and not returned to the market, if the government esteems that energy savings must be pushed forward even further. This purchase by the government could be made possible by using funds gathered from taxes (for example taxes on fossil fuel sales). This value network is illustrated in Figure 15 and the full business model is depicted in Figure 16.

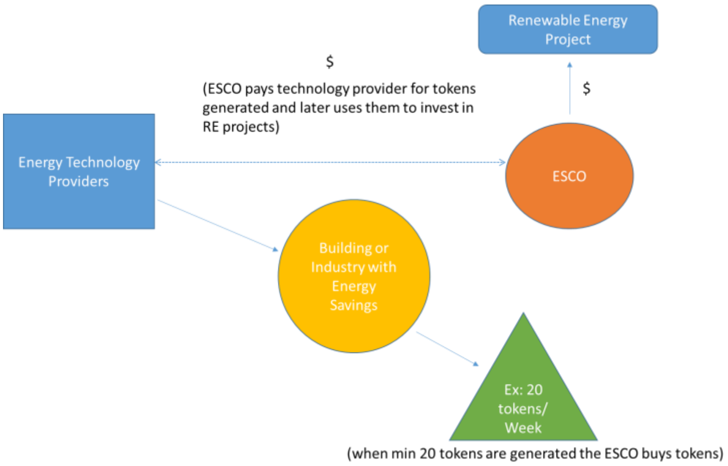


Figure 15: Revenue streams and token relationships in the Negawatt business model

Source: Strategyzer.com

Figure 16: Complete Negawatt business model

4.5 Microgrid business model (elaborated after the workshop)

The microgrid business model has not changed significantly after the workshop results. In the slightly revised business model (figure 17), we envision a P2P trading platform as the main channel for trading renewable energy generated, and the attributes it comes with. In addition, the trading of ancillary benefits (for example from aggregated data sold to insurance companies) could be envisioned as a second means to generate further revenue if the local grid has the need for such services. The main actors of this business model are the engineers operating the smart grid control technology and allowing for the trading with smart contracts, and the traders/smart contract proponents. By "traders" we mean more the contract managers and not traders in the traditional sense because trading happens automatically via the BlockChain and smart contracts. The regulators are also an important player, but not necessarily, depending on the market situation.

Figure 17: Revised microgrid P2P trading business model using the traditional business model canvas (source: Strategyzer.com)

It has not been proven yet if BlockChain can actually make sense in the context of local P2P trading of energy (for example in the context of the microgrid (RCP) law in Switzerland and the potential growing market for auto-consumption communities). Most likely the value of BlockChain and smart contracts in this context will come in the next 10-15 years, but not in the next 5 years. Current microgrid developments could allow for P2P distributed trading of energy with other existing technologies and BlockChain will most likely add sufficient enough value once several microgrids are connected or allowed to trade energy with each other, or when microgrids can trade their energy with more than one local grid operator. More insights on this can be found in the literature reviews conducted in (Bürer et al., 2018;2019).

4.6 Discussion of the results

From our current analysis of the workshop results, we can say that two use cases are at least seen by participants to provide potential value to society and to be clearly areas where BlockChain (or smart contracting) can really add value to the given goals outlined for each of the contexts provided.

Among both choices we can also compare them in order to prioritize even further. But this depends on what we believe is more important – is it more important to focus on an area where BlockChain can provide more value to society or is it more relevant to focus on where smart contracting can offer more value.

Our assessment shows that maybe not BlockChain technology specifically, but smart contracting in general can provide great value to both contexts. If one looks even further into the second criteria for selection (value to society) then the choice depends on whether one believes that new technologies that provide opportunities to renewable energy applications provide more value or those that provide opportunities to energy efficiency applications provide more value to society.

If the view is that energy efficiency improvements are the first step towards an effective energy transition, then it makes full sense to explore further the Negawatt application in a next stage of exploration and business model conception, testing and validation. This is also true because very little literature exists already on this potential use case. Furthermore, as we continued to develop the model behind the scenes (after the workshop) it was clear that the Negawatt concept could be combined also with renewable energy goals and therefore offer value on both fronts.

To conclude, both applications have value for society and must be further developed and tested in future research work. This project helped to spur forward the knowledge in this area among researchers in academic institutions as well as the private sector and public sector stakeholders who participated in the workshop.

5 Current Trends and Future Scenarios

In this last section we will present some new trends and future scenarios where BlockChain can enable further innovation in the area of Energy Transition.

5.1 P2P Distributed Energy Trading for residential microgrids

In Switzerland, Swissgrid is the TSO, that is, the company which owns and operates the national high-voltage transmission network. At the low-voltage level, 630 distribution system operators (DSOs) are in charge with distributing electricity to the consumers via the low voltage network. These DSOs are often very small companies which supply electricity for just one single commune. Only 30% of them produce also electricity on their own. The Quartierstrom P2P DET pilot project uses the utility grid operated by the local DOS, the Wasser- und Elektrizitätswerk Walenstadt (WEW). Because of that, the first operational P2P DET systems is based on a partnership with the existing local utility grid. Therefore, we consider the DSO as a relevant actor from a business model and value proposition perspective. We also consider the P2P Platform operator, who is in charge with the "virtual grid" and provides significant added-value services. The interconnection between elements of the virtual and physical grid are depicted in Figure 18.

Quartierstrom is a pilot project led by the ETHZ and the University of Saint Gall. In the region of Walenstadt (SG), 37 households (27 prosumers and 10 pure consumers) are participating to a local electricity trading market. The P2P platform allows the project participants to buy and sell solar energy generated by PV modules directly between them, without intermediaries such as the utility grid or any other trusted third party (Ableitner et al., 2019; Brenzikofer et al., 2019).

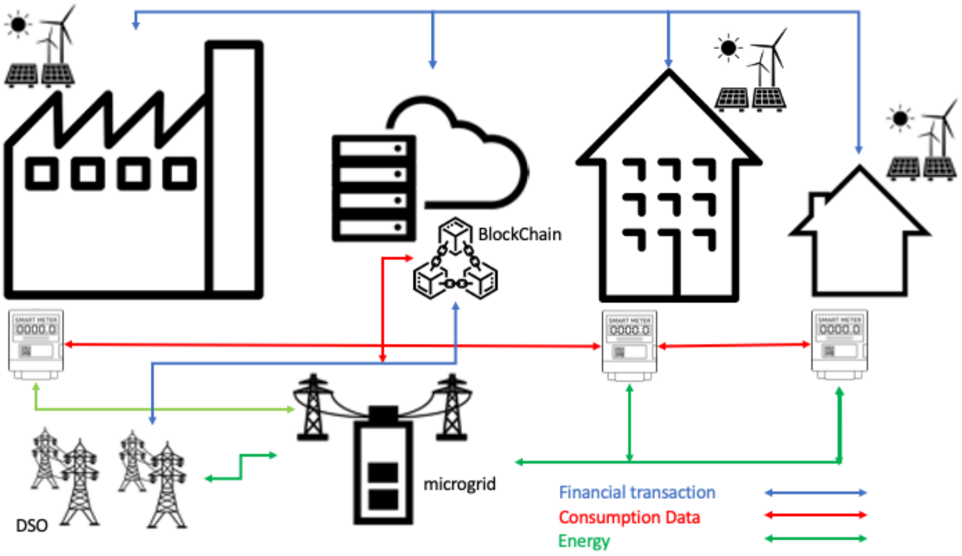


Figure 18. Virtual and Physical microgrids enabling P2P-DET applications

The automatic energy trading is made possible by the BlockChain platform based on Ethereum. Prices are set following a double auction mechanism where both prosumers and consumers indicate the amount and the price at which they are willing to sell or buy the locally produced energy.

All bids are transmitted by smart meters and registered in an order book and bids with lower selling prices and higher purchase prices are prioritized. The double auction algorithm is run iteratively every 15 minutes (Brenzikofer et al., 2019). The discriminative pricing method is applied to each trade, which means that the final price is the mean between the lowest seller's price and the highest buyer's price (Ableitner et al., 2019). Each transaction is implemented by means of a smart contract (Brenzikofer et al., 2019).

The local grid operator and electricity supplier, the Water and Electricity Works Walenstadt (WEW), provides its distribution grid for the pilot test and collect grid usage tariffs (Brenzikofer et al., 2019). In addition, the WEW contributes balancing the electricity supply and demand in buying surplus solar energy and supplying energy when the local demand exceeds the local supply (Ableitner et al., 2019). Under the current Swiss legislation, private PV module owners have no choice but to sell solar energy to the public electricity supplier. However, given the experimental purpose of the project, arrangements were made to allow local producers to sell solar energy directly to local consumers (Ableitner et al., 2019).

5.2 Bridging industrial and residential microgrids through electric vehicles.

The ultimate goal of a microgrids is the full independence from the main grid, therefore supplying energy to members of the microgrid with local (possibly renewable) energy sources, without the need of balancing the energy supply and demand from external sources.

In many European countries or in big cities, people tend to live in multi-family or condominium housing structures, contrary to the typical individual house pattern of rural, semi-rural or peri-urban regions, not to mention the typical North American dispersed living landscape. This socio-demographic characteristic indeed has very profound consequences for the future penetration of *electric vehicles* (EV), due to the fact that people living in multi-family houses in many case do not have access to an individual parking place for their vehicle, that is usually parked on public domain or on other non-electrified spaces; correspondingly, that portion of the population cannot rely on an individual or even shared power outlet that could be reliably used to charge private vehicle. It is thus easily understandable that switching to EVs is very negatively impacted by this all-too-common situation linked to past urban planning and architectural choices.

Hence, finding alternative charging solutions for dwellers without access to adequate power supply outside of ultra-fast charging stations – that can be assumed to remain significantly more expensive and less distributed on a given territory at least on the medium-term -, represents a crucial endeavor. Concomitantly, it is certainly desirable that the power supplied to EVs is generated by renewable energy sources, typically by PV installations. This represents an ulterior "social handicap" for people who do not own an individual house or have access to a connected parking space, since they usually cannot install PV modules on the (shared) housing space they occupy.

In order to remove this important socio-technical obstacle to EV penetration, especially in dense urban areas, the concept proposed here suggests considering either the workplace or large commercial buildings – such as multi-functional malls or even multi-sport centers – as alternative EV charging spots. Indeed, industrial or service buildings – e.g. large factories or administrative centers – usually have both large roof surfaces that could be used to install important PV capacities and broad either internal or external parking spaces reserved for their employees. Indeed, a paradigm shift (for slow and daily charging) is suggested in which workplace or shopping centers become main, standard EV charging spaces, instead of each one's residence.

The basic cornerstone of such a system would be the owner(s) of the requested surfaces for the PV modules. Key here is the scale economy that is expected by purchasing a large number of solar panels and the corresponding power control infrastructure. The CAPEX of this large implementation is expected to be significantly lower than the sum of individual, territorially decentralized PV modules investments. Therefore, the production price of the renewable power lies at significantly lower levels by working hypothesis.

In order to ensure the financial viability of the novel EV charging framework, two types of (smart) contracts between PV plant owners and customers – employees or customers of a given commercial mall - can be built:

a) Energy-based contracting: The owner sells the electric power for EV charging at a price slightly higher than generation (including charges to cover CAPEX amortization, OPEX and investment for EV stationary charging infrastructure) for a fixed time period, with priority given. Business model must be designed in such a way that power is significantly cheaper than in standard charging stations and to cover expenses for grid imports in case of insufficient production.

b) Surface-based contracting: The owner rents a given PV surface to employees or regular customers and the production is put at their disposal for EV charging. Rent must include charges for CAPEX amortization of charging infrastructure. In case the difference between production and consumption for EV charging is positive – on a time-basis to be defined contractually as well -, the owner can sell the overproduction to the local grid (and thus increase profitability of the scheme).

The proposed framework presents an additional significant advantage, that would bring interesting inputs for grids in residential areas and even for the future microgrids. Indeed, the framework is primarily intended for people who do not have access to adequate power supply at home for EV charging and their access should be prioritized. However, individual homeowners could also form a second circle of customers and, in fact, use the battery of their EVs, that they have charged on their workplace or at the commercial mall, as the battery for their houses (alone or in complementarity with a stationary storage). Hence, within the proposed paradigm change, EV batteries would/could provide support to the low-voltage distribution grids – e.g. for covering the evening demand peak – or even support local future micro-grids (based on separate contracts).

Since majority of the people work during daylight hours, it is indeed during work time that the probability is higher than sun shines and can be used to charge EVs; hence, our proposal to foster charging at workplace or at commercial sites, in the spirit of an EV charging shift adapted to the particularity of PV generation.

The role of BlockChain and Smart Contracts technology is fundamental in this application because it will make possible the above-mentioned contracting policy as well as the revenue sharing and the payments for EV charges. Hence, several microgrids can be dynamically connected through EVs which would efficiently store energy that can be used/charged just-in-time and just-in-place.

6 Conclusions

In this chapter we have considered the role of BlockChain and Smart Contracts technology from business-enabling perspective and provided a framework and a methodology for assessing the relevance of that technology in the context of Energy Transition.

We also considered the current constraints for adoption of new business models enabled by those technologies as well as related issues and potential risks.

We have presented the methodology for designing new business model with a multi-stakeholder approach by using the Business Model Canvas framework. Two cases have been presented and discussed together with their implications from societal, environmental and technology perspectives.

One Swiss implementation of the Peer-to-Peer Distributed Energy Trading system has been presented and a new solution for its issue has been proposed for dealing with supply-demand imbalance.

We believe that, in the short-term, BlockChain technology may contribute substantially in transforming the energy sector. However, the several issues and risks need to be properly addressed such as those linked to the complexity of power grids and in the application of complicated smart contracts to an already complex sector.

In the long-term, the new financing models enabled by BlockChain have the potential to stimulate the participative building of RIES infrastructure in completely different way than what is done today. This may lead to the democratization of individual ownership and therefore a full participation of citizens in future energy systems.

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