BLOCKCHAIN X ENERGY, A NATURAL MATCH

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BlockLab

1 A NATURAL MATCH

September 2017. Blockchain technology is making headlines weekly, typecasted as the biggest disruptor since the internet. Whether it's the travel business, the music industry, the financial system or the real estate market, business managers worldwide are being urged to prep for a major shakedown. Cut out the middle men, overpower the moguls, clean up corrupted market structures - blockchain as the new revolutionary.

Then again, the wittiest businesses choose to move forward and embrace blockchain technology to further strengthen their positions: an infallible insurance system, fraud free certifications, e-voting on the stock exchange – all mint condition use cases, and also all reassuring current key positions and power blocks. Blockchain as the next optimization tool.

For the energy market though, blockchain might be assessed best as a major *enabler* of an inevitable transition. The biggest disruptor is already there, on the supply side. The renewables are taking over out of necessity, providing energy in a way more intermittent and diversified way than the fossils do. The largest challenge for a sustainable energy system is therefore to build a supporting market structure. The system needs radical change in order to survive and that shift should be directed towards highly flexible networks that are able to tackle the weak spots of the emerging energy solutions.

So, as the fossil system is already a publicly acclaimed write off, blockchain will neither be its optimizer, nor its disruptor. It will most probably proof to be a strategic partner for the energy transition at hand, because blockchain technology and the next grid, well, they look like a natural match.

2 A TRANSACTIVE GRID

The energy transition
The energy transition is gaining rapid and irreversible momentum. Solar energy will be cheaper than coal in countries like the UK and the Netherlands by 2021 and is already so in Germany, the USA and Spain[1]. Costs of wind energy are dropping fast, especially off shore where the first park without subsidies is currently being built in Germany. Meanwhile, fossil energy sources are experiencing a strong headwind. In a few years' time, natural gas in the Netherlands has gone from cornerstone of the welfare state, via 'the transition fuel' to a social liability. Coal is facing strong societal opposition and the Economist has heralded the death of the oil-fueled internal combustion engine as a result of the fast-growing use of electric vehicles[2].

The energy transition needs to make use of all renewable sources available. It is clear that electricity will play an increasingly central role as an energy carrier as mobility, heating and industry become electrified and solar and wind energy will continue to grow. But also, geothermal energy and residual heat from industries and data centers need to be harnessed, as well as hydrogen and biofuels. The future energy system will be a multi commodity market – proportions will have to emerge, but a very diverse landscape it will definitely be.

Rotterdam will be strongly affected by the energy transition. Its large international petrochemical cluster, the city and surrounding region are responsible for a third of the Dutch carbon emissions and energy use[3]. This not only makes the energy transition important from a sustainability, but also from an economic perspective.

Challenge: avoiding billions of energy costs
Up till now the leading problem framing for consumers, policy and business largely consists of three main measures according to the so-called *trias energetica*: reducing energy demand, more efficient applications of energy and promoting renewable energy production. Gradually a new question is taking center stage: how to connect energy production and consumption in a sustainable and reliable energy system with minimal physical assets. Failing to respond to this question will result in a glut of expensive but underutilized tangible assets. Let's pinpoint some of the hottest issues for the near future.

- **Power generating capacity.** As solar and wind energy provide electricity at zero marginal costs, they drive down the average electricity prices and increase the volatility. As a result, fossil fueled power plants are being paid (and thus maintained) to keep running as a backup, wind turbines are let run idle at times and plans are made to curtail solar energy feed when supply exceeds demand. Apart from the resulting inefficient use of power production capacity, this implies that the phase out of fossils is slowed and subsidies for renewable energy remain necessary due to the lower revenues even as the costs of renewable drop. This inconvenient truth is dubbed

[1] Bloomberg Energy Outlook, 2016
[2] The Economist, The death of the internal combustion engine, August 12th-18th, 2017
[3] A. Aazami, M. Taanman, O Larcin, Van Volume naar Waarde, 2016

'clean energy's dirty little secret' by the Economist[4] and the energy sector is responding to this. For example, Dutch TSO Tennet and energy company Engie are piloting virtual power plants that aggregate the unharnessed reserve capacity of decentral sources like batteries, heat pumps and water boilers in order to reduce dependency on large conventional power plants.

- **Grid congestion.** If relying on electricity alone, electricity use of small users may triple and peak demand will increase four- to five-fold in winter, leading to congestion on the electricity grids. To maintain current high levels of reliability, huge investments will be needed. A BAU scenario speaks of annual costs of around two billion euros in the Netherlands alone[5]. With smart energy applications, these costs can be reduced substantially. For example, additional household congestion costs for electric vehicles drop by 57% with smart charging of batteries and additional congestion costs for heat pumps drop by 31% according to a study by Ecofys.

- **Use of heat sources.** Industry in the Rotterdam harbor is permitted to release 150PJ a year in waste heat. This waste heat currently has no value. Yet it is double the amount of heat the 1.6 million households in the larger region use for heating and for which they pay around 1.5 billion euros a year. A four to five billion euro regional heat infrastructure is being planned to further connect industry to small residential and business heat users. The aim is to create an open infrastructure in which also heat from geothermal sources and greenhouses can be used.

- **Storage capacity.** Electric vehicles currently represent 1% of total car sales in the Netherlands and are expected to take over in the coming decade. Already half of all battery capacity produced worldwide is being put in electric vehicles. And these cars stay parked for 95% of the day, driving only 37 kilometers a day on average. If used for local energy storage, each battery pack could service around fifty households for an hour, redeeming them of the need to install their own.

- **Pro-active end users.** Currently households, SME's and other small users hardly play an active role in the electricity markets at all. They pay a fixed, time independent price based on one or two tariffs, feed electricity from their solar cells into the grid based on simple net metering, and do not participate in the reserve market or price incentives to balance the grid. On average households pay 1600 euro's a year on their electricity bill. And even though it could save them hundreds of euro's a year, about half of the consumers has never even switched between energy suppliers since the market liberalized in 2004[6]. And that would only be step one, in the new grid selling your electric vehicles' reserve battery capacity on the reserve market may bring in an additional 250 euro each year[7].

The smart turn for the energy transition

From this angle, a multi-billion opportunity arises in the Netherlands alone. Benefits fall to governments in the form of lower subsidies for renewable energy, to consumers and businesses in the form of lower energy bills, network companies in the form of lower investments in electricity grids, producers that make more optimal use of their renewable energy generating capacity and society at large in the form of a cheaper and more swift transition to a sustainable energy system.

The main challenge to tap into this large potential is to create new market and business models based upon IT solutions that can securely, smart and efficiently connect the demand, production, storage and flexibility of millions of devices and prosumers. The development of the needed smart grids (energy grids connected to an IT structure) that form the infrastructural backbone is a first step and well underway. However, according to the Rocky Mountain Institute experiments to better manage and regulate the energy grids generally face four issues: (1) controlling demand is difficult as costumers are concerned about their privacy, sharing of data and of control of their own devices by third parties, (2) the tracking and validating of flows (energy, but also carbon credits for example) is often expensive or difficult, (3) full entrance to energy markets is restricted for small players and (4) the grids still carry their top-down legacy[8].

A future outlook is to create not just smart electricity and heat grids, but fully transactive grids. Grids which are organized from distributed nodes instead of the traditional hierarchical grid structure. These would allow *all* energy devices and actors, both small and large scale, to perform economical transactions and determine loads, prices and optimal allocation of resources through fully interconnected hierarchical markets. It could open up the energy markets to all parties, adequately deal with privacy issues and individual preferences, be cheap and reliable to run and more resilient in the face of cyber-attacks or black swan events. It is within this context that the concrete economical and societal urgency of blockchain technology kicks in.

[4] The Economist, Clean Energy's Dirty Little Secret, Feb 25th-March 3rd 2017
[5] Ecofys, De waarde van congestiemanagement, 2016
[6] Autoriteit Consument en Markt, Trendrapportage Energiemarkt voor consumenten – tweede helft 2015, 2016
[7] Interview Vandebron, August, 2017
[8] Rocky Mountain Institute, The Energy Web Foundation: Bringing Blockchain Technology to the Grid, Feb 14th 2017

3 BLOCKCHAIN TECHNOLOGY

Ledgers and contracts
One of the best pitches so far: 'what internet did for information, blockchain will do for value transactions'. Blockchain technology became known through Bitcoin, has gain quite some attention as a fintech tool and is making headlines recently via the legitimation of cryptocurrencies in Japan and Russia and via ICO's, initial coin offerings. But the crucial point to remember is that blockchain technology is not limited to money flows. Value transactions can be about intellectual properties, shares, licenses, material flows … and energy.

The core of a blockchain is one large ledger that registers all transactions of all partners connected to the network, including the corresponding balances. All connected computers have their own identical copies of the ledger, so that it can only be changed if all partners approve. A party that wants to do a transaction, sends it into the blockchain network. Next, every computer connected checks the ledger to determine whether or not the transaction is possible and legit. Only if a transaction gets approved by all peers, it will be registered in the ledger – which will then be updated on all computers involved. Once entered into a blockchain, information cannot be erased. Thus, a blockchain contains an accurate, time-stamped and verifiable record of every transaction ever made and the network does not need a central authority.

The next step is that blockchain technology allows us to develop smart contracts that bring a lot of innovation possibilities to the table. Contracts are captured in codes and, when approved by all users, are able to execute themselves on the blockchain. In fact, any 'if…., then….' statement can be programmed and added to your assets. For example: 'if it's January 1, if investor X did not go bankrupt and if the balance increased more than Y since January 1 of last year, transfer 25% of the increase to X'.

The benefits are obvious: blockchain enables us to handle very complex and diversified transaction systems automatically, opening up complete new perspectives on grids, networks and markets, all way more decentralized.

Key assets for the transactive grid
Let's focus on the crucial cornerstones blockchain has to offer for our holy grail, the transactive grid.

- **Diversifying and activating the playing field.** Blockchain technology can reduce the transaction costs so energy transactions by smaller energy users and producers may become economically interesting. Hence P2P energy trading (eg BMG[9], next page), a new paradigm in the energy market where people and business can generate their own energy from renewable energy sources and exchange these with others. The consumers who both generate and consume energy become prosumers and they can either store it with energy storage devices, or supply others who are in energy deficit.

  But only so much can be done peer to peer. National and international connections to large energy users (industry), suppliers (off shore wind parks) and storage options (e.g. in hydrogen and ammonia) are necessary and further help even out local differences in for example wind speed or use peaks. One step beyond peer to peer is the aggregation of distributed production, storage or demand, enabling networks of peers, for instance EV drivers, to create serious leverage on the energy market.
  Many existing projects started from the microgrid level to investigate the operation of P2P energy trading. They rely on availability of local energy sources, therefore local levels form the basis, together with a sophisticated ICT system for managing and balancing the microgrids. These experiments can be seen as miniature ecosystems, that prelude a new market structure and are worthwhile monitoring.

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[9] Mengelkamp, Esther, et al. "Designing microgrid energy markets: a case study: the brooklyn microgrid." Applied Energy (2017).

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- **Agents for a demand response market.** In a demand and response market, end users adjust their power consumption in response to price changes on the grid. The simplest example is people turning on the washing machine at night because of the lower rate. As rates vary with supply and load, an effective demand response market helps balancing the net load, reducing peaks and avoiding congestion. Ultimately this means that a fully effective demand response market can prevent unnecessary investments in overcapacity or fallouts because of undercapacity.

  Blockchain provides us with virtual agents who represent us and act on a digitalized demand response market on our behalf[10]. They operate fully automated and real-time, creating a far more dynamic and meticulous market then humans and businesses could ever reach themselves. When equipped with the right data and computing power, an agent can also analyze its owner's future power production and consumption and use it to choose strategic positions in the grid's negotiations. With the right interface, end users can program their agents with specific goals, boundaries and risk margins.

- **Machine-to-Machine (M2M).** As agents take over the execution of contracts, the handling of transactions and the checks on authenticity, not only humans and businesses but also machines can actively join a blockchain driven grid. Electric vehicles, factory installations and even washing machines can install their own agents on the demand response market. This option holds the promise of a very fine-grained energy grid. Where demand response on a household or business level flattens larger load peaks, all these machines joining the game help flattening out even the smallest peaks. Machine to machine trade could be the fine sandpaper for our load curves.

A good example of a P2P community is the Brooklyn Microgrid (BMG), a project run by LO3 Energy. The BMG provides a local energy market on which community members can trade energy P2P with their neighbors. The Brooklyn area has an outdated electrical grid, the grid struggles when the operations on the grid gets raised by severe weather events, the rate of utilization approaches its limits. The BMG can decouple from the grid when the load is high and operate on their own renewable generated or stored energy.

The project consists of two main components:

1 A virtual community and energy market platform, providing the technical infrastructure for the local electricity market.
2 A physical micro-grid, to share energy and act as a back-up to prevent power outages. By uncoupling from the traditional grid, it can operate in island mode.

An example of aggregating energy services is the pilot by Tennet, IBM and Vandebron that starts October '17. In this case blockchain allows EV users to gain access to and profit from the centralized imbalance market.

Vandebron aggregates data of 100's of parked electric vehicles that may each deliver 10kW. Each car is registered to the blockchain through the hyperledger platform. Based on user data, statistical analysis and the amount of electricity available from the EVs Vandebron can bid on Tennet's imbalance market which requires a minimum of 1MW.

[10] Prinsloo, Gerro, Andrea Mammoli, and Robert Dobson. "Customer domain supply and load coordination: A case for smart villages and transactive control in rural off-grid microgrids." Energy 135 (2017): 430-441.

Challenge: scalability
Scalability is the capability of a system, network, or process to handle a growing amount of work, or its potential to be enlarged to accommodate that growth. This is a bottleneck for the current existing blockchains and a lesson for the new blockchains to be released. Development teams now have a strong focus on scalability, extensibility and interoperability of blockchains, because they are crucial to achieve IoT involving networks and solutions.
There are several approaches[11], which can work along each other coherently:

- **Payment Channel technology[12]:** Payment channels allow for practically unlimited, bidirectional transfers between two participants, as long as the net sum of their transfers does not exceed the deposited tokens. These transfers can be performed instantaneously and without any involvement of the actual blockchain itself, except for an initial one-time on-chain creation and an eventual closing of the channel. This is named for Ethereum under the *Raiden Network* and for Bitcoin it's called the *Lightning Network*.

- **Scalable Autonomous Smart Contracts[13]:** *Plasma* is a proposed framework for incentivized and enforced execution of smart contracts that is scalable to a significant amount of state updates per second (potentially billions), enabling the blockchain to be able to represent a significant amount of decentralized applications worldwide.

- **Scalable heterogeneous multi-chain:** *Polkadot* is not like previous blockchain implementations which have focused on providing a single chain. Polkadot itself is designed to provide no inherent application functionality at all. Rather, Polkadot provides the bedrock relay-chain upon which a large number of validatable, globally-coherent dynamic data-structures may be hosted side-by-side. We call these data-structures 'parallelised' chains or parachains. In principle, a problem to be deployed on Polkadot may be substantially scaled out over a large number of parachains.

Towards a transactive grid
Transactive energy goes beyond demand response. It is expected to maintain the dynamic balance of supply and demand by enabling real-time, decentralized, automated, and autonomous transactions among distributed generation and load resources. On top of the scalibilty challenges, an effective transaction platform is key for a transactive energy system. The role of such a platform is to facilitate the deployment of applications that help maintain stability of the grid, as well as to implement efficient new market mechanisms[14]. And yes, the idea of a transactive grid was already there, platforms already exist, but now the introduction of blockchain technology is a very good reason to amp up ambitions.

4 THE PLAYING FIELD

What's happening?
Back to reality, we are not there yet. Of course, the blockchain x energy match is being made throughout the world and indeed the first applications are there. But things have just begun, most cases are in a stage of early development. According to the Rocky Mountain Institute, blockchain has great potential, but "even to blockchain experts, it is still unclear exactly where the technology's value lies and what the roadmap to commercial implementation looks like in the energy sector."[15]
Screening the current playing field, these are the main findings:

- Organizations understand the value of the distributed ledger technology better and the ecosystem of blockchain is growing and harmonizing with the real world. Energy businesses have started creating use cases, mainly pilots and experiments of course. The Indigo advisory group listed hundred use cases in July, expect dozens to follow over the coming months. This is partly due to the fact that mainstream has only recently jumped the bandwagon, but just as much a logical implication of the fact that blockchain technology itself has to mature on issues like scalability.

- The playing field is now an interesting mixture of establishment acknowledging the benefits from their own perspective and startups who have nothing to lose and feel free to work out completely new models. This is not so much a clash between start-ups and the incumbents, but rather looks like the beginning of a fertile ecosystem and it strengthens the assessment that blockchain is not a disruptor but a new strategic partner in an inevitable transition. Some cases in point are startups who aim to collaborate with the current system. For example, Power Ledger organized a public token to develop the platform that eventually will play a role in the industry and Gridplus[16] is developing a Smart Agent that will be able to programmatically buy and sell electricity on behalf of the user and intelligently manage smart loads by leveraging the Ethereum public blockchain.

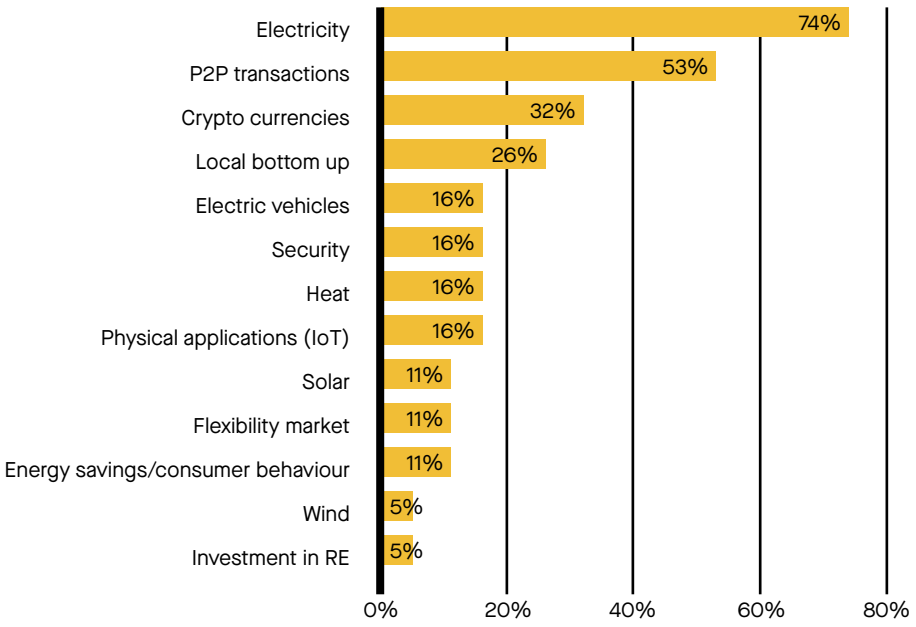
[11] The given examples are mainly on Ethereum, which there is a big open-source community developing on scalability issues.
[12] raiden.network/101.html
[13] plasma.io
[14] Kvaternik, Karla, et al. "Privacy-Preserving Platform for Transactive Energy Systems." (2017).
[15] Jesse Morris, The Energy Web Foundation: Bringing Blockchain Technology to the Grid February 23, 2017
[16] Gridplus Whitepaper: goo.gl/xesfv2

- While this paper focuses on the transition towards a transactive grid, many of the innovations are simply complementary to the current market. They use blockchain's functionalities for more effective metering, billing, registrations of ownership or certifications of origin. Although their contribution to the revolution may seem small, most of these applications might prove relevant to the future grid as well. Take Electron which offers a shared registration platform for all UK gas and electricity supply points to facilitate faster switching. This technology is now being extended to cover new types of assets.

- There are several pubic & permissioned platforms that attract a big crowd of individuals, corporation and institutions. These are also the same blockchain networks that are making serious leaps for wide-scale use. E.g. Ethereum is momentarily the most used public blockchain with smart contract functionality, which also offers permissioned change interoperability. It being a public blockchain harnesses an ecosystem of all other applications, besides energy.

- Electricity is the main focus in most innovation projects, as reflected by eighteen use case proposals for the Rotterdam Region submitted to BlockLab (see figure). However applications that focus on heat and security, two of the regions strongest assets, are also promising.

KEY THEMES IN THE ROTTERDAM REGION



And where? Rotterdam, the Netherlands, Europe, the world...
The energy transition, blockchain and the transactive grid are truly global tasks and opportunities. But there is no need to wait for the Valley. Rotterdam has a dense energy footprint, a high diversity of energy use (residential, industrial, greenhouses) and well established (inter-) national links. This, combined with a growing tech start-up scene means it has both an urgency and a means to realize blockchain's potential. The Netherlands are building up a track record. The former BAS Nederland was the first energy company allowing payments by blockchain; in November 2016 the first wholesale energy trade using blockchain technology occurred on a conference in Amsterdam, the world's biggest blockchain hackathon takes place here; and all the large grid operators (Enexis, Alliander, Stedin, Tennet) are already experimenting with blockchain.

Zooming out further, Europe is undoubtedly the most active region globally, according to the latest heat maps. Not just in terms of blockchain in energy but also in terms of the broader core developer network, with the Netherlands, Germany, Austria and UK all competing for pole position[17]. So if we muster the resources and will, this may well turn into one of those topics in which Rotterdam can take a lead, together with our partners in The Netherlands, Europe and the world.

[17] According to NY Based Indigo Advisory, Blockchain in Energy and Utilities; use cases, vendor activity, market activity, accessed online July 2017

5 AGENDA

The blockchain x energy agenda for the Rotterdam region must lead us towards nothing less than fully functioning transactive grids, but it must also take into account the early stage this development is in. Breakthroughs are needed in both the core of blockchain technology and the bone structure of the energy market. So, step one, let's start developing use cases with the means at hand; step two, let's prepare for serious upscaling within the next decennium; step three, let's actively contribute to the grand design in all its aspects – including market model, regulations and a backbone platform.

1 Start developing use cases

Blockchain technology needs a track record; the energy market needs experiments. Realizing use cases with the means at hand provides us with both and at the same time contributes to the development of innovation contexts and communities. Innovation projects in the next few years should focus on:

- **Applications preluding the transactive grid.** Peer to peer contracts can already function on a small scale, aggregation models can already be tested. Agents can prove themselves on first tasks like dynamic contract management. And the cross-over with IoT that enables machine to machine transactions might get started right now.
- **Tested within the grids at hand.** Micro grids can already be realized, as subsidiaries of the mains; Rotterdam recently announced Europe's largest smart grid as a testing ground; and a consortium including The Green Village is preparing a smart heat grid testbed. These are the contexts at hand for experimentation and validation.

2 Prepare for upscaling

While pioneering and building a frontrunner knowledge position, eyes should also be on the prize - scaling up on reach and impact:

- **Adopt scalable solutions** for blockchain technology as soon as they're worthy, as well as expected breakthroughs on interoperability and new consensus models. This means simply staying up to date, but also actively engaging in the international discourse, in order to be able to assess new models in a high-level expert network.
- **Future proof design of new infrastructures.** The designs of new grids like the expanded heat grid must involve no regret strategies for blockchain technology, making sure we do not make decisions now that impede a smart heat, hydrogen and projected multi-commodity grid in the near future.

3 The grand design

It may sound very un-bottom-up-py but a transactive grid will not emerge from local use cases only. Blockchain can only live up to its promise if it can connect smart machines to new market models and regulations. These will involve a grand design and as these new markets concern a critical infrastructure and upset some of the vested interests, this is just as much a political and social task. The dialogue towards a new model started around thirty years ago, gained serious traction in the last few years and now involves network administrators, governments, industries, scientists and climate advocates internationally.

Some blockchain heads should take a stance and join the debate. BlockLab will therefore connect energy key players and blockchain pioneers, learning by doing will be the MO, and yes, we are very optimistic about the results. Because the energy transition and blockchain technology, they indeed seem to be a natural match.

BlockLab

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