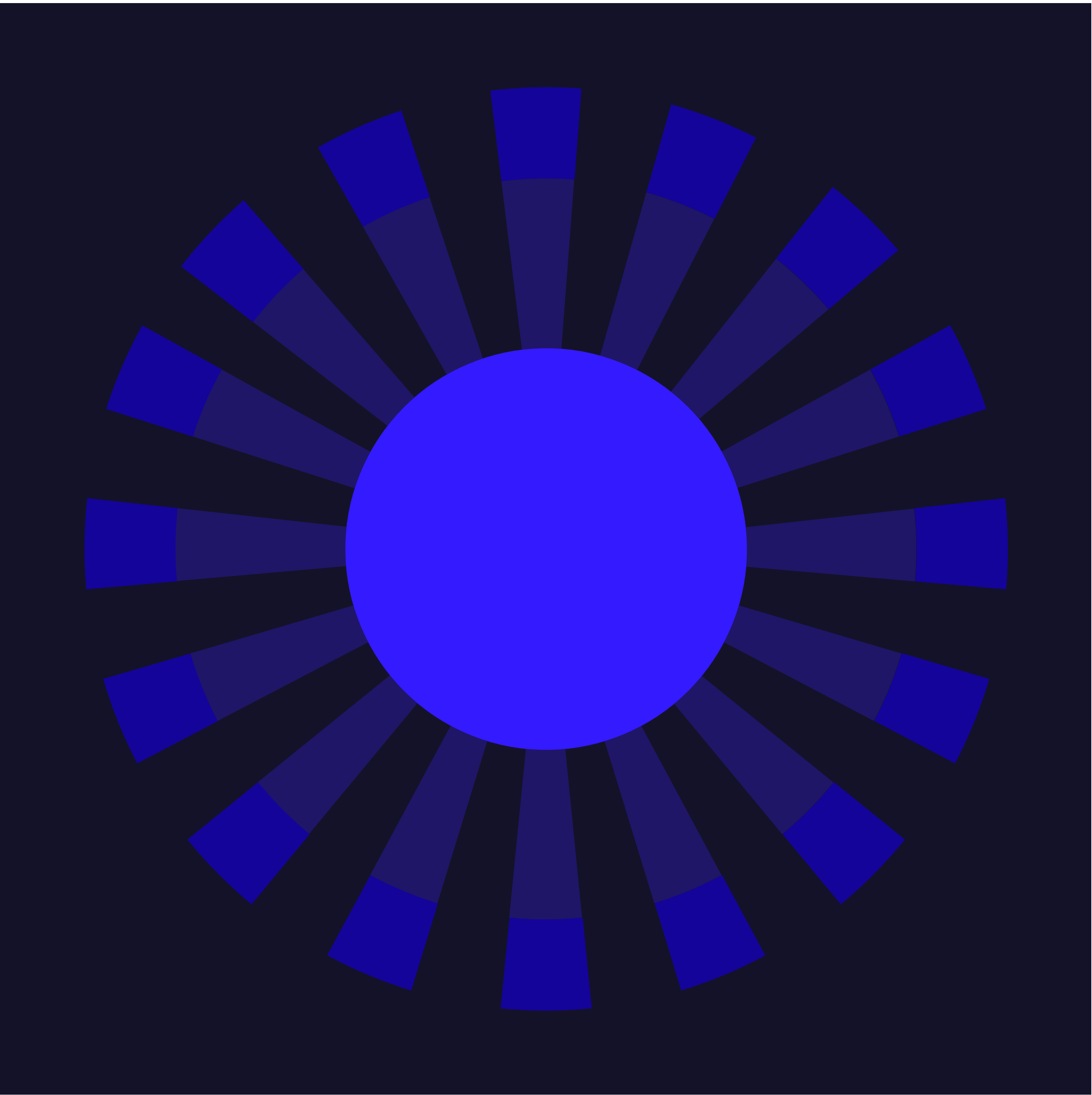
The Energy Stack
The 3Ds of Energy: Decarbonization, Digitization and Decentralization

Outlier Ventures



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Executive Summary

The Transition to Distributed Energy

Our modern energy system is failing us. Ever since the industrial revolution our economy has been powered by non-renewable sources of energy dominated by coal, oil, and natural gas. The economic gains we have made as a society as a result of extraction, and our resulting usage of these sources of energy, have been unparalleled in human history. However, as we begin to understand the impact our energy usage is having on the global climate, there is a growing understanding that we must transition to a low-carbon energy system. We as a society have prioritized economic growth over environmental welfare.

Even as we begin to understand our energy system's negative impact on the environment, global energy demand is expected to rise by 48% by the year 2040. Over the next 20 years, we must find ways to meet this demand with low-carbon solutions. The good news is that the cost of renewable energy sources such as solar and wind have reduced dramatically in recent years, to the extent that they are now as cost effective as purchasing power from the energy grid.

As well as lower installation and running costs, cheaper battery storage is making it easier to balance supply and demand of renewable energy sources, a problem which has until recently, had limited the use of renewables. As the production and distribution of energy evolves, so does consumption. Emerging smart cities and demand for electric cars is forcing energy systems to adapt and redesign the way in which energy is delivered.

Taking all of these elements together, we are transitioning from a centralized energy system reliant on burning fossil fuels, to a distributed and peer-to-peer system in which renewables are increasingly consumed. This transition brings with it a whole host of technological challenges brand new to the energy sector.

In order for the energy network to adapt, it must use the latest data technologies available. For example, utilizing sensors connected to the Internet of Things (IoT) to digitize the grid; working with blockchains to track and share data; and implementing artificial intelligence algorithms to optimize and automate the entire energy system. To integrate these advanced data technologies holistically, the energy sector should look to the Convergence Stack as a framework.

Sensors Collect Data to Digitize the Grid

As a consequence of its reliance on coal, oil and gas, the traditional energy infrastructure has struggled to adapt to changing consumer demand. Once electricity passes into our homes, for example, the system loses track of it. As fossil fuels are very slowly phased out, variable renewable energy sources are "plugging" into the grid. Due to their unpredictable nature, balancing supply and demand becomes a real challenge. We cannot monitor, control, and balance what we cannot measure.

The starting point for the creation of a smart home - and by extension a smarter grid - is the use of sensors, which measure energy usage like smart meters and offer two benefits. . Firstly, these sensors allow data to be collected from appliances such as fridges, ovens, lights, and even electric vehicles. Secondly, renewable energy production from solar panels and wind turbines can be monitored and combined with battery storage data, to help balance supply and demand on the network. For example, transmission system operator Tennet aims to balance supply and demand by implementing blockchain technology with electric cars and household batteries, to prevent congestion in the high-voltage grid.

Blockchains Track and Secure Data

Once we collect data from IoT sensor networks, it needs to be authenticated, validated and secured. Today's existing data infrastructure allows information to be stored in databases with only a single-owner, and lacks tools to facilitate the effective sharing of data. Often, these databases are not encrypted and are prone to hacking attempts. As an increasing number of energy grids are brought online, the issue is exacerbated, making the entire system more susceptible to cyber attacks.

As an increasing number of renewable sources and devices equipped with batteries interact in energy networks, and as the process of energy trading and certifying renewable energy production becomes more mainstream, it is crucial we support these use cases by using blockchains.

Blockchains are a cryptographically linked list of timestamped records. They can be implemented in different ways depending on the specific needs of the applications. They can be tweaked to prioritize speed, security or decentralization, and different blockchain networks can make independent trade-offs. Different energy use cases will have contrasting needs; for example, the trading of renewable energy certificates might need to prioritize security, while more complex automated transactions using smart contracts will need to prioritise speed. Regardless of the particular configuration, blockchain networks were created to be foundational infrastructure systems designed to track and secure data. Their usage is becoming more widely used by blue chip and large corporate organizations; for example British Gas recently partnered with home energy assistant Verv to provide customers with clear bills offering a breakdown detailing the amount of energy purchased from British Gas, and the portion coming from solar panels.

Artificial Intelligence Optimizes the Entire System

In order to save both energy and money, the securely collected data must then be analyzed for production and consumption optimization. . Artificial intelligence company DeepMind recently used machine learning algorithms trained on weather forecasts and historical turbine data to predict wind power output 36 hours ahead of generation, increasing the value of the energy by around 20%. DeepMind didn't use blockchain-based data so it had to go through the expensive and laborious process of collecting and standardizing all of the data. Projects like Ocean Protocol can make useful energy data easily available to everyone and systems like Fetch.ai can use agents to collect missing data autonomously. With more data and algorithms being used, the entire energy system can become more efficient; from automatically dimming street lighting, to introducing energy surge pricing to incentivise moderate or off-peak usage, to the automatic selling of excess household energy.

The Convergence Stack is a framework to understand the convergence of new data technologies like the IoT, blockchains, and AI. We must move to a low-carbon economy as fast as possible to avoid the consequences of the worst climate change predictions, and to do so, the energy sector must upgrade its data infrastructure immediately. We can no longer afford to wait.

The 3Ds: Decarbonization, Digitization and Decentralization

The energy industry is finally changing. Fossil fuels have accounted for a consistent 60-70% of share of the global power generation mix since the 1970s. This equilibrium is coming to an end. Social and political factors have combined to push renewable forms of energy into the mainstream. Climate change has long been on the policy agenda and pushed by green political parties and activists around the world, but the industry has been slow to act. The Paris Agreement and recent Intergovernmental Panel on Climate Change Fifth Assessment Report starkly outlines the urgency of the problem. We need to hold the increase in global average temperature to well below 2°C above pre-industrial levels, and ideally limit the temperature increase to 1.5°C. Social, political and economic pressures are forcing the industry to transition to a low-carbon economy. This shift is being driven predominantly by three factors: decarbonization, digitization, and decentralization.

Decarbonization

It might not be enough, but by 2050 it is estimated that only 29% of the electricity production worldwide will come from burning fossil fuels, down from 63% today. This reduction is driven primarily by an investment of $11.5 trillion which is being ploughed into a new global power generation capacity. This investment will, according to Bloomberg Energy, lead to wind and solar technology providing almost 50% of worldwide electricity consumption, with hydro, nuclear and other renewables taking total zero-carbon electricity up to 71%. The decarbonization is partly being driven by government and consumer pressure, but fundamentally change is occuring now because the costs of renewable energy have fallen so dramatically. By 2050, it is estimated that the cost of an average photovoltaic (PV) power plant will have fallen by 71% and wind energy production by 58%. Today, creating PV and wind power stations is already cheaper than building new large-scale coal and gas plants.

Additionally, consumer demand and government action is speeding the shift to low-carbon energy sources. Legislators are demanding businesses become sustainable by purchasing renewable energy, and necessitating that new buildings are built to be sustainable and energy efficient. Consumers are becoming increasingly environmentally-aware in their buying behaviours, opting for products that have a lower carbon footprint and reduce their plastic waste. This evolving attitude is forcing companies to compete to reduce their environmental impact and shift to renewable energy sources across their supply chains. As demand for decarbonization increases, supply will need to grow in equal or outpaced measure, resulting in a virtuous cycle of decarbonization. Even if we ignore the political and environmental cases, in 2019 the economic case certainly makes sense.

Digitization

The increased number of distributed devices added to the energy system such as solar panels, batteries and electric vehicles, leads to vast amounts of data being produced throughout the energy chain. We are collecting all that data by adding sensors to any 'thing' and connecting them over networks. Sensors are mainly focused on data collection of the environment - extraction, production and distribution. Sensors are now extending into storage devices and homes, gathering insights about behavioral consumption patterns mainly through smart meters.

The IoT includes a wide variety of modules, such as smart batteries for solar panels, smart meters, wind turbines, fridges and other household appliances, smart buildings, vehicles, automotive engines, and charging stations. It is becoming possible to measure consumer energy usage data, track renewable energy production and prove its origin. Green energy producers can issue renewable energy certificates (RECs) and manufacturers can check the performance of any particular appliance. Balancing the grid can be a reactive rather than a proactive process. Digitization is the basis for the coming machine-to-machine economy, whereby any smart device equipped with batteries is able to buy energy when the price is low, and sell when the price increases, for a profit.

Decentralization

Micro-generation on a local scale is becoming more cost-efficient than maintaining large power plants which come with a significant energy loss to the grid. Advancements in solar photovoltaics are enabling consumers to become producers while improved batteries provide a way to store intermittent renewable energy, helping reduce transmission costs and energy losses. Microgrids are local grids that can operate either as part of the wider traditional grid, or disconnect and function autonomously. A decentralized energy grid is more robust against failures and provides energy independence to its users. Transactive grids allow users to buy and sell energy in a peer-to-peer fashion, securely and automatically using smart contracts. Energy can be traded back to the traditional grid, too. Batteries and the IoT enable any smart device to store energy and take part in the energy exchange on transactive grids.

New advances such as "virtual power plants" and "virtual batteries" will become the digital representation of these new grid technologies, in order to allow transactive and microgrids to interact. Distributed energy production units and devices equipped with batteries will join such virtual power plants. For example, houses could be harnessing solar energy, while simultaneously feeding it back to a local microgrid connected to another microgrid in a neighboring city, forming a virtual transactive grid. Electric vehicles and battery-equipped appliances could then be transacting energy according to energy demands on the grid.

Decentralization is a solution to the fragmentation in the automotive and electric charging industry. Monika Dernai from the Energy Services team at BMW, points out that ''no single original equipment manufacturer (OEM) can solve this alone". "In a Smart City where you have different mobility providers and roaming platforms for charging, this is where collaboration of OEMs on a DLT and Vehicle to Grid solution looks most promising," she says.

Regulation and Legacy Infrastructure Choking Innovation

As the 3Ds: decarbonization, digitization and decentralization push the sector forward,, regulation and legacy infrastructure continue to slow down innovation. Current infrastructure is not suitable for the emerging energy stack. It was built on the premise of steady energy generation by large, mainly fossil fuel-based power plants, and predictable supply and demand. Wind farms, solar PVs and other renewable energy generators add unpredictability to the network. Additionally, installation costs of distributed and renewable energy sources such as solar and wind may be too high for some areas, meaning new infrastructure is restricted to specific locations. Currently micro-producers need a utility provider license to sell energy to their peers or to businesses. They can only sell it back to the grid, meaning peer-to-peer transactions are often not permissible under current legislation. Regulations are also yet to fully recognize microgrid operations, and the ownership of data created by smart meters, appliances, IoT devices and other softwares is still unclear.

For instance, countries including Germany, Croatia, Cyprus, the Czech Republic, Greece and Ireland have decided against a national roll-out plan of smart meters, which not only hinders the digitization process, but will also slow down new services that could be developed using that data. According to the Agency for the Cooperation of Energy Regulators, approximately 37% of EU consumers currently have smart meters, a figure far below the 80% objective agreed by all EU countries for 2020. Regulation is important to protect consumers, especially in markets such as energy, which provide a public good. But unfortunately the political nature of the industry and the knotty challenge of ensuring competition for public goods have resulted in misaligned incentives and a failure to encourage long-term investment and innovation.

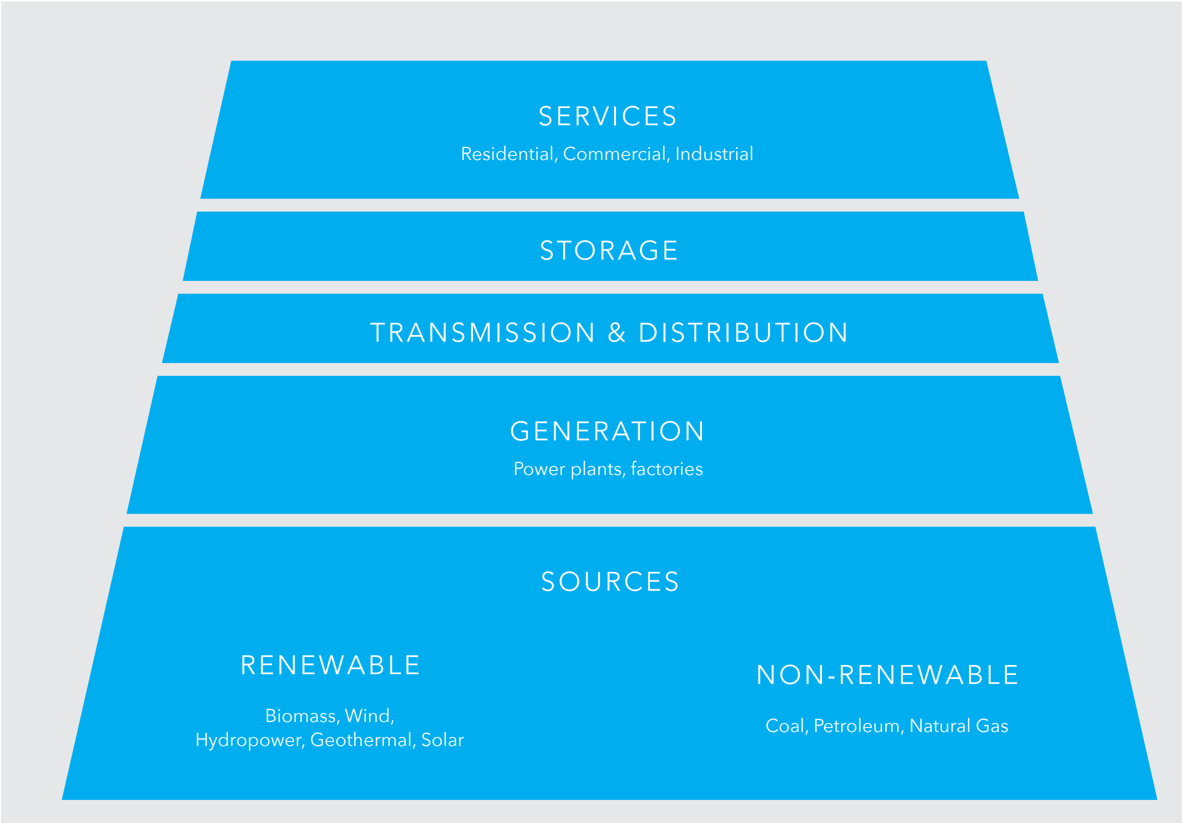
View: Monika Strum - Siemens

Having been in the energy field for over 20 years, I expected the sector to be an early adopter of DLT (i.e., distributed ledger technology). However, regulation has slowed down the speed of innovation. For example, take the roll out of smart meters across Europe. The roll out of Smart Meters in Germany was delayed by the German Federal Office for Information Security (BSI) due to licensing of the devices' gateways and security concerns. At Siemens, we support the addressing of security considerations.

Anyhow, it can lead to delays of applying new technology. If you want to build up peer-to-peer energy market based on DTL, you have to have the ability to combine the physical level with the commercial level. Regulation is key to allow for this.

Despite this, we see blockchain and data marketplaces being increasingly supported. Making data available in a trusted way is the key to accelerate innovation in the energy sector – and in other fields. At Siemens, we also work on blockchain applications in mobility and industrial factories.

Profit Moving from Production to Consumption



Today most of the value in the energy chain is captured by non-renewable energy producers. Oil and gas companies like Exxon Mobil, Royal Dutch Shell and Saudi Aramco are some of the most highly valued companies in the world. Many of these companies focus on energy generation and refinement, but broadly speaking the further towards consumption you get in the energy value chain, the less profit there is available. This pyramid style value chain is common of extractive primary industries, the most valuable activity is getting the energy out of the ground and into a usable form. After this point, very little value is added on top.

Renewable energy options change the value chain. It is relatively easy to capture energy from the sun or the wind, and certainly easier than drilling for it in the seabed. As extraction costs come down, the cost of energy decreases in tandem. Distribution costs are also reduced, as energy can be used from its harvesting point in the case of solar, and at the very least closer to the point of use with wind farms.

Therefore as production and distribution costs continue to fall, the cost of the system should also reduce, making energy cheaper for people around the world.

As decarbonization, digitization, and decentralization reshape the sector, value-added services will come to be a crucial leverage point in the value chain. Software and algorithms to manage and predict supply and demand will begin to optimise the grid, and these tools will be offered to grid service providers and consumers to reduce energy usage.

Expect to see smart batteries become a fixture in households around the world, in a bid to manage household energy usage more effectively. Utility providers have the opportunity to become smart energy providers using data from thermostats and batteries to reduce consumption. The value chain won't change overnight and national regulation will mean the impacts will vary by country, but broadly speaking, we will see a value capture move from production to consumption; and with it, a shift away from offering a commodity product to a differentiated service.

A solution for the energy industry: Energy Web Foundation (EWF)

EWF aims to provide a solution for the needs of the energy sector. The solution, the Energy Web Chain, is a publicly-accessible blockchain with known entities validating transactions on the network using the proof-of-authority consensus algorithm. This permissioned network reduces the number of nodes in order to achieve an increase in the number of transactions that can be processed - this results in 30 times the performance improvement and two to three times less energy consumption compared to an example such as Ethereum.

EWF is a not-for-profit foundation designed to be a multi-stakeholder decision-making body. Regulators must be involved to ensure the stability and safety of energy systems and protection of consumer interests. Equally, the global energy blockchain community must be empowered to influence the evolution of the network. The goal is to keep a balance between decentralization and regulatory compliance.

The foundation has over 100 energy and blockchain affiliates, including several of the biggest energy companies in the world. The foundation includes stakeholders from across the value chain including utilities, grid operators, renewable energy and cleantech companies, and blockchain startups. The aim is to get as many applications to be built on top of the network as possible, with startups like Grid Singularity, FlexiDao and Share & Charge and large utilities like Engie and Singapore Power already experimenting.

Applications

1. EW Origin: a reference application showing the transformative power of blockchains in renewable energy certificate and carbon accounting markets,
2. EW Link: a set of architectures and standards for securely connecting physical devices to the blockchain, enabling them to independently communicate and transact, and
3. EW D3A: a vision and simulation tool for localized, democratized electricity markets enabled by blockchains.

View: Annette Werth - Trende

Are the current energy systems adequate for the coming distributed and renewable energy sources?

Let's imagine a world with abundant renewables where you will eventually have more distributed than central energy generation. Regulating the grid will be very complex and attempting to do this in a fully centralized way would be a nightmare. If every consumer can suddenly produce their own electricity and control it with a battery, you will want to introduce incentives for them to help match supply and demand, but also alleviate grid constraints locally. So far, batteries are mainly used for increasing self consumption but with the right regulations and incentives they could also help stabilize the grid as a whole. Blockchains are extremely hard to be tampered with, which is a great advantage for securing our energy systems.

How are business models being affected?

The marginal cost of generating a renewable KWh is 0. As renewables are proliferating, how can you sell energy per KWh? It stops being a package of energy and it starts being highly dependent on time. You will not be paying for KWh but rather for a service to have electricity 24 hours/day; you will pay in a similar way that you're charged for your phone - you pay a one-off fee per month and how much you consume as a total matters less. Electricity will become more like a service than consumption. We won't pay for fuel, but for covering the cost of the initial investment in renewables, storage and grid services. That will require totally different business models, with loads of new challenges and opportunities.

Once electricity shifts from a commodity to a service, you could bundle it with other services whether it's internet connectivity, home automation or EV charging. Value is moving towards data analysis which tracks energy consumption behavior, demand response and load balancing insights. In the past, government subsidies have been the main driver towards renewables. But now we are looking for more sustainable mechanisms such as markets and P2P trading to provide incentives to increase renewable penetration and help manage demand and supply.

Under the existing regulatory framework, grid operators are typically allowed to recover the cost of building and maintaining the grid infrastructure by charging fixed transmission fees. In this case, a residential customer with PV and a battery will mainly want to use the battery to store excess solar power generated during the day for her own use during the night. In the future, however, it is highly likely that she will also be able to earn a fee for charging/discharging her battery to help balance the grid. In off-grid areas with no existing grid (no transmission fee and often only solar energy and batteries as energy supply), the situation will be very different requiring totally different business models than the ones traditionally employed in most developed economies. This is a fast growing market with huge future potential.

The Energy Stack

The Convergence Stack (figure 1) is a representation of an emerging data value chain. This value chain sees data produced, distributed and consumed in an increasingly open, distributed, decentralized and automated way. We are seeing the contours of this change with blockchain technology, smart contracts, sensor networks, self-sovereign identity, and decentralized exchanges. But these technologies cannot be viewed in isolation. They form part of a larger shift.

Collected by the IoT and software in an ever-increasing array of devices and machines, data is authenticated, validated and secured using decentralized technologies such as distributed ledgers and consensus. Data is transported and routed across various networks before ending up in marketplaces to be packaged up and sold. Finally, it is processed, analyzed and automated using a range of technologies including distributed computation, decentralized machine learning, and smart contracts.

This entire flow is coordinated and incentivized using crypto-tokens designed to incentivize behaviors for people, machines, devices and agents to the benefit of the overall ecosystem. Incentives can be tailor-made for the energy markets, networks and even individuals ushering in a new age of nano-economics and incentive design. Resource allocation and coordination can take more decentralized and automated forms depending on the values of the users. In our energy systems, we are seeing experiments with data ownership; methods in proving energy production and consumption origin; and ideas around how to govern transactive virtual grids in a decentralized way, in order to allow consumers to become prosumers and active stakeholders.

The Convergence Stack provides a framework for understanding the convergence of the IoT, blockchains, and AI. The energy sector needs a new data infrastructure. We will look at the most important technologies of the energy ecosystem: the IoT, identity, data marketplaces, and distributed compute and machine learning.

View: Simone - Flexi DAO

What is the problem in the energy sector that you are solving?

We are working on certification of renewable energy using blockchain, as we saw an increase in renewable power purchase agreements (PPAs). A lot of corporates buy renewable energy for corporate responsibility; currently they can only prove the energy's origin once a year, and there are a lot of inefficiencies with the certification process. It is decoupled by time and extremely bureaucratic - it takes between 6-12 months to release one certificate. Instead of using auditors, we use blockchain to timestamp the generation data from renewable sources to create a digital certificate in the form of a token that is transferred to the consumer based on the consumption. FlexiDAO does not want to replace the legally binding Guarantees of Origin or Renewable Energy Certificates, but rather act as an add-on transparency layer for further granularity that is valued by end-consumers.

Why do we need DLTs to improve our energy systems?

Blockchains will make the energy market much more efficient in the long run. We see FlexiDAO blockchain as a mass coordination mechanism. In the 19th century, time was established as the coordination mechanism to enable every single communication. Then it was the dollar that enabled worldwide trade; now, there will be a new coordination mechanism standard for data to enable the coordination of millions of devices that will communicate based on data. Blockchains are the underlying layer of trust that enables those devices to communicate with each other without revealing sensitive information. We need a network to interlink all the big silos of data.

The Convergence Stack

Application	6	Applications e.g. Balance.io, Veil, Graphite	Marketplaces e.g. Ocean Protocol, Streamer, Wibson	Learning e.g. Supervised, Unsupervised, Reinforcement
Interfacing	5	UX e.g. MetaMask, Brave, Status	API e.g. Infura, DAppNode, vipnode	Middleware e.g. Aragon, Augur, Dharma
Verification	4	Authentication e.g. Evernym, Handshake, WebID	Query e.g. The Graph, ChainLink, XYO Network	Compute e.g. TrueBit, Enigma, Starkware
Routing	3	Scaling e.g. Lighting, Plasma, bloXroute	Databases e.g. The Graph, Chainlink, XYO Network	Bridges e.g. ILP, Cosmos, Polkadot
Distribution	2	Ledgers e.g. Etherium, IOTA, Fetch.AI	Storage e.g. IPFS, Swarm, Sia	Networking e.g. libp2p, FB0SS, OpenFlow
Hardware	1	Processing e.g. HSMs, Intel SGX, AMD-SP	Storage e.g. Trezor, KeepKey, Ledger	Networking e.g. Gateway, Switch, Bridge

Data Collection

Sensors measuring the external environment are often bundled together under the umbrella term the ‘Internet of Things’. They include all sensors in smartphones and wearables such as gyroscopes, accelerometers, and proximity sensors as well as hundreds of others sensors across the energy stack. It is estimated that the amount of data created annually from these sensors will reach 180 zettabytes (one zettabyte is equal to one trillion gigabytes) by 2025. This is a significant increase, up from 4.4 zettabytes in 2013 - and an average person anywhere will interact with connected devices every 18 seconds (nearly 4,800 times a day). The increased number of distributed nodes added to the energy infrastructure, microgrids, and data storage units contributes to vast amounts of data being produced throughout the energy chain. Cheap sensors can be placed anywhere in the energy chain from oil fields and wind farm equipment to transmission equipment, all the way through to homes and offices. The IoT will collect so much data that it will reshape the energy value chain.

The Internet of Things

We define the Internet of Things or "IoT" as the interconnection of identifiable connected devices into energy's internet infrastructure. The concept includes any 'thing' that has a sensor and transmits data over a network, including; smart batteries for solar panels, smart meters, wind turbines, fridges and other household appliances, smart buildings, vehicles, automotive engines, user devices, charging stations and parking lots. This allows for distributed intelligence, automation, and streamlined processes, all necessary elements in an industry such as energy which is notorious for its small profit margins.

IoT sensors facilitate digital measurement of consumer usage data, the tracking of renewable energy production and consumption. Smart, transactive grids where energy flows both ways can now operate on a micro scale. Load balancing is smoother and smart power plants are safer and more stable. Meter reading will be able to be taken without sending humans, reducing operation costs and this process simplification will also be felt in invoicing and billing internal processes. One company revolutionizing the sector is Tado, a startup that uses smart thermostats to the heating and air conditioning systems creating an internet for homes and small businesses. Through a smartphone app the system can detect motion, heat leakage, and weather conditions. Adaptive algorithms then run and save up to 31% on heating costs.

View: Walter Kok - Energy Web Foundation

Who makes money and how?

With blockchain in energy, one of the big potential shifts is from value primarily accruing to relatively few big players such as utilities to a scenario in which many smaller players—down to individual prosumers—can become active participants in a much more decentralized market. By way of analogy, look at what we've seen in finance. Traditionally, banks make money through loans: they get your money, pay very little for it, and then lend it to others for a profit. Peer-to-peer finance now provides a decentralized alternative to the traditional model.

Now what is instead of money we're talking about energy? Perhaps you have a battery and rooftop solar panels, and you have more energy than you consume. A blockchain-based decentralized energy market means that now you have an alternative to simply buying energy from one's utility; you have the option to sell your surplus energy back to the grid or to your neighbor for a profit.

What are some low hanging fruits blockchains can improve?

Although electricity grids are modernizing and utilities are increasingly investing in digitalization, many parts of the system remain analog and opaque, with manual, inefficient back-office processes that bloat costs, create barriers to entry for smaller participants, and fail to tap into the full potential of distributed energy resources. A number of blockchain use cases strike right at the core of those problems. For example, corporate renewable energy purchasing is huge global trend that continues gaining momentum, yet remains a huge administrative burden.

Blockchain-based solutions such as EW Origin provide a compelling low-hanging-fruit solution: they improve transparency and the verifiability that green energy is actually green, while disintermediating the market and introducing automation to the buying, selling, and ownership tracking of green energy attributes, making it easier and cheaper to participate for renewable energy generators and corporate buyers alike. The electric mobility market is another huge opportunity. Electric vehicle (EV) drivers just want a seamless charging experience—to be able to charge at any station / charge point, when and where they need to. Yet the current EV charging station landscape is siloed across many networks. A blockchain-based solution like that being developed by EWF Affiliate Share & Charge could enable universal access, vastly improving the EV driver experience while simultaneously boosting asset utilization rates by making EV charging infrastructure available to a wider audience of possible users.

Projects to Watch

XAGE

Xage is using blockchain technology to create a security fabric and secure IoT devices. It enables autonomous operation, credential rotation, access control, and zero-touch deployment. The more IoT devices connect to the network, the safer it becomes. It provides role-based access control and isolates a compromised device, preventing it from harming the rest. ABB Wireless is using the Xage security application on certain edge gateways at power utility substations. It allows for remote access to IoT devices allowing for remote maintenance and power rerouting. It allows smart meters to communicate securely which in turn helps to detect outages.

Slock.it

Share&Charge is a project by innogy Innovation Hub and Slock.it enabling private individuals to rent their home charging station in a peer-to-peer fashion. This allows first for charging station owners to recoup the cost of their investment over time and second, enables electric vehicle drivers to gain access to considerably more charging points in their immediate geographical area. Additionally, smaller utilities and SMEs are able to gain access to an affordable and reliable payment solution.

Authenticate, Validate & Secure

Blockchains and distributed ledgers fit into the Convergence framework at the distribution layer with storage and data integrity technologies, identity and reputation tools, and consensus algorithms. These technologies combine to provide authentication, validation and security characteristics superior to the existing closed and proprietary data infrastructure. The energy sector faces some tough challenges as it struggles to accurately monitor and measure energy production from ever more sources. How do we know a power plant is actually generating renewable energy, and be sure renewable energy certificates are legitimate? The challenge gets harder if we try to move to a real-time system and incorporate payments to prosumers. Ledgers and identity solutions are two crucial technologies needed to support a new energy infrastructure.

Ledgers

Depending on functionality, ledgers can be blockchains, smart contract platforms or dApp platforms. This is the area that seeded the broader ‘web 3.0’ movement and the source of fiercest competition today. Projects like Ethereum, Dfinity, Hashgraph, Sovrin and Fetch.AI are differentiating on scalability, security and decentralization, making different trade-offs depending on the targeted applications. Some are prioritizing scalability like IOTA and Zilliqa, others security like Tezos and Cardano, and realistically Bitcoin is the sole current player committed above all else to maximising decentralization. In addition to these public offerings, there are of course private chains like Corda, Quorum and other blockchain-as-a-service (BaaS) solutions focusing on enterprise customer requirements; in these private cases, the known identities of participants makes decentralization less of a concern than security and scalability.

The energy sector has its own intricacies and we see different approaches both from other sectors and from within the energy industry itself. For example, Energy Web Foundation has built a tailor-made blockchain forked from Ethereum, which uses proof-of-authority instead of proof-of-work, which would ironically cost significantly more in energy consumption. Grid+ is using Ethereum and, in order to avoid having all IoT devices sign Ethereum transactions, the team is developing a RESTful API through which other IoT devices can connect to Grid+. LO3 have taken an approach where participants need to be trusted and known before they join. They are building a permissioned data platform creating localized energy marketplaces for transacting energy across existing grid infrastructure.

Singapore enables renewable energy certificates trading

Once a solar or a wind farm produces renewable energy and feeds it back to the wider grid, we cannot track those single "renewable" electrons. This makes it hard for businesses, organizations, and individuals to buy renewable energy with full assurance of its provenance. Renewable energy certificates (RECs) solve this problem by certifying the amount of renewable energy at the point of creation which then can be purchased by organizations. Singapore's government-linked utility company SP Group has launched the first decentralized marketplace for renewable energy certificate trading using Energy Web Origin tool stack. Companies or consumers can buy these certificates, and renewable energy providers use this consequential funding to generate power. This way, they can meet and surpass sustainability targets and run greener businesses through Power Purchase Agreements (PPAs). DBS Bank was one of the first few certificate buyers on the newly-launched marketplace.

Chevron joins UK-based energy commodity trading platform

Energy trading between producers, traders and banks is a fragmented, costly and inefficient process. Involving thousands of transactions and a lot of paperwork, the process leads to large trading pools such as Nordpool, which are able to exert pricing power on suppliers. Startup VAKT uses blockchain technology to manage transactions, from trade entry to final settlement, eliminating reconciliation and paper-based processes. Counterparties and third parties can reconcile trade data, share digital documents and manage transactions across the full lifecycle. After a trade is completed, each counterparty enters their transaction details into the platform for trades to be matched. Customers can nominate banks to provide trade finance, with each bank permitted to access the documentation and submit competitive offers. After uploading financing documents, inspectors and shippers can be permitted to add any further useful data.

"Joint Ventures in the oil and gas industry rely on complex processes to ensure financial balance among all joint venture partners. Today these parties have siloed systems to capture and record cost related events that must be allocated across joint venture partners. This setup leads to a situation where discrepancies between partners introduce the need for costly audits and can increase complexity and settlement times. To overcome these pain points a blockchain can act as a single source of truth between all these parties where they can see the same data and trust it has not been manipulated." Benjamin Stöckhert; Business Development Manager Blockchain, SAP"

Identity

The first implementation of blockchain technology in the Bitcoin network was designed in a way that enabled peer-to-peer transactions to be validated by a network of nodes rather than by an administrator. It was decided that nodes on the network could be anonymous rather than requiring an identity to transact; such design choices are understandable for a global censorship-resistant payment network. However, the majority of commerce takes place between known parties, and trading using the existing financial infrastructure needs its buyers and sellers to be identified. In some areas of our energy systems, identity requirements are very important. The emergence of self-sovereign identity products like Evernym using the Sovrin ledger help mitigate some of the privacy risks.

In the near future, electric vehicles, smart appliances, renewable energy generators, smart buildings and even human energy consumers will be verified securely without having to provide identity documents to vendors or service providers. Chain of Things, a research lab and venture studio, are working on Blockpass, an identity application for regulated industries and the "Internet of Everything".

Additionally, they are developing Chain of Solar to track solar energy production and provide proof of renewable energy production by logging the data onto a blockchain. Current smart meter providers have taken measures to ensure their security and integrity. The communication network, for example, is a closed network only accessible to parties with the right security keys and physical connections. Data is only stored on the smart meters, rather than a centralized database.

View: Anya Nova - Power Ledger

What problems are Power Ledger solving?

Renewables need to scale six times faster. In the energy market we see a gap for assets between 1 MW and 50MW that don't get enough investment. The answer lies in capital allowing people that actually want to invest to do so. It is all about the democratization of energy, and helping people set their own prices for their solar. Solid infrastructure is the next step needed for more people to be able to invest directly in clean energy generation, rather than as part of an ETF or investment portfolio, and not needing to satisfy the requirement of being a sophisticated investor. If you can afford the cost of the token, you can invest in your community solar farm and if you own a percentage of that, you'll also get a percentage of the profits generated.

What is Power Ledger's solution?

We're just a software layer, we work with existing infrastructure. What we need is the widespread introduction of smart meters, which most of Australian households have already transitioned into. We read the data from those smart meters to measure how much energy was produced and consumed, and how much was pushed back and pulled from the grid. Let's say you generated 100KWh, which we can measure from your smart meter. Similarly, my smart meter shows I have consumed 150KWh and pulled 50KWh from the grid. This difference of 100KWh indicates that I must have gotten it from you so I'm taking all that energy from you at a particular price that you've set. Because the meter is taking a reading every 30 minutes, we know exactly what's happening and being traded by whom.

Projects to Watch

Sovrin
Sovrin is an open-source, open and global utility for trusted, self-sovereign identity. It is not owned by any single actor and anyone can use it and improve it. It enables any individual, organization or IoT to own and control their digital identity. They can verify the authenticity of claims and improve privacy by giving control of how, what and when information is shared.

Power Ledger
A blockchain-based energy trading platform offering decentralized buying and selling of renewable energy. Consumers can trade electricity with one another and receive payment in real-time in an automated and transparent way. Users can trade electric vehicles which have their data and IDs authenticated on the blockchain. It enables shared ownership of renewable energy assets and trading renewable asset ownership, as well as microgrid management.

Decentralized Data Marketplaces

Once data has been collected by IoT devices, validated and secured by ledgers and identity solutions, it now needs to be used. Marketplaces are a valuable part of the ecosystem here, allowing the buying and selling of data and digital assets. These marketplaces are made possible because of the distributed ledgers, consensus mechanisms and interoperability protocols at the lower levels. It is only because data has been unlocked lower down that it can be traded further up the ecosystem. We will see the emergence of a whole host of new types of exchanges beyond today's cryptocurrency exchanges. New energy marketplaces will enable the sharing of data and value collected by IoT, AI data and personal data, as well as other digital assets like non-fungible tokens (NFTs) and even a new class of automated software agents. Individuals who produce energy now will produce data and be paid for both, for the benefit of themselves and others.

Data Marketplace for AI

With the emergence of deep learning as the most useful machine learning technique, a range of AI applications like consumer behavior recognition have also come to the fore. Machine learning also facilitates energy production optimization of wind turbines and energy consumption of large data centers by optimizing the cooling systems. Data is oil. Just like IoT data, or any data for that matter, data for AI algorithms tends to be accumulated by the largest companies. Decentralized AI data marketplaces will reduce, and eventually remove the competitive advantage of network effects involved in private data hoarding, enabling anybody to monetize data.

The single biggest challenge for all but a handful of Internet giants is the difficulty in accessing enough high-quality data to feed AI algorithms. This lack of access and ability to acquire the data has already led to winner-take-all dynamics in a few technology areas like search, social media and e-commerce. As artificial intelligence follows software by eating the world, almost every product regardless of the market will be infused with the powers of AI. Multiple energy service providers will now have access to data through marketplaces in order to train their algorithms and provide competitive energy optimization and other services.

The previously referenced startup Verv samples the current and voltage coming into your house at 1 million times per second. It then collects data for individual household appliances that have distinct patterns of frequences. Verv uses Ocean Protocol to create its own data marketplace for energy, where users exchange their household energy data for cheaper electricity. Data can be provided on an individual basis, or aggregated and anonymized across a number of households. Customers interested in the data include insurance companies, appliance manufacturers, utility providers, and the grid.

Data Marketplaces for IoT

IoT data is already being captured and collected in vast quantities by sensors on energy infrastructure, electric vehicles, and users' devices, but as more devices are being added to the grid, the ecosystem risks further fragmentation. On the consumer side, operating system providers like Apple, Google, and Amazon are attempting to leverage their dominant market position in mobile, virtual assistant and retail markets to sell more devices to collect more data. IoT devices can be owned by several parties in the energy ecosystem that might not share the same incentives, goals and ambitions. Fragmented data collection from IoT devices, combined with misaligned business models, results in poor collaboration, innovation and user experience for consumers.

IoT data marketplaces incentivizes constituents including smart grid operators, federal and local governments, autonomous vehicles fleet operators and prosumers to share and exchange their data on those marketplaces. More entrepreneurs and companies can provide value which is driven by healthy competition and in turn, increases the overall value of the energy ecosystem. Terbine is an IoT data marketplace where data owners can share and sell their IoT data. Energy-related data that consumers can find on the marketplace include wind speed, air temperature, snow depth and solar radiation flux density.

Projects to Watch

Ocean Protocol
Ocean Protocol is an ecosystem for sharing data and services. It provides a tokenized service layer that exposes data, storage, compute and algorithms for consumption. It helps to unlock data, particularly for AI, and uses blockchain technology and tokenization so data can be shared and sold in a safe, secure and transparent manner. Ocean Protocol collaborates with Verv and enables it to create its own data marketplace for energy, aiming to give control of data back to consumers. People can earn VLUX tokens for providing access to their household data. Data sharing, in turn, allows users to offset their electricity costs, essentially exchanging data for electricity.

Grid Singularity
Grid Singularity is a green blockchain technology company, leading the development of an open, decentralised energy data exchange platform under the auspices of the Energy Web Foundation (EWF). Their goal is to coordinate increasing numbers of small energy producers and flexible loads, in a trustless, open, decentralized network. Grid Singularity is building a grid management agent, D3A, which creates a new market model for the transactive grid. It enables energy transactions on a single platform.

Process, Analyze & Automate

At the top of the ecosystem is where process, analysis and automating activities take place. Data is transformed into action and insight using traditional and distributed computing techniques. Smart contracts and artificial intelligence blur, offering differing levels of automation and decentralisation depending on the type of input data and level of trust the use case demands. Traditionally low profit margins make automation critical for the energy ecosystem. Vast amounts of energy data need to be processed and analyzed to enable proactive energy usage behavior. Smart devices equipped with a battery become autonomous economic agents that can process data and react to energy market changes in real-time, putting into practice these new business models and yielding monetary value.

Distributed Computation and Machine Learning

Distributed computing, also known as federated learning, refers to a computing assignment in which a problem is broken down into more simple tasks. These simple problems are distributed out to a network of trusted computers. These computers can be any of the participants we saw above in the energy ecosystem. Today, the majority of devices contributing computing power are servers, PCs, and laptops, but as more energy generating devices get connected to the IoT, we can envisage a scenario in which energy infrastructure can also contribute power. In the short term this might be a small contribution, but as more infrastructure is connected, you might end up with large devices like connected vehicles and smart devices participating meaningfully. In fact, in order to fully utilize sensor deployments and idle city assets, computational tasks like energy grid analysis could be done locally, without having to use cloud servers elsewhere.

Rather than just contributing computational power, this mechanism can be furthered in thinking about how these same energy assets can do machine learning. Machine learning, and in particular one specific technique called deep learning, is a wonderful tool for gathering knowledge from a large amount of data that for instance, can make energy production of biofuels more efficient. Decentralized machine learning will allow energy participants of any kind to become autonomous economic agents and perform calculations, and exchange data and value on behalf of their owners or for ‘themselves’.

Machine learning could support smart devices to learn the best time to sell energy and the optimum point at which to buy back from the transactive grid, by parsing through vast amounts of data. Using the same theory, smart grids should learn how to effectively handle load-balancing based on previous statistical data of energy usage. Savera is an open source project which is building a simulator to help people estimate their rooftop solar potential, and simulate the performance of a virtual solar plant. This helps them to experience the prospect of owning a rooftop solar plant customized to their needs.

Researchers from Nanyang Technological University Singapore have proposed a solution that enables real-time processing and predictions for a building-based smart grid using occupant profiling. The product is a distributed machine learning platform which analyzes occupant movement and energy usage. It then allocates solar energy on the additional electricity power grid to reduce peak demand on the main grid based on forecasts. Evidence from their experiments improved accuracy of the proposed energy prediction by 14.83%, while the peak load from main grid was reduced by 15.20% and saved 51.94% of energy cost.

View: Annika Ljaš - WePower Network

What problems are WePower solving?

Main issues include legal and advisory fees as well as trust between the two parties that want to trade. For example, the producer wants to be sure that their buyer will eventually buy and transfer the funds, and we can facilitate this trust through our platform. We have standardized the power purchase agreement (PPA) and we added flexibility and liquidity. Direct transactions with renewable electricity producers are enabled and this solution allows participants to hedge electricity prices so they can ensure a stable cost base on their company's balance sheet.

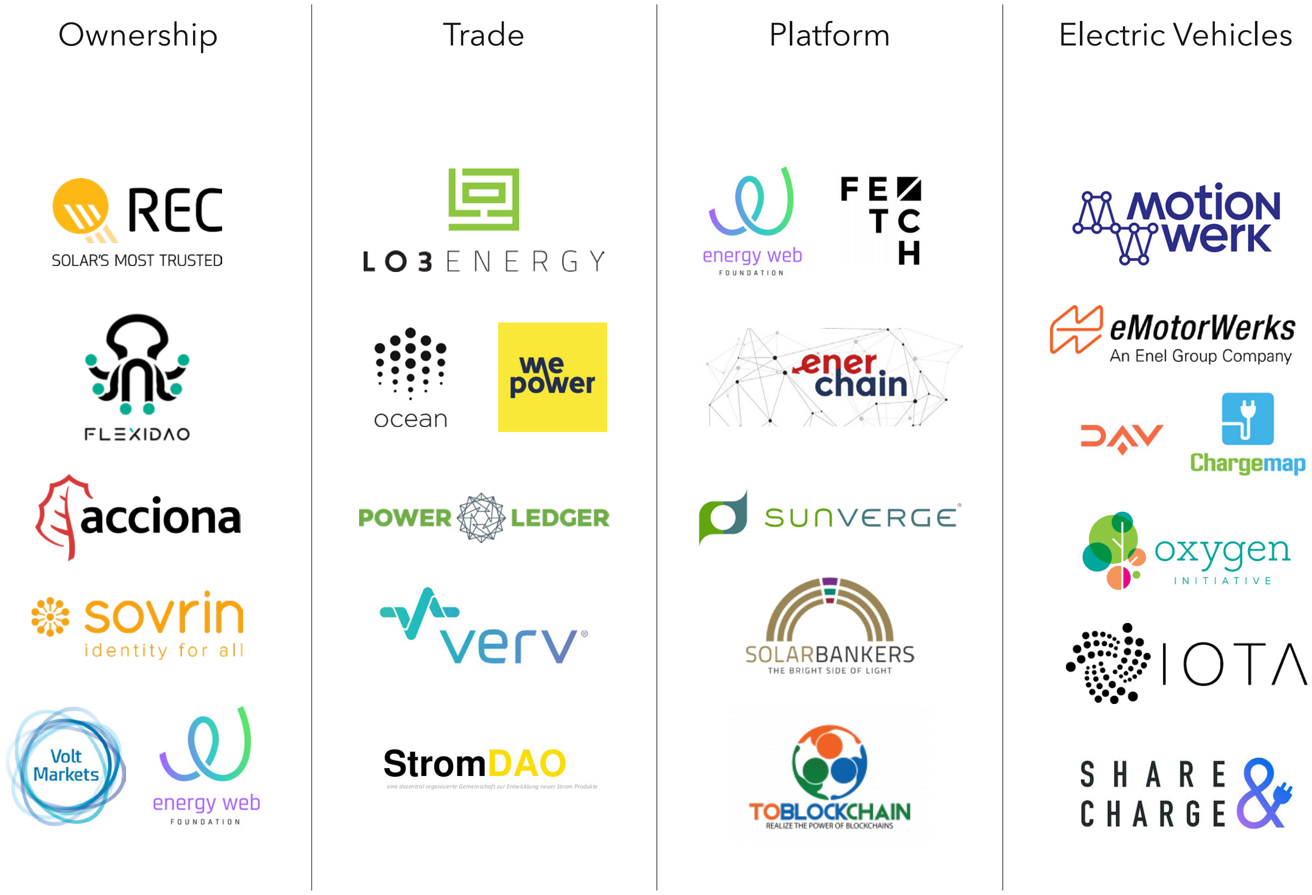
Current power purchase agreements come with zero flexibility in terms of consumption profile. Should their energy consumption needs change over time, e.g. one part of the data centre facility is being closed down for some time, then the corporate energy buyer can adjust their needs. At the event of decreased energy consumption, PPAs that are signed on WePower allow the corporate energy buyer to sell part of their energy in the secondary market. WePower allows them to restructure their portfolio in real time. Retailers will lose money, and middlemen are being cut out as more direct deals are taking place. DSOs are rethinking their approach. Will they be more involved in those different parts of the new market or will they try to stick to the old model which might not work? A lot of re-inventing needs to be done in order for the old players to remain relevant and competitive.

Project to Watch

Fetch.ai
Fetch.ai has built a ledger which is designed to allow data to act autonomously. Autonomous Economic Agents (AEA) are digital entities that can transact independently of human intervention and can represent themselves, devices, services or individuals. Agents can work alone or together to construct solutions to today's complex problems. The digital world in which agents live is called the Open Economic Framework (OEF). This world acts as a value exchange dating agency: each agent sees a space-optimized in real-time just for them, where important things are clear and visible and less important things are simply removed.

Underpinning the digital world is the smart ledger: a new generation of learning ledger that provides a collective super-intelligence to support agents' individual intelligences. It provides market intelligence, previously locked up in centralized silos, to everyone so that any agent that wants something is assured of the shortest possible route to find another that has it. Fetch's smart ledger scales to support millions of transactions per second and is able to restructure itself to present the OEF's digital world to the agents that use it. Fetch can increase energy usage efficiency and improve wind turbines' and moving solar panels' energy production performance. It can turn any smart IoT device with a battery into an autonomous economic agent that buys energy when prices are low and sells when they go up. Your electric vehicle can be part of any virtual grid automatically based on real-time supply and demand.

Convergence Landscape in Energy



The convergence stack is not just a conceptual framework. We are beginning to see projects build solutions that support the development of a new energy infrastructure. The challenges of legacy infrastructure, regulation, and working with slow-moving incumbents has resulted in startups focusing on a few core service areas where early traction can be achieved. Startups are predominantly focusing on building solutions for ownership, trading and electric vehicles, as well as the underlying platforms to support these new services. We expect to see the range of services grow as the industry digitizes and opens up data. The key for startups is to focus on markets that can be tackled today and embrace the complexity of the sector by working with incumbents rather than ignoring them and trying to build a parallel grid.

Three Things The Energy Sector Must Do Today

1. Utilize the Internet of Things to collect energy-related data

Data unlocks new energy data-driven business models such as energy as a service, renewable energy certificates, and energy storage as a service. IoT sensors such as smart meters turn any device into a smart one. Energy companies need to be in a position to collect as much data as possible from IoT sensors and software to get insights about energy production, distribution and consumption patterns. For example, we can monitor energy production of any distributed renewable energy sources such as solar panels and we can use this data to minimize energy loss and balance the load more efficiently. Data collection is foundational for smooth grid integration, which is becoming more challenging as more distributed energy resources are being deployed.

2. Use blockchains to share data and data marketplaces to make it available

Once we gather data from IoT we then need blockchains and smart contracts to secure and keep track of it so we can distribute it safely across networks. Today the energy market faces issues with trust in regards to energy production and consumption; this is where blockchains and smart contracts help us with energy trading and certifying renewable energy production. We then need to sell and exchange data in marketplaces that allow buying and selling of data and digital assets. To make such marketplaces possible, we need to work with regulators to assist them and open data to service providers to innovate with. Working with industry consortiums like Energy Web Foundation is another way to promote open source and open standards in order to avoid data silos.

3. Deploy learning algorithms to optimize and automate the grid

Finally, after timestamping and securing our data, we need learning algorithms and smart contracts to help us optimize and automate energy production, distribution and consumption. Humans are not the only participants in the emerging energy markets. We need learning algorithms to turn any IoT equipped with batteries into autonomous economic agents. For example, an electric vehicle can monitor the grid's load in real-time, buy energy when demand is low at an economical price and sell it back to the grid when demand rises for a premium. Making good use of algorithms is paramount to optimize companies' products and be able to take part in, what we call, the internet of energy.

The Convergence Stack is a framework to understand the convergence of new data technologies like the IoT, blockchains, and AI. We must move to a low-carbon economy as fast as we can to avoid the consequences of the worst climate change predictions, and to do so the energy sector must upgrade its data infrastructure immediately. We can no longer afford to wait.

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Interviewees

Pierre Samaties
CEO, Innogy

Gerard Bel
CEO, Klenergy&Pylon

Fausto Bernardini
CEO, prosume.io

Thorsten Zoerner
CEO, StromDAO

Anya Nova
Crypto-economist,
PowerLedger

Matthew Hale
Divvi, Everty

Annika Ljaš
Head of PR and Communications,
WePower Network

Mikk Lemberg
Marketing Project Manager,
WePower Network

Simone Accornero
CEO, FlexiDAO

Samuel Tan
Chief Digital Officer, SP Group

Killian Tobin
CEO, Omega Grid

Yvo Hunink
Co-founder, Energy Bazaar

Oriol Pujoldevall
Engineer, Energy Web
Foundation

Paul Geluk
Founder, Clearwatts

Odysseas Bassioukas
Venture developer, Innogy
Innovation Hub

Dr. Claudio Lima
Co-founder, BEC-Blockchain
Engineering Council

Nick Gogerty
CEO, SolarCoin

Jim Procanik
Executive Director, Veridium
Foundation

Julie Alexander
Director of Urban
Development and Smart Cities
Lead, Places For People

Monika Sturm
Principal Key Expert, Siemens

Benjamin Stoeckhert
Business Development
Blockchain, SAP

Annette Werth
Director of P2P, Trende

Andreas Papazidis
Business Analyst, Shell

Thomas Folker
CEO, Leap

Mayank Malik
Chief Architect at SLAC National
Accelerator Laboratory, Stanford

Walter Kok
COO, Energy Web Foundation

Monika Dernai
Strategy and Business
Development, BMW Group

Adam Ville
CTO, VAKT

Molly Webb
CEO, Energy Unlocked

Ashley C. Pilipiszyn
AI & Computational Sustainability
PhD, Stanford

Engage with us

Our reputation has originated as a consequence of our deep commitment to open research and thought leadership in the decentralisation space broadly, and more specifically, through our Convergence Stack thesis.

We engage regularly with start-ups, academia, and the corporate ecosystem and are open to collaboration and consulting opportunities throughout the community. Current research themes are focused on smart cities, energy, mobility, connectivity, augmented reality, and "crossing the chasm" to mainstream decentralised technology adoption.

If you wish to discuss your project or initiative further, please contact Lawrence, Charlotte or Catherine.

Research enquiries

Lawrence Lundy-Bryan
lawrence@outlierventures.io

Media and communication enquiries

Charlotte Baker
charlotte@outlierventures.io

Corporate partnership enquiries

Catherine Thomas
catherine@outlierventures.io

Member of

Outlier Ventures

www.outlierventures.io