GRID+

WELCOME TO THE FUTURE OF ENERGY

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CONSENSYS

1 Abstract

In the past ten years, the cost of distributed energy resources (DERs), such as solar panels and wind turbines has decreased significantly. This has led to expeditious and widespread adoption. Additionally, battery prices are rapidly decreasing, making them economically viable to supplement variable-generation renewable-resources by storing energy for the electrical grid. The confluence of these developments has created an emergent electrical grid, where the means of production are less centralized, and the control systems are less likely to be strictly top-down. The concept of independently owned and controlled DERs is known as the transactive energy grid.

The transactive grid promises to increase durability of the electrical grid, while simultaneously increasing efficiency, and enabling the adoption of more renewable energy. However, the distributed nature of the transactive grid, poses two major challenges, primarily related to technical control and grid administration. Both challenges can potentially be addressed using a blockchain. The ConsenSys energy team has several years of experience building and demonstrating proof-of-concept blockchain-based distributed energy resource management solutions. Through this experience, ConsenSys identified the opportunity to form Grid+, which will build natively Ethereum-based utilities in deregulated markets. Grid+ will demonstrate production ready blockchain-based energy solutions at scale in competitive commercial environments. In doing so, Grid+ will enable the transactive grid of the future while proving the advantages of Ethereum over incumbent technologies.

Grid+ is developing a hardware and software stack to create a secure Ethereum enabled gateway and connect Internet-of-Things (IoT) devices. The hardware gateway, or “smart energy agent”, is an Internet-enabled, always-on appliance which will securely store cryptocurrencies and process payments for electricity in real-time. The agent will also programmatically buy and sell electricity on behalf of the user and intelligently manage smart loads (e.g. Tesla Powerwall or Nest thermostat). The software stack will work in conjunction with the smart energy agent to make payments, using a combination of Grid+ designed payment-channels and a Raiden network hub (when available). Grid+ is developing a system architecture that allows a typical user to leverage cryptocurrencies while remaining unaware of it’s use. Interestingly, the implementation of a secure, always-on system, with low friction payment rails, provides a missing piece of critical infrastructure in the broader cryptocurrency ecosystem. The Grid+

infrastructure has many uses beyond electricity and will be key to enabling the widespread adoption of cryptocurrencies.

2 Introduction

2.1 The Energy Supply Chain

Before the Grid+ system is explained in great detail, a brief introduction of the current electrical grid, its stakeholders, and the challenges facing them will be presented. If the reader is intimately familiar with the electrical grid, they may skip this section.

Presently, the services needed to provide electricity to the consumer can roughly be divided into four categories: generation, transmission, distribution, and retail.

2.1.1 Generation

Generation is electricity production by large-scale energy producers. Historically these producers have been hydrocarbon (or nuclear) based power plants.[1] In recent years large wind

[1]“International Energy Outlook 201: Chapter 5- Electricity.” *U.S. Energy Information Administration*. https://www.eia.gov/outlooks/ieo/pdf/electricity.pdf

and solar farms have come online.[2] In order for these alternative-energy entities to be considered a “generator” they must have generation capacity greater than 1MW.[3]

2.1.2 Transmission

Transmission is the business of moving electricity over long distances, usually from power plants (generators) to consumer networks (distributors).[4] For example, in Texas there are a series of power lines that span over 500 miles, operate at high-voltage (~300 kV), and transport wind power from West Texas all the way to Houston.

2.1.3 Distribution

Distribution is the movement of electricity from the transmission (high voltage) network to the consumer. Distributors operate lower-voltage electrical lines that connect to individual consumer households or businesses.[5] In the event of a power outage, consumers call their distributor to take care of the problem (e.g. re-wiring a fallen tower). For example, AEP[6] is the distributor in central Texas.

2.1.4 Retail

Retail is the sale of electricity to the consumers. Retailers are responsible for administering and billing consumers. Depending on your region, retailers may be known by different names (e.g. Retail Electricity Provider, or REP, in Texas). In deregulated markets, you might refer to the retailer as your “utility”. Examples include Green Mountain Energy and Reliant Energy.

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[2] Friedman, David. “Four Charts That Show Renewable Energy is on the Rise in America.” *U.S. Dept. of Energy.* (14 Nov. 2016) https://energy.gov/eere/articles/4-charts-show-renewable-energy-rise-america
[3] North American Renewables Registry Operating Procedures (April 2013) http://www.narecs.com/wp-content/uploads/sites/2/2013/12/NAR-Operating-Procedures_April_2013.pdf
[4] “Electricity Explained- How Electricity is Delivered to Consumers.” *U.S. Energy Information and Administration.* https://www.eia.gov/energyexplained/index.cfm?page=electricity_delivery
[5] “Electricity Distribution.” *Institute for Energy Research*. (2 Sept. 2014) http://instituteforenergyresearch.org/electricity-distribution/
[6] Contact AEP Texas, https://www.aeptexas.com/contact/

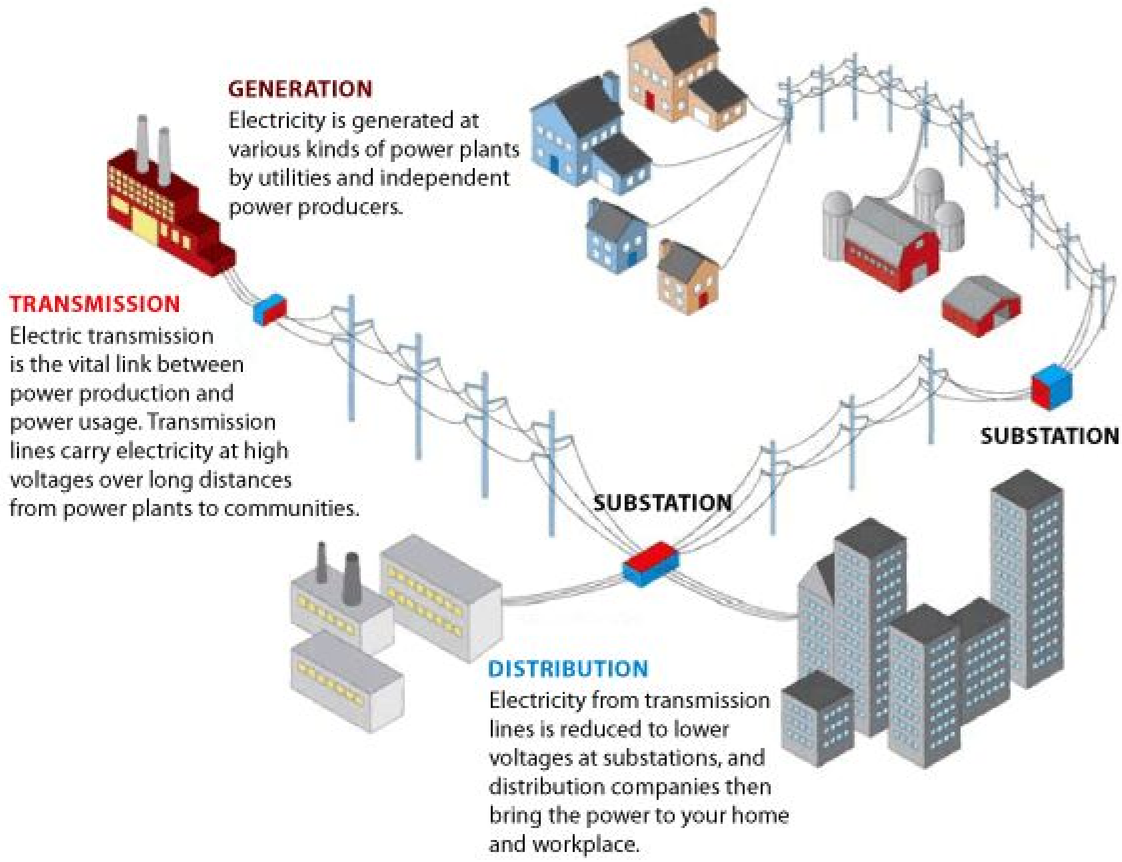

Figure 1: Diagram of Electrical Grid [7]

2.2 Regulated and Deregulated Markets

Electricity markets in the United States can be divided into two distinct groups: regulated and deregulated. Figure 2 shows which states fall into each category.

[7] http://www.incontext.indiana.edu/2010/july-aug/images/power_fig1.gif

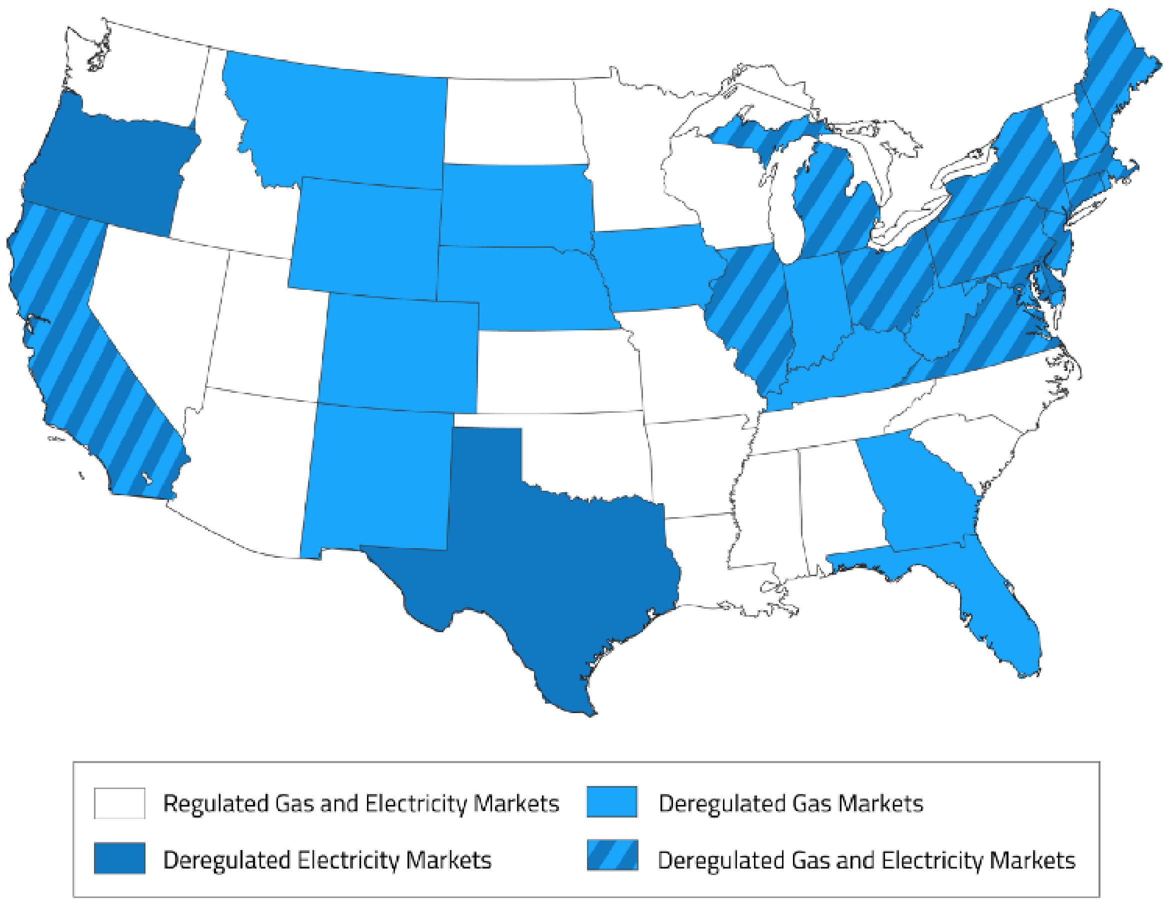

Figure 2: Electricity Markets in the U.S. [8]

In regulated markets, the four entities in the energy supply chain can operate as a single, vertically integrated monopoly.[9] In deregulated markets, governments mandate market segmentation such that each role in the supply chain must be operated by a separate entity.[10] Deregulated markets offer substantially more competition and are more akin to a free market because each company must sell their services in a competitive marketplace, which is typically run by a government-franchised non-profit Independent System Operator (ISO). In addition to running these competitive markets, ISOs are also tasked with maintaining grid stability and

[8] https://www.electricchoice.com/map-deregulated-energy-markets/
[9]Woodcock, Robin Deliso. "Regulated and Deregulated Energy Markets, Explained." *Energy Smart Blog.* (27 June 2014)
https://www.energysmart.enernoc.com/regulated-and-deregulated-energy-markets-explained
[10]"Regulated and Deregulated Energy Markets." *Customer First Renewables.*
http://www.customerfirstrenewables.com/resources/regulated-deregulated-energy-markets/

reliability via market signaling.[11] This latter job is performed via a computer control system, which the electricity industry refers to as a Supervisory Control And Data Acquisition (SCADA) system.[12]

The SCADA system is used by the ISO to create signals for real-time energy as well as services markets such as ramping control, frequency regulation, or voltage support. The market signals are provided to market participants, who then bid into the market and provide the services needed to keep the grid running at the right voltage and frequency.

In deregulated markets, electricity retailers buy electricity at wholesale prices (in 1MWh energy increments) and then sell that electricity directly to consumers. Retailers are not responsible for powering customers directly, but are responsible for metering and billing. In addition to paying for generation, transmission, and distribution, consumers also pay fees to their retailer. These costs are largely comprised of marketing, administration, and managing risk/compliance for bad debts and customer funds. This can (and often does) add up to quite a large percentage, as shown by the average price of electricity in various states in Figure 3.[13]

[11]To learn more about ISOs, in particular what they do and how they operate in New England, *see https://www.iso-ne.com/about*
[12]*See* generally "SCADA SYSTEMS." http://www.scadasystems.net/
[13]"Electric Power Monthly." *U.S. Energy Information and Administration.* (29 June 2017) https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

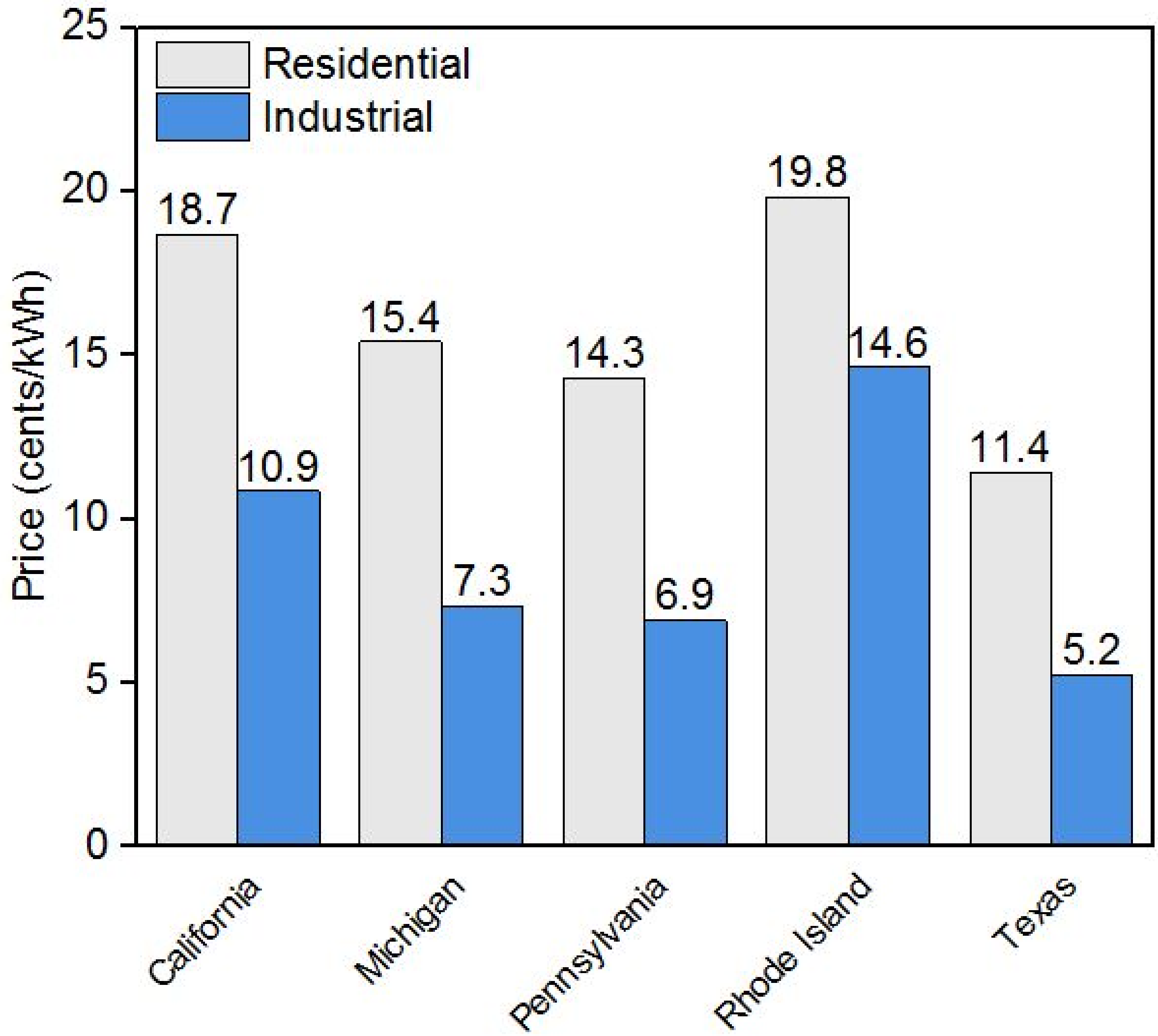

Figure 3: Residential[14] vs. Industrial[15] pricing

The difference between the residential and industrial price shown above comes mostly from the costs passed to the consumer from their retailer. This illustrates the amount by which electricity prices can be reduced from lowering costs associated with retail operations.

[14] In this paper, we use "residential" and "customer" pricing interchangeably. Residential customers (e.g. households) are just one kind of utility customer (as opposed to commercial) and will be the target demographic of Grid+.

[15] Industrial pricing reflects wholesale + distribution costs. Thus, the wholesale rate (the rate we are targeting) will be lower than these numbers.

2.3 Existing Retailers

Sometimes referred to as “utilities”, retailers are responsible for billing and interacting with customers in the last mile of the energy supply chain. An energy retailer buys electricity in the wholesale markets, pays the distribution system operator a fee for getting the electricity to the customer, and then bills the customer for the service at a large markup over their cost of goods sold. Typically only about 50% of the cost of retail electricity is used to pay for the electrical energy itself.[16] The other half is tied up in administrative burden, marketing, and risk management associated with bad debts. Retailers are often slow to evolve and rarely welcome new technology with open arms.[17]

When a customer signs up for a legacy utility a credit check process begins, which determines the likelihood that the customer will default on payments. Retailers are credit facilities, as they provide energy on credit and then bill consumers in arrears, usually on a monthly basis. Retailers deploy complex risk assessment algorithms[18] which take into consideration the percentage of potentially delinquent customers and then add the expected uncollected value (plus a buffer) into the rest of their customers’ bills. This means customers who pay on time are subsidizing delinquent and non-paying customers. This is exacerbated by the fact that states regulate how long utilities must continue to provide power to their customers even after delinquent payments (typically 3-15 days[19]).

2.4 Challenges of Renewables

The installation of photovoltaic (PV) arrays is hastening the grid’s decentralization and empowering consumers to become producers (turning them into “prosumers”). Approximately 38% of residential electricity cost pays for transmission infrastructure and losses during

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[16]“Wholesale Vs. Retail Electricity Costs.” *ISO New England*. https://www.iso-ne.com/about/what-we-do/in-depth/wholesale-vs-retail-electricity-costs

[17]St. John, Jeff. “Dispatches from the Grid Edge: Tracking the (Slow) Adoption Curves for Software in the Utility and Energy Industries.” *GTM Squared*. (13 April 2017) https://www.greentechmedia.com/squared/read/tracking-the-slow-adoption-curves-for-software-in-the-utility-and-energy-in

[18]Manning, Patrick and Tim Polak.“Winning Good Customers, Losing Bad Debt.” *Bain Brief*. (7 April 2011) http://www.bain.com/publications/articles/winning-good-customers-losing-bad-debt.aspx

[19] “Consumer Guide: Your Rights as a Residential Electric, Gas, or Steam Customer under HEFPA.” *NY Department of Public Service*. http://www3.dps.ny.gov/W/PSCWeb.nsf/979df87f099d1063852576880061e6b3/d580f8b12cdac9f985257687006f395e?OpenDocument

transmission.[20] When a customer installs PV modules, however, the generated power need only travel a few meters from source to load. Moving power from a person's roof to their refrigerator is significantly more efficient than sourcing it in from a generator 150 miles away. Household PV ownership has proven it can offer a much more efficient energy solution that can also pay for itself over time. Solar adoption has outpaced even the most aggressive estimates from a decade ago, and it is not expected to slow down anytime soon. (Figure 4)

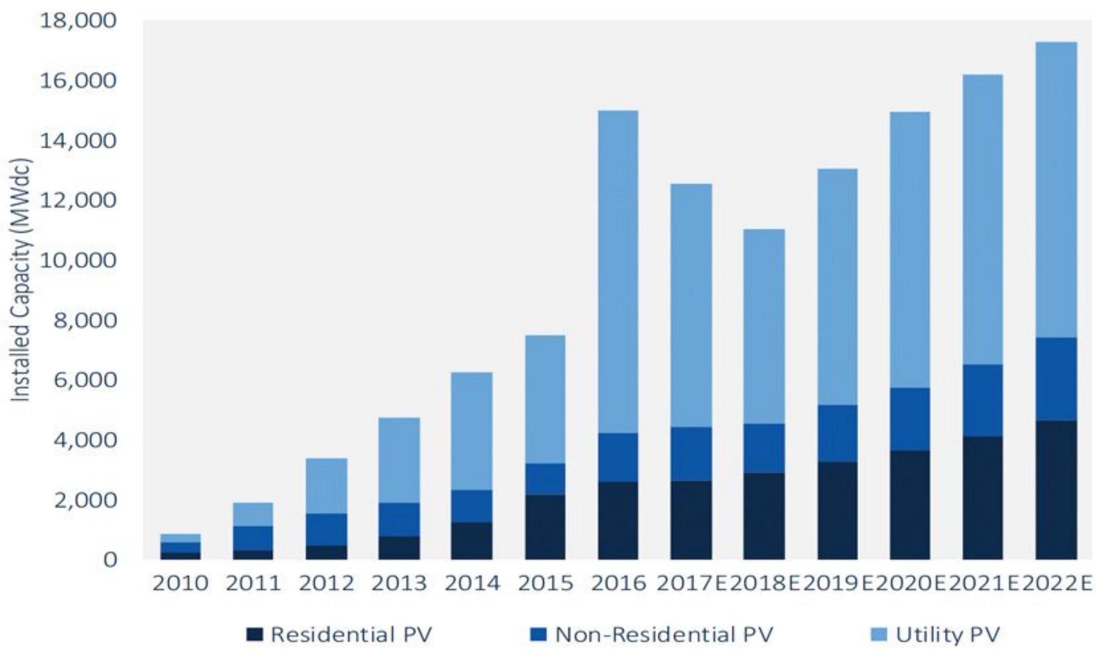

Figure 4: U.S. PV Installation Forecast, 2010-2022 [21]

Although environmentally friendly, PVs introduce new problems for the electrical grid because the generated power must either be stored or used immediately. Typically, generated energy is consumed by household load and any remainder is sold back to the grid. This may seem like a sustainable system, but it poses serious technical challenges when deployed at scale. In some regions, PV penetration is so high that more energy is pumped back into the grid than the grid can handle, resulting in a condition called overvoltage.[22] The grid must respond by curtailing production to remove excess energy or risk damaging its infrastructure. Furthermore, solar generation is intermittent and is affected by local cloud cover and weather conditions. This

[20] "Electricity Explained: Factors Affecting Electricity Prices." *U.S. Energy Information Administration.* https://www.eia.gov/energyexplained/index.cfm?page=electricity_factors_affecting_prices
[21] http://www.seia.org/research-resources/solar-market-insight-report-2017-q2
[22] Mulkern, Anne C. "A Solar Boom So Successful, It's Been Halted." *Scientific American*. (20 Dec. 2013) https://www.scientificamerican.com/article/a-solar-boom-so-successfull-its-been-halted/

intermittency causes rapid drop-offs or increases in produced energy which must be buffered by other energy producers to maintain grid stability.[23]

Perhaps the most well known example of the challenges that are created as a result of high solar penetration is the so called Duck Curve[24], shown in Figure 5.

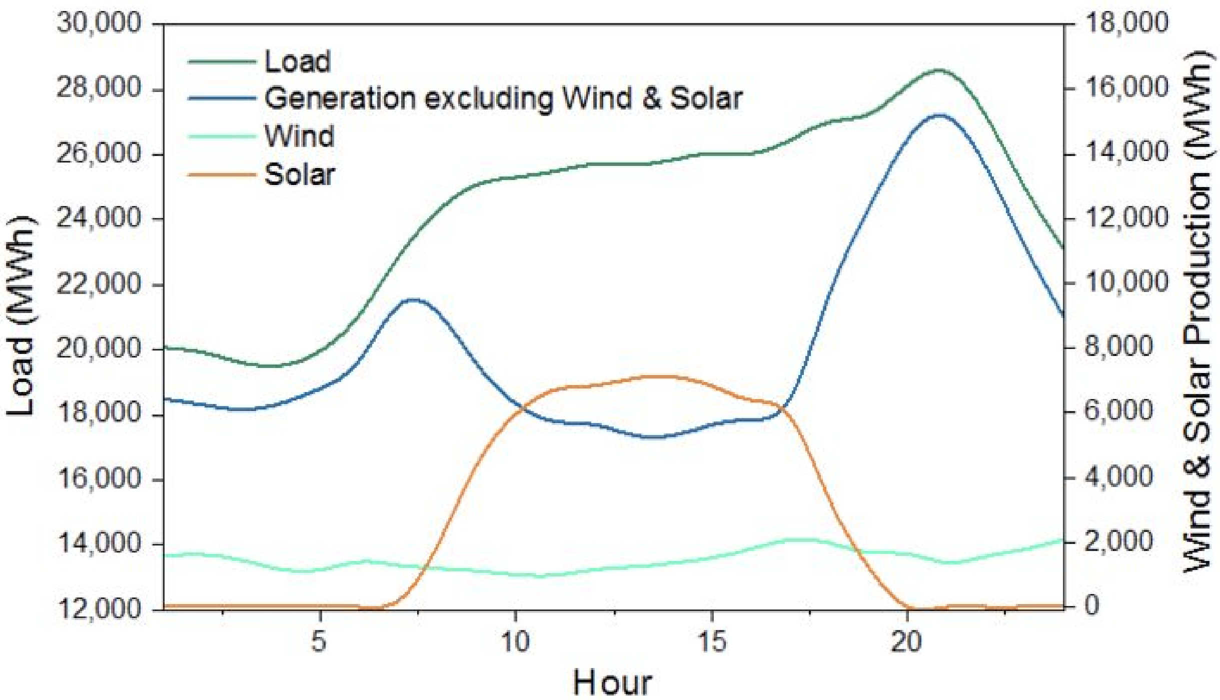

Figure 5: California's electrical load on April 17, 2017 [25]

Colloquially named for the silhouette of a duck, this curve shows two peaks in hydrocarbon-based power production (blue line) during the morning and night. The problem is that solar energy is only generated during the day, but the peak load demand is in the evening. Therefore, power plants must quickly ramp-up generation by 50% or more as sunlight wanes. This process is inefficient and challenges the capabilities of large power plants. On some days in California, the solar production mid-day is so high[26] that CAISO[27] actually pays solar generators to *not* produce energy. This process is known as "curtailment".

[23] Fares, Robert. "Renewable Energy Intermittency Explained: Challenges, Solutions, and Opportunities." *Scientific American*. (11 March 2015) https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/

[24]St. John, Jeff."The California Duck Curve is Real, and Bigger than Expected." *GTM.* (3 Nov. 2016) https://www.greentechmedia.com/articles/read/the-california-duck-curve-is-real-and-bigger-than-expected

[25] http://www.seia.org/research-resources/solar-market-insight-report-2017-q2

[26]Paulos, Bentham. "Too Much of a Good Thing?: An Illustrated Guide to Solar Curtailment on California's Grid." *GTM*. (3 April 2017) https://www.greentechmedia.com/articles/read/An-Illustrated-Guide-to-Solar-Curtailment-in-California

[27] California ISO, http://www.caiso.com/Pages/default.aspx

If energy storage capabilities had grown at the same rate as PV adoption, the Duck Curve would not exist. Fortunately, breakthroughs in battery manufacturing are driving down storage costs (Figure 6).[28] The levelized cost of energy storage (LCOS) is now as low as $0.13USD per warrantied kilowatt-hour[29], a figure making batteries economically viable *now* if retail energy were priced dynamically like wholesale energy.[30]

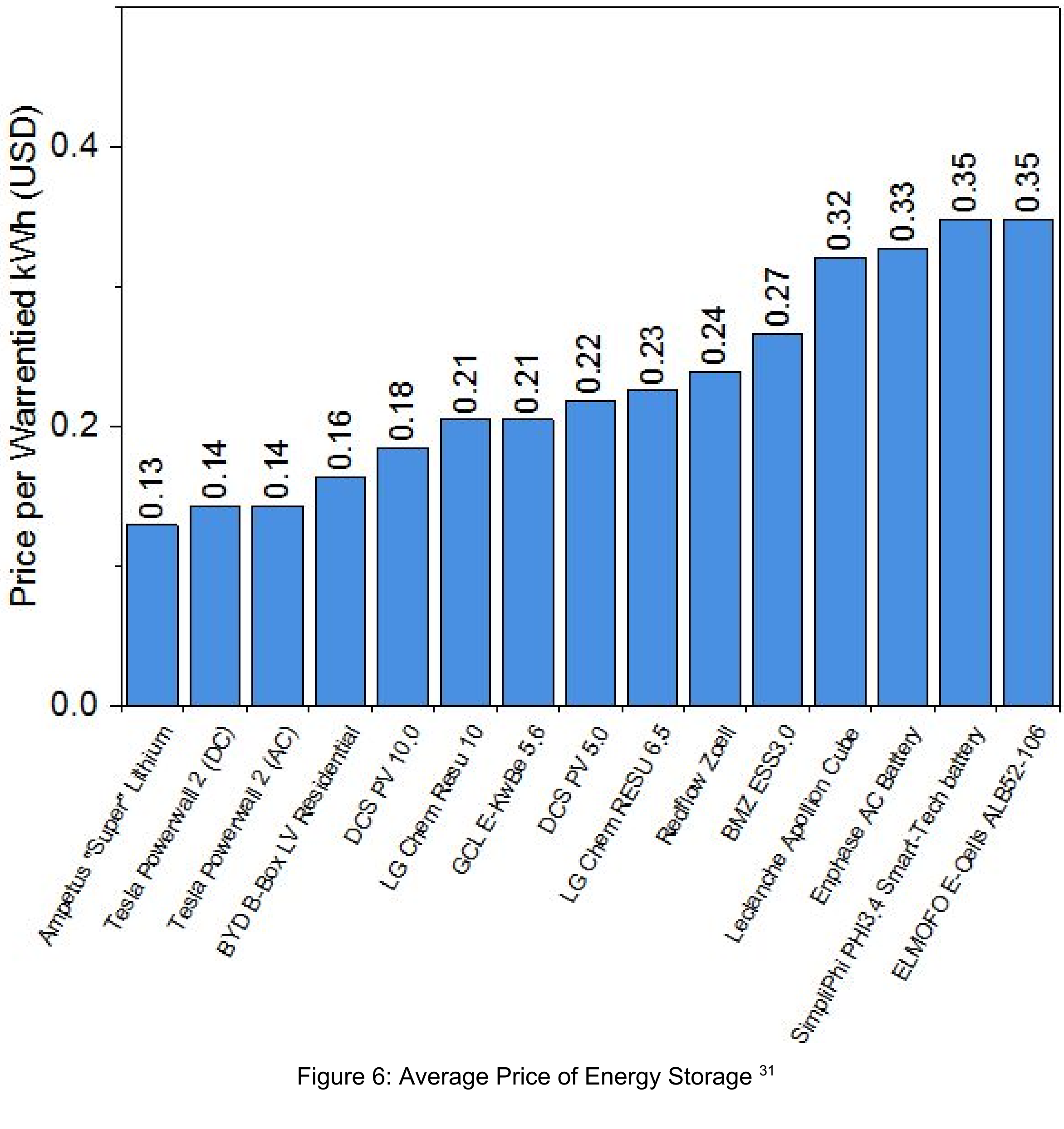

Figure 6: Average Price of Energy Storage [31]

[28]Mearin, Lucan. "Without Tesla's Batteries, the Power Grid Could Fail." *ComputerWorld from IDG.* (27 April 2015)
http://www.computerworld.com/article/2915338/sustainable-it/without-batteries-like-teslas-the-power-grid-could-eventually-break.html
[29] Explanation of a warrantied kWh, https://www.solarquotes.com.au/blog/powerwall-2-warranty/
[30] Solar Quotes, https://www.solarquotes.com.au/battery-storage/comparison-table/
[31] https://www.solarquotes.com.au/

2.5 Using Ethereum in Electricity Markets

An often overlooked aspect of public cryptocurrencies is that of *user agency*.[32] In short, *user agency* is the concept that the user is in charge of her assets at all times, and those assets are easily exchangeable for other assets. Users of public cryptocurrencies secure their own funds and authorize their own transactions. Public blockchains enable consumers to make payments using any "tokenized" asset.

Grid+ provides an accounting layer for the energy ecosystem by utilizing Ethereum smart contracts. Users retain control of their own assets and can choose exactly how they are utilized in the system. By moving the transaction logic for both energy and payments onto a trustless architecture (blockchain + state channels), Grid+ reduces the administrative burden of processing transactions over legacy rails (traditional payment processors typically charge fees of 1.5 - 2.5%[33]). Additionally, by pushing market signals to customers, Grid+ enables customers to make smarter decisions about their energy usage. This lowers their own costs, while also increasing the efficiency, robustness, and reliability of the electrical grid as a whole.

In this section, key terms related to the Grid+ technology stack are defined. Readers knowledgeable about Ethereum and related concepts may skip these definitions.

2.5.1 Ethereum

Ethereum is a readable, writable, and programmable ledger accessible to any individual with an Internet connection. Thousands of users all over the world run software (each of these users is running a "node") that maintain the ledger and these users are financially incentivized by the system itself to do so. Any user (even ones not running a node) may write a program and upload it to Ethereum. To do so requires some amount of ether, Ethereum's underlying currency, be paid to the owner of the node which appends the program to the ledger.

The program, now uploaded to the Ethereum "blockchain" (a specific kind of ledger), will live on for as long as at least one person continues to run an Ethereum node. The program cannot be changed and anyone may interact with it. A program on the ledger is called a "smart contract", a term coined in 1994 by Nick Szabo to describe a piece of code capable of executing some

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[32] User Agency and IoT Identity." *Grid+*. (30 May 2017) https://blog.gridplus.io/grid-3-user-agency-and-iot-identity-ce36239b9e2b

[33] "Credit Card Processing Fees and Costs." *Value Penguin.* https://www.valuepenguin.com/what-credit-card-processing-fees-costs

function within a decentralized ledger.[34] Smart contracts can be trusted by anyone to execute exactly as-specified in their code, and the code itself is publically visible on the ledger. Once deployed to Ethereum, these pieces of logic cannot be tampered with, destroyed, or restricted by any party in any way.

2.5.2 Tokens

In the context of Ethereum, smart contracts colloquially referred to as “tokens” include a minimum set of functionality defined by a community standard called ERC-20.[35] This standard exists to ensure all tokens have the same minimal functionality (e.g. ability to be transferred) and facilitates token interoperability.

Tokens can represent anything. For example, Alex could issue Alex Coin, redeemable (only by Alex) for 1 hour of his labor. Nick Johnson[36], one of Ethereum’s core developers, created BeerCoin, stating “a person's BeerCoin is only as valuable as the recipient's belief that they're good for the beer, should it ever be redeemed”.[37] Tokens can also be issued and backed by fiat money deposits from a trusted organization or government. Such tokens might then be redeemable for the issued fiat currency (e.g. US dollars) by the issuing institution. Grid+ believes that fiat backed stable tokens will enable far more commerce to be conducted using Ethereum’s rails in lieu of traditional payment processors.

2.5.3 Stable Tokens

A problem that has plagued digital currencies since their inception is price volatility. Cryptocurrencies (e.g. ether, bitcoin) underlying decentralized protocols (Ethereum, Bitcoin) are not issued by central institutions. Thus, they are not backed by anything but trust that there will be future demand both for the protocol and its native token. This leads to rampant speculation which, in immature markets, leads to huge slips in liquidity and large price volatility.

The future of money cannot depend on volatile assets, which is why stable tokens have remained a popular topic of conversation. Although difficult to implement on the Bitcoin blockchain, stable tokens are simple to issue on Ethereum since all that is needed is an institution to back them. If a trusted counterparty has a large reserve of U.S. dollars, it can mint USD tokens and sell them for $1 on a currency exchange. Those minted tokens can now move

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[34] Szabo, Nick. “Smart Contracts.” http://w-uh.com/download/WECSmartContracts.pdf
[35] Ethereum EIPs, ERC20, https://github.com/ethereum/eips/issues/20
[36] Nick Johnson, https://twitter.com/nicksdjohnson?lang=en
[37] Johnson, Nick. “Introducing BeerCoin.” *Reddit.* (Aug. 2016) https://www.reddit.com/r/ethereum/comments/4v7opj/introducing_beercoin/

through the Ethereum ecosystem freely until some user chooses to redeem her tokens in exchange for a bank wire.

2.5.4 Payment Channels

Although tokens can move from user to user (and also from user to smart contract), each one of these transfers (called “transactions”) require that the global Ethereum ledger be updated. A transaction requires the requester pay ether to the node making the ledger update. Before seeing the updated token balances, all users must wait for the next ledger update, which takes about 15 seconds in Ethereum.

It is not feasible for mainstream users to create a transaction every time they want to buy something. Both Bitcoin and Ethereum have seen massive network congestion[38] as a result of increasing popularity, but much of that traffic can be ameliorated using technology called payment channels.

As an analogy, imagine you are at a bar and plan to stay there all night. If you open a new tab and close it out after paying for each round, you must sign multiple receipts and the bar incurs multiple transaction fees from their payment processor (this is why they always ask if you want to leave a tab open). If you instead keep your tab open across several rounds, you need only sign one receipt at the end and you save the bar some amount in transaction fees.

The concept is similar in Ethereum. Instead of creating 1,000 ledger updates, one can open a payment channel and instead pass 1,000 mathematical proofs that prove the sender can pay some number of tokens to the receiver. These can be verified outside of Ethereum (“off-chain”) and only one proof (typically the last one) is needed to close the channel. Thus, one thousand transactions can be reduced to two: one to open the channel and one to close it.[39] Simple payment channels like the ones Grid+ uses are easy to design today, but more complicated state channels are an ongoing topic of research and experimentation. (Appendix)

[38]“Mempool Size.” *Blockchain*. https://blockchain.info/charts/mempool-size?timespan=1year
[39]Miller, Alex. “A Simple Ethereum Payment Channel Implementation.” *Grid+*. (12 June 2017) https://blog.gridplus.io/a-simple-ethereum-payment-channel-implementation-2d320d1fad93

2.5.5 Proof of Stake and Casper

Readers familiar with Ethereum will be well aware of the coming Casper implementation[40] of "Proof-of-Stake". Casper (and more broadly Proof-of-Stake) is a significant upgrade to the Ethereum protocol expected to be deployed around Q1 2018. At a high level, Casper allows users who own ether to deposit it to a smart contract and then become permissioned to update the ledger. If one or more of these bonded validators act out of turn or attempts to update the ledger in a way which violates state transition rules, those changes will be rejected by the broader set of stakers and those fraudulent validators will lose their entire ether deposit. If instead these validators act honestly, they earn some amount of ether commensurate with the fees in the transactions they have processed.

Note that this process of "validating" transactions in Casper requires that users cryptographically "sign" data stating that they believe the data is factual and will induce a valid update of the ledger. This has some security implications which will be discussed later.

Although the transition to Casper will not affect how Grid+ operates (in that it will not change Ethereum's usability), this protocol upgrade will be referenced later for other purposes. For more information, see Vitalik Buterin's article[41] on proof of stake as well as his other writings on Casper (in the same blog).

[40] Ethereum Research, Casper
https://github.com/ethereum/research/blob/master/casper4/papers/casper_paper.md
[41]Buterin, Vitalik. "A Proof of Stake Design Philosophy." *Medium.* (30 Dec. 2016)
https://medium.com/@VitalikButerin/a-proof-of-stake-design-philosophy-506585978d51

3 Value Propositions

Ethereum brings several efficiencies to the energy industry, an industry historically slow to adopt new technology. In January two Grid+ team members, Alex Miller and Mark D’Agostino, presented to a large group of European energy retailers at a conference hosted by Rockstart[42] in Amsterdam. Alex and Mark discovered each utility had a budget set aside for innovation projects, but most were hesitant to adopt a cutting edge technology such as Ethereum. Grid+ believes the organizational intransigence of often state-franchised monopolies offers a competitive advantage for Grid+.

Grid+ can immediately introduce efficiencies to electricity retailing by leveraging the public Ethereum blockchain. This creates incentives for consumers to invest in distributed energy storage, which will ultimately make renewable energy production more sustainable and efficient. There are many advantages to the proposed Grid+ system, which are broadly grouped into short and long term value propositions.

[42] Rockstart Smart Energy Accelerator, https://www.rockstart.com/accelerator/smart-energy/

3.1 Short Term - Energy Retailer

Grid+ will operate as a commercial electricity retailer in deregulated markets. There are fundamental efficiencies Ethereum offers that will help Grid+ significantly undercut costs of incumbent utilities. Approximately 50% of a retailer's cost are not associated with the purchase of wholesale energy and can potentially be removed through better technology and more efficient processes.

3.1.1 Lower Variable Costs

Billing and settlement remain a largely manual process (think spreadsheets, calls to the bank, and paper mail) for retailers. All these processes can be automated, and likely will be at some point, with or without Grid+ (automation is coming for us all[43]). Automation will reduce overhead costs, allowing Grid+ to lower consumer utility bills.

In addition to automation (which itself is an efficiency), Grid+ also introduces the efficiency of *user agency*, which means that Grid+ do not need to process transactions itself - the Ethereum network takes care of that. All payments are recorded automatically and moved from one smart contract (a payment channel) to another smart contract (the fee vault, which is called Karabraxos - more on this later), without needing traditional payment processors. Thus, the only variable cost associated with accounting and payments will be the costs of executing smart contracts on the network, and these costs are largely mitigated by payment channels.

3.1.2 Eliminating Bad Debts

In addition to foregoing centralized payment processing, *user agency* also allows Grid+ to eliminate costs related to risk. Rather than pooling risk as legacy utilities do, Grid+ will require customers to pay for their electricity in real-time via currency stored on their agent device. As the customer uses electricity their agent (an automated, always-on appliance) will make payments, via a payment channel, at each billing cycle in real-time (every 15 minutes or one hour, depending on the local ISO). In addition to adding currency to their agent (either ether or the Grid+ stable coin, BOLT), Grid+ will require customers make a refundable deposit that can be partially drawn-down if the agent fails to pay on time. The deposit serves two purposes. First, it prevents interruptions in service if connectivity is lost. Second, it provides a buffer if the agent runs out of funds. Grid+ customers will be notified as their deposit is consumed, and once it

[43] "Humans Need Not Apply." *CGP Grey*. https://www.youtube.com/watch?v=7Pq-S557XQU

reaches some lower threshold, the customer will be notified of service termination. Customers will always be able to top-off deposits if their deposits get partially utilized. Real-time payments coupled with the deposits will prevent the accumulation of bad debt in any meaningful quantity.

3.1.3 Lower Marketing Expenses

Grid+ will offer a significantly lower price of electricity compared to incumbent retailers which will likely lower the cost of customer acquisition over time (~$150 for current retailers[44]). Grid+ anticipates initially spending more on customer acquisition, than the incumbent retailers, as it establishes its brand and presence in existing markets. However, Grid+ also anticipates customer acquisition costs decreasing over time. Since Grid+ is able to offer substantially lower prices, it will have much lower customer turnover, which can be as high has 30% per year for traditional retailers in deregulated markets.[45]

3.2 Long Term - Distributed Storage and Open Markets

Since customers are given nearly frictionless access to the wholesale energy markets, they will experience market-driven price fluctuations, which will enable their agents to make smarter decisions about consumption. As the price of storage (i.e. batteries) drops, there will eventually come a time when, it is in a rational consumer's economic interest to purchase a battery to arbitrage energy prices and provide ancillary services to the electric grid.

3.2.1 Enabling Efficient Markets

The computation and allocation of costs associated with using the distribution network introduce some of the largest inefficiencies in today's electrical grid. Fees are billed in a non-dynamic way, socializing the cost of the infrastructure over all market participants on a per kWh usage basis. Presently, pricing does not consider that each customer's kWh represent different real costs due to variations in geography, network connection topology, and time of use. This socialization of cost disincentivizes the adoption of DERs leading to economically irrational outcomes. With the adoption of smart-meter technology at each node in the grid, including the customer endpoints, the data needed for computing real-time dynamic distribution costs will become available.

[44]Drummond, Iain and Josh Lutton. "Reducing Customer Acquisition Costs." *Woodland Associates*. (28 Feb. 2013) https://woodlawnassociates.com/electrical-potential-solar-and-competitive-electricity/
[45] Borràs, David and Javier Serra. "Churn Management in Utilities." *Arthur D. Little.* (2015) http://www.adlittle.com/downloads/tx_adlreports/ADL_Churn_management_in_utilities.pdf

3.2.2 Natively Support P2P Markets

Geographically and topologically segmented markets will emerge once dynamic, granular locational marginal pricing (LMP) is implemented on the distribution grid. Once this occurs there will be situations where customers will not want to interact with wholesale markets directly, but rather trade energy locally. At this point customers will be able to utilize Ethereum to facilitate the exchange of energy directly in a peer-to-peer manner, rather than clearing on a centralized market. Trading will be limited to customers of Grid+ or other participating retailers until regulators make accommodations for P2P markets generally.

3.2.3 Integrate ISO Wholesale Markets

The problems that are faced by retail electricity markets, namely inefficient mechanisms for accounting and settlement, as well as counterparty risk, are also issues in the ISO-operated wholesale markets. Unlike the retail markets, the wholesale markets include far fewer participants, but have much larger trade sizes.

Wholesale markets trade what are called “forward contracts”, which is a contract promising to deliver energy at some future time. Therefore, there are considerable counterparty risks when interacting in a market where some participants trade forward contracts. This risk has manifested itself a number of times and has cost market participants and consumers large amounts of capital with the most recent large failure being the bailout of Constellation Energy.[46] NASDAQ has also realized that trading of financial instruments can benefit from blockchain technology and have developed their own platform, Linq.[47] In the long term Grid+ anticipates extending the technology developed for the residential business into the ISO operated wholesale markets, at which point there would be no distinction between retail and wholesale markets.

[46]Hancock, Jay . “The Messed-up Wholesale Electricity Market.” (17 Jan. 2011) http://www.mresearch.com/pdfs/455.pdf
[47]“Building on the Blockchain.” *NASDAQ* (March 2016) http://business.nasdaq.com/Docs/Blockchain%20Report%20March%202016_tcm5044-26461.pdf

4 Intelligent Agent

The vast majority of customers who sign up for Grid+ will have no desire to learn how cryptocurrencies work. Grid+ is building a seamless solution that leverages the power of the public Ethereum network without requiring users possess a high degree of technical aptitude. One critical piece of the system that makes this possible is the Grid+ agent device, an always-on, Internet-aware device shown in Figure 7.

Figure 7: Grid+ Agent Prototype

4.1 Basic Usage

At its core, the Grid+ agent is a computer that pays for a customer's electricity usage in real time. After the agent is registered, the customer purchases U.S. dollar stable tokens (called BOLT) from Grid+ with a credit card or bank transfer. Once the payment settles, these BOLT tokens are transferred to the user's agent. As long as the agent holds BOLT, it may read from the household smart meter and pay for the electricity usage in real-time. A schematic of this process is shown in Figure 8.

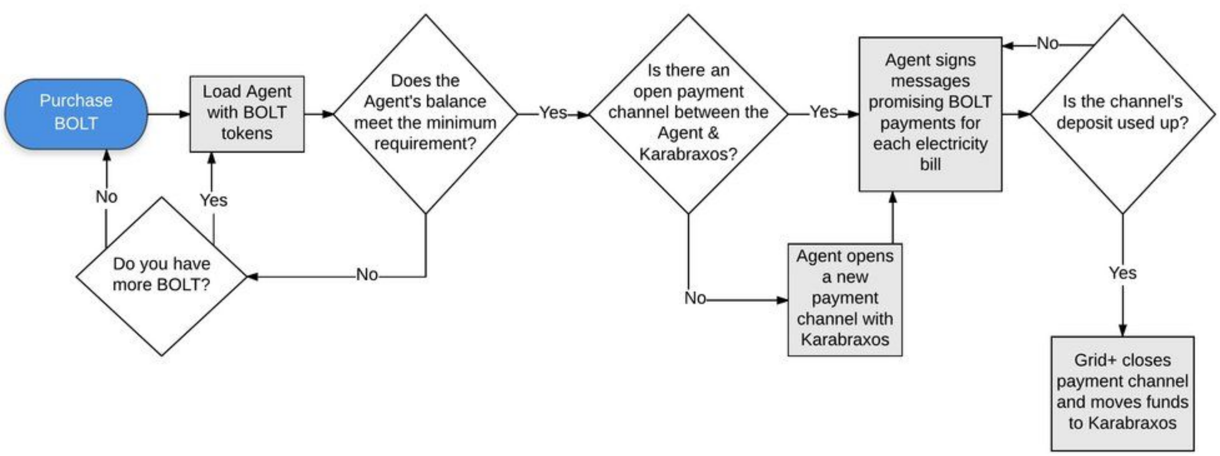

Figure 8: Basic agent process

A customer may get started with Grid+ by signing up, purchasing an agent, registering that agent, and buying BOLT on the Grid+ web console. The customer does not need to do anything else until the agent runs out of BOLT (note that Grid+ will offer an automatic-payment option).

4.2 Agent Registration & Key Generation

Before shipping agent devices, Grid+ registers the serial number from the device in the Grid+ registry contract.[48] Only Grid+ can register devices in this contract, which ensures unsupported devices do not report data and cannot make transactions. After registering the device, its serial number is mapped to an Ethereum address generated by Grid+.

Once delivered to the customer, the agent may be registered with a serial number found inside the box. This maps the owner's wallet address to the serial number, which is itself associated with the agent's digital identifier. The agent is capable of making digital signatures[49] from a secure hardware enclave and may act autonomously while still being registered with Grid+ and owned by the customer.

There is clearly a problem with the registration workflow, and it may be obvious to some of the more advanced crypto users. If the device signs messages with the key Grid+ generated, this defeats the purpose of *user agency* and makes Grid+ responsible for its security. Thus, the device must generate its own key after the user claims it.

The technical details of this process are based on the following two lines of Solidity (an Ethereum programming language[50]) code in the Grid+ registry contract:

```
mapping (bytes32 => address) registry;
mapping (bytes32 => address) owners;
```

The first line maps a hash of the agent device's serial number to an address. For each issued agent device, Grid+ assigns a serial number and generates a setup key on the device. Grid+ then calls a function on the registry contract to whitelist the setup key. After the setup key (on

[48] Grid+, Contracts, https://github.com/GridPlus/Contracts/blob/master/Registry.sol
[49] Specifically the agent will make ECDSA (Elliptic Curve Digital Signature Algorithm) signatures using the secp256k1 curve. These signatures are presently required to participate in Ethereum and the corresponding cryptographic key pairs serve as the agents' digital identities.
[50] Solidity documentation, https://solidity.readthedocs.io/en/develop/

device) is registered, it is seeded with a small amount of ether and the agent is shipped to the user.

Once the user receives and boots the device for the first time, it will automatically generate a new key-pair and call the registry contract to replace its setup key with the new wallet key-pair. Only the consumer has access to the newly created private key, thus she now has *user agency*. Further, to ensure utmost transparency, Grid+ has open sourced all its client code, which it welcomes the broader community to thoroughly review.

The second mapping above is set by the human user claiming a device. The owner must have a serial number on hand and may only claim a device that was registered by Grid+. To see how this works in action, please explore the Grid+ demo application.[51]

4.3 Advanced Usage

The design of Grid+ system architecture is shown in Figure 9.

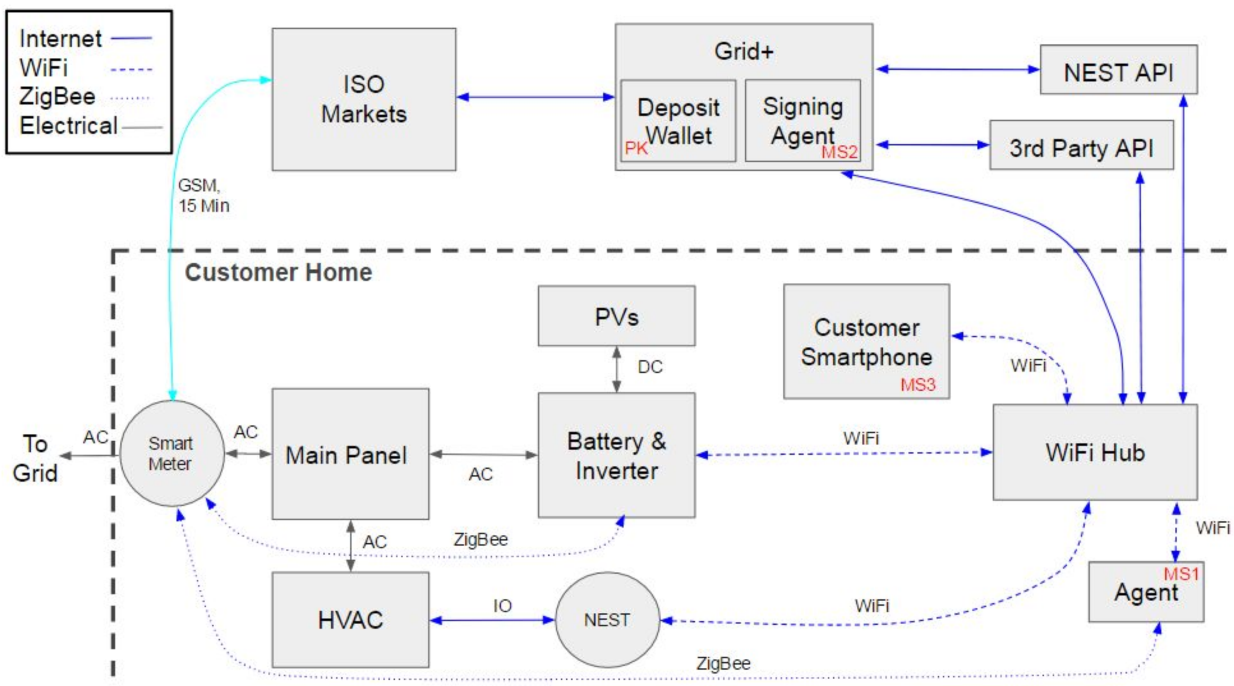

Figure 9: Grid+ System Architecture

For additional security, Grid+ will allow the use of a multi-signature wallet. For those unfamiliar with this concept, it is relatively simple. In order to initiate a transaction to move funds or trigger

[51]Grid+ Demo Application, https://app.gridplus.io

a contract, the transaction requires ECDSA signatures from more than one private key. A user can create a 2 of 3 multisig contract account which requires at least 2 of the 3 keys to sign any given transaction. Grid+ plans to use a simple multisig utilizing detached signatures[52] as designed by Dr. Christian Lundkvist. Under Metropolis (Ethereum's next major update), multi-signature wallet contracts will be able to transact as normal accounts[53].

The multisig scheme prevents a hacker from gaining access to customer funds if the agent device is hacked. The benefits of *user agency* are nullified if an attacker can connect to your wifi and break into your agent to move your agent's BOLT and ether into another account. The diagram above shows MS1, MS2, and MS3 - which all represent different private keys in a multisig setup. This allows a user to utilize a *vault* setup wherein she can deposit larger sums.

Practically, this means a user is *always* in control of her funds (MS2 + MS3). In a situation where the agent device is stolen/destroyed, the user still maintains the ability to access her vault (MS1 + MS2). This setup scheme allows large amounts of value to be stored - outside of the agent device's hot wallet. While this setup is *recommended*, it is not required. Multisig transactions incur a larger transaction fee (although this may not be true in future versions of Ethereum[54]) and there exists some economic trade-off between security and cost which can be different for each user. In a scenario where a casual user spends $50 per month on energy, she may be willing to store that on her agent's hot wallet. When energy bills are in the hundreds or thousands of dollars, or a user wishes to store six months of electricity worth of cryptocurrency on the agent, she may desire the additional level of security provided by a multisig account.

4.4 Agent Energy Trading

To better understand what decisions an agent makes on behalf of a user, the reader must first understand some of the intricacies of the electricity market.

It was previously stated that Independent System Operators (ISOs) manage wholesale markets wherein producers sell electricity and utilities buy it for resale to their customers. This is a simple description, but it is also a gross oversimplification of how wholesale electricity markets work. Wholesale markets have much higher degrees of complexity, largely driven by the fact that load on the electrical grid must match, nearly exactly, the generation at any given point in time. If

[52] Christian Lundkvist, Simple-multisig, https://github.com/christianlundkvist/simple-multisig
[53] Ethereum EIP 86, https://github.com/ethereum/EIPs/pull/208
[54] Ethereum EIPs, Signature Abstraction, https://github.com/ethereum/EIPs/pull/208

generation significantly deviates from load either a high-voltage or low-voltage situation occurs, either of which can severely damage equipment attached to the network. ISOs have created systems that help manage the grid in a stable manner throughout the day, but prefer to use market mechanisms to coordinate consumers and producers in such a way as to keep the grid balanced. To ensure this goal, ISOs have created markets in which they incentivize the coordination of disparate interests. Three of largest markets are day-ahead, real-time, and demand response.

4.4.1 Day-Ahead and Real-Time Markets

One of the mechanisms that helps to maintain the stability of the grid is the ability to forecast both demand and production. ISOs operate what are known as day-ahead-markets which allows both generators and utilities to buy and sell forward contracts on electricity for one day in the future. These markets typically operate in 1 hour windows, such that from 1pm to 2pm on a given day, market participants bid on the forwards for 1pm to 2pm the following day. The forwards market is locked in by 2pm, and the corresponding parties are then contractually obligated to produce or consume the specified amount of energy the following day from 1pm to 2pm. This gives the generators time to plan their production to match what the market believes will be the demand one day in advance. The ability to plan ahead helps producers manage their operations and supply chains in a manner that is significantly more efficient[55] and minimizes drastic changes in demand on other generators in the network. This also incentivizes consumers to try and accurately predict their consumption one day ahead because they can mitigate price volatility in real-time markets since prices in the day-ahead markets are often less expensive.

The real-time market is exactly as it sounds. It is the market for buying and selling energy in real-time or near real-time. Depending on the specific market there can actually be one or multiple markets that fall within the real-time designation; such as 1 hour, 15 minutes, or 5 minutes. The difference between the real-time prices and the day-ahead prices for the Maine interconnection on June 11th, 2017 are shown below in Figure 10.

[55] Marcel Antal et al. “A System of Systems Approach for Data Centers Optimization and Integration into Smart Energy Grids.” *Science Direct.* (24 May 2017) http://www.sciencedirect.com/science/article/pii/S0167739X17310129

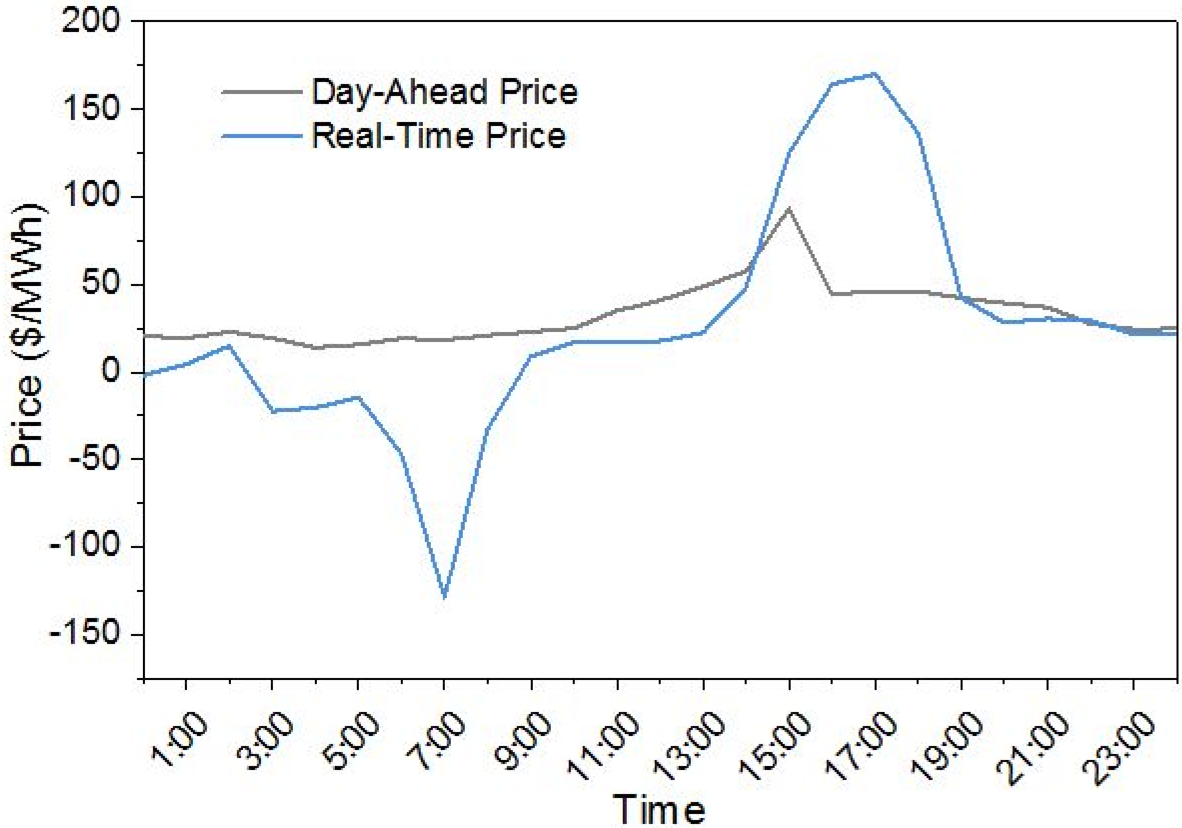

Figure 10: LMP for Maine Node 06/11/2017 [56]

How much energy will a user need tomorrow? Should she buy it in the day-ahead markets, real-time markets, or some combination thereof? These are questions a smart agent device can answer. Normally, this decision is made by a utility which is not strongly incentivized to optimize costs for individual consumers. Instead, they attempt to minimize overall volatility, and socialize the average cost of energy throughout the day over their customer base. Most utilities will charge their customers a flat rate regardless of how much electricity their customers use, when they use it, or how much it actually costs to buy. The flat rate is based on the average wholesale price plus some non-negligible markup (~30-50%).[57]

Although energy storage has many benefits and is an ideal distributed resource to be controlled by independent smart agents in real-time, the fact remains that there does not yet exist a high degree of energy storage penetration in the market place. This will likely change in the near

[56] https://www.iso-ne.com/isoexpress/web/charts
[57] Bohi, Douglas R. and Karen L. Palmer. "The Efficiency of Wholesale vs. Retail Competition in Electricity." *The Electricity Journal.*
https://www.hks.harvard.edu/hepg/Papers/Bohi_Palmer_Efficiency_1096.pdf

future[58] as market incentives are updated to accommodate the burden renewables place on the grid. In the proposed scenario wherein residential customers have access to real-time pricing in the wholesale market, the incentive for installing energy storage exists. Customers with energy storage can have their agent conduct temporal energy arbitrage and generate revenue. This can be done simply by buying electricity when it is cheap and selling it back or consuming it when energy is expensive. For example, if electricity is -$0.10/kWh from 6-8am (a price not inconceivable based on Figure 10) and +$0.25/kWh from 4-6pm, a savvy arbitrageur would be able to net +$0.35/kWh. For a Tesla Powerwall II[59], this would generate around $3.5 per day or $1275 dollars per year, allowing the Powerwall to pay for itself within six years. (Appendix)

4.4.2 Demand Response

Although ISOs can control the generation side of the electrical grid through day-ahead and real-time energy markets, they must employ other methods to incentivize loads and ensure grid balance. One of these balancing techniques is called demand response. Rather than paying generators to produce more energy, ISOs can pay consumers who have flexibility in their loads to shut-down those loads for a short period of time. This creates a new set of opportunities for a customer's agent to react to the economics of the demand response market.

The Nest smart-thermostat[60] is an example of what is known as a dispatchable load. A customer's agent can monitor the demand response markets and, if configured to do so, use a Nest to turn off heating or air conditioning for a short period of time in order to earn revenue. The grid's market signals for demand response can be broadcast to all nearby Grid+ agents, which can offer bids stating they will turn off their household air conditioning if a certain price is paid. If enough bids are made to satisfy the ISO's resource increment requirement (usually 100 kWh), then the aggregate bid would be broadcast into the demand response market by Grid+. The revenue that is generated from the service could then be sent to participating agents.

In addition to offering services to demand response signals, a customer's agent could also use the Nest to intelligently control the home's temperature based on the real-time market prices. For example, if the price of electricity is usually highest at 7pm, the thermostat could cool the house 2 degrees below the set temperature of the house by say 6:30pm and then allow the house to rise 2 degrees above the set temperature by 7:30. This in turn saves the customer

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[58] Miller, Alex. "The Future of Energy Markets." *Grid+*. (18 May 2017) https://blog.gridplus.io/gridx-the-future-of-energy-markets-da104c285363
[59] Tesla Powerwall, https://www.tesla.com/es_ES/powerwall?redirect=no
[60] NEST thermostat, https://nest.com/thermostat/meet-nest-thermostat/

money by avoiding expected consumption of energy at peak prices. Moreover, there are also situations wherein the real-time price of electricity can spike in excess of 3-5 times the average electricity cost due to shortfalls in generation and/or congestion in distribution. (Figure 10) If the agent knew that the home was already within the consumer's pre-configured comfortable temperature range, it could choose to forego purchasing energy for 15 minutes in anticipation that the electricity rate will normalize in the near future.

As more of the user's devices are connected to the agent, it will be able to make even more intelligent consumption decisions. For example, if you own a TESLA, you might normally come home from work and start charging your car. If your agent knows that you aren't going out tonight, it could defer charging the car until the early hours of the morning when electricity is significantly less expensive. Both Nest and Tesla provide APIs that can be used to interface these devices with the Grid+ system.

It is important to highlight the value of smart devices that moderate a customer's electricity consumption profile. These IoT devices on their own hold valuable data, but lack the ability to transact on a shared financial infrastructure and create an economic benefit for their owner. The Grid+ smart energy agent is the central point of both the financial connectivity and decision making for a customer's collection IoT devices.

4.4.3 Intelligent Economically Driven Decisions

The decision-making capabilities of the agent will be further enhanced as information sharing between customer and agent increases. For example, if your smart phone periodically broadcasts your location to your agent, the agent would be able to figure out when you are leaving the house, and when you are coming back. If you stay late at work, or decide to go downtown on a date, your agent would know to delay cooling the house until you are on your way home. Say you have a conference in Portland, your agent could look at your calendar and determine that you will not be home for the next three days. It could then decide not to purchase as much energy in the day-ahead markets because it will know that you will not need to run your AC system.

Note: This could result in privacy concerns for some users, however the data that is transmitted from the Grid+ smartphone app will be encrypted with the agent's public key and will only be readable locally by the customer-controlled agent.

4.5 Secondary Uses of the Agent

The Grid+ agent device is integral to the Grid+ system; however, Grid+ imagines other users in the Ethereum ecosystem will benefit from it as well. The Grid+ agent is a standalone computer with natively integrated hardware and software for the Ethereum protocol. The agent will maintain its own Ethereum light client, which is designed for resource-constrained computing environments.[61] Users will be able to utilize the agent for transaction signing in a secure enclave. The security topology of the Grid+ system will enable secure and robust storage of cryptocurrency, secure signing of prepare and commit transactions in Proof-of-Stake with Casper, and a secure cryptocurrency API for IoT devices.

4.5.1 Storing Cryptocurrency

Ever since the earliest days of Bitcoin, securely storing cryptocurrency has been a primary concern and a challenge for many users. Although there have been a number of advances beginning with paper wallets, multi-signature accounts, and hardware wallets, all of these methods largely depend upon assets being stored offline to maintain security. Offline wallets create significant friction in signature creation, and multisignature wallets introduce “social latency”. Furthermore, physical wallets rely upon the availability of a single device or safe storage of a single plaintext backup. Fundamentally, both the air gapped nature of incumbent methodologies as well as the transactional friction introduced make these methods incompatible with an efficient, frictionless economy of the future. This is most apparent when it comes to using cryptocurrency in IoT applications such as the transactive grid.

Taking this into account, Grid+ proposes a new security architecture that combines all of the state-of-the-art methods of securing cryptocurrencies into a single system. The multi-signature system coupled with a secure hardware enclave, secure computing transaction verification, physical second factor verification, and segregation of key storage, creates a system where users will be able to reliably and safely store larger amounts of cryptocurrency in a standard-setting, secure, robust, and high availability (almost always online) way.

4.5.2 Proof-of-Stake Signing

After the implementation of Casper, Ethereum stakers will need to ensure online connectivity with near-zero downtime, or else risk a negative interest rate on deposits. Thus, many in the

[61]Ethereum, Light client protocol, https://github.com/ethereum/wiki/wiki/Light-client-protocol

space believe running instances on Azure or AWS, which have nearly 100% uptime, is the most desirable option. But storing private keys in the cloud will put potentially billions of dollars worth of ether at risk.

The Grid+ agent can serve the purpose of a "Casper-in-the-Box" remote signer. A user may run the Casper protocol in AWS or Azure and pass the raw, unsigned transaction details to the Grid+ agent device. The agent would then locally sign the staking transactions. This ensures that private keys never leave the protection of a secure enclave, under the staker's supervision. Once again - this structure coincides with the Grid+ team's strong belief in *user agency*. Even more interesting is to imagine using an application running on top of Ethereum to provide the data to help secure the network. One could envision that a staker might outsource computational jobs to Golem[62], or iExec[63], and have unsigned transactions with provable, appropriate data returned to the agent device. The agent would pay for those computations in GNT or RLC, then sign and broadcast the transaction details constructed using purchased computation. All data analysis is done via an Ethereum application and transactional data is signed on a customer's agent. Thus, the Grid+ agent can potentially secure the Ethereum ecosystem running Casper without ever leaving the Ethereum rails.

4.5.3 Ethereum API for IoT

Although the secondary use cases may appear to only be serving a niche use case, over time Grid+ anticipates the agent could be game changing to cryptocurrency adoption. The initial use case of signing processed transactions during the Casper implementation is a small one. However, in the future the Grid+ agent can serve as a financial gateway for all IoT devices. If the projections for IoT enabled devices are true, these types of agent devices connected to the Ethereum network could be of profound importance. By 2020 it is estimated there will be 20 billion connected devices that will need to transact value.[64] The Ethereum network can serve as the transactional layer for a device connected world. However, having all IoT devices sign Ethereum transactions will be inherently insecure, thus using a proxy agent to sign on behalf of other IoT devices is a logical construct. Therefore, Grid+ is developing a RESTful API through which other IoT devices can connect to the Grid+ agent and send or receive payments in a simple, secure, and permissioned way. Grid+ imagines this device will become standard as IoT becomes ubiquitous.

[62]Golem Network, https://golem.network/
[63]iExec project, http://iex.ec/
[64]Gartner Newsroom, (7 Feb. 2017) http://www.gartner.com/newsroom/id/3598917

4.6 Integration and Testing

Is this all theoretical, or has Grid+ actually implemented the above designs? The Grid+ team felt it was necessary to do real world testing prior to announcing this design pattern to the world. Over the past year, working in conjunction with one of the world's largest energy companies, the Grid+ team has deployed code onto a specific 3kWh smart-battery from a European producer. Grid+ has proven the concept and is now rewriting much of that code in a lower level language for what will be a large, production deployment. Grid+ is working with some of the most progressive energy companies in the world, and looks forward to experimenting on larger batteries (such as the 14kWh Tesla Powerwall). It is important to note that both the Grid+ design and its ambitions to operate multiple retailers do *not* rely upon meaningful penetration of distributed energy storage in any of the markets serviced by Grid+. Storage capabilities opens up many additional revenue streams for Grid+ customers (including offering ancillary services to the grid), but Ethereum by itself can still enable lower cost electricity via dis-intermediation and *user agency*.

5 Tokens

Note: This section is undergoing active structuring with leading law firms. While we do not expect major rewrites, some of this section may change in the future. In the event of a change, the whitepaper version number will be incremented.

Grid+ will operate with a two-token model, with each token being ERC-20 compliant.[65] The BOLT token is a stable-coin, redeemable by Grid+ customers for $1 worth of energy and backed by USD deposits. The GRID token allows Grid+ customers to purchase electricity at wholesale price. Each GRID token may be redeemed for a certain amount of electricity at wholesale price, with that number being a function of the total supply.

5.1 The BOLT Token

BOLT is the currency required to use the Grid+ platform. It is a stable currency, with each BOLT redeemable for $1 worth of energy on the Grid+ platform at all times. BOLTs are only created

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[65] The Merkle, What is the ERC20 Ethereum Token Standard? https://themerkle.com/what-is-the-erc20-ethereum-token-standard/

when customers deposit fiat (or ether, which is sold for fiat) to Grid+ and are destroyed when Grid+ customers redeem BOLT for USD. These creation and destruction events are defined according to a technical specification first proposed by a member of the Grid+ team, Alex Miller. [66] The customer may purchase BOLT tokens directly for her device or may purchase them for her own wallet and move them to her device at any time. Before an agent can pay for energy, it must open a payment channel with Grid+ by depositing BOLT, a process that occurs automatically. Both energy wholesale costs and fees are taken from this BOLT deposit when the channel is closed.

5.1.1 BOLT Redemption

Any Grid+ customer who holds BOLT is free to exchange them for fiat money at any time. This requires KYC (which occurs when the customer signs up for Grid+ service) as well as a fee associated with initiating a bank transfer. In the event of redemption, BOLTs are destroyed and the token supply is decreased.[67]

5.1.2 The Fee Vault: Karabraxos

Grid+ does *not* collect fees directly; rather they are routed from each closed payment channel to a smart contract known as Karabraxos, which can be found at `karabraxos.eth`. (Figure 11) The main purpose of Karabraxos is for Grid+ to be transparent about the number of BOLT it is earning and for the public to have some idea of how much liquidity will be available for usage in Raiden when available.

*Note that Karabraxos holds BOLT collected both from retail electricity customers **and** from fees generated by the Grid+ Raiden hub.*

[66] Ethereum EIP621, https://github.com/ethereum/EIPs/pull/621
[67] BOLT contract, https://github.com/GridPlus/contracts/blob/master/BOLT.sol; *see also* EIP 621, https://github.com/ethereum/EIPs/pull/621

Figure 11: Artist's conception of Karabraxos

5.3 The GRID Token

A fixed number of GRID tokens will be created once and sold in the upcoming Grid+ token sale. Each GRID token is a credit on the Grid+ platform, redeemable at any time for electricity (in kWh) at wholesale cost. At the time of redemption, GRID tokens are converted to a fixed number of kWh (a function of the current supply) and assigned a timestamp by the redemption contract. Once redeemed, GRID are taken out of supply forever via a mechanism modeled after EIP 661.[68]

5.3.1 GRID redemption

GRID tokens are redeemed for wholesale electricity on-chain:

```
function redeem(bytes32[3] sig, uint amount) {
    ERC20 grid = ERC20(GRID_ADDRESS);
    if (!grid.provable_redeem(sig, amount)) { throw; }
    uint kwh = getKwh(amount);
    Redemption(msg.sender, amount, kwh, now);
```

[68] https://github.com/ethereum/EIPs/issues/661

```
}
```

This function provably redeems GRID tokens using the specification outlined in EIP 662.[69] This redemption removes GRID tokens from the sender's balance and also from the total GRID supply. Once redeemed, a `Redemption` event[70] is emitted by the contract, linking the agent's address to the number of GRID redeemed as well as the number of kWh credited through this redemption. The `getKwh` function is as follows:

```
function getKwh(uint amount) returns (uint) {
    ERC20 grid = ERC20(GRID_ADDRESS);
    uint grid_amount = safeMul(amount, 100);
    uint kwh = safeDiv(safeMul(grid.initialSupply, grid_amount),
grid.totalSupply);
    if (kwh > 50000000000000000000000) { kwh =
50000000000000000000000; }
    return kwh;
}
```

Note that only a percentage of total electricity sold by Grid+ can be purchased at wholesale using GRID per unit time.

The number of kWh received per GRID redeemed is a function of the number of GRID tokens in existence at the time of redemption, with a ceiling of 50,000 kWh/GRID and a starting reward of 100 kWh/GRID. This ceiling is reached when the total GRID supply decreases to approximately 0.5% of the initial supply and holds until there are no more GRID left.

A projected redemption reward curve is shown in Figure 12 using an initial GRID supply of 200,000,000. Note that the GRID supply has not yet been finalized and this is simply an example.

[69] https://github.com/ethereum/EIPs/issues/662
[70] Ethereum StackExchange, What is an event? https://ethereum.stackexchange.com/questions/11228/what-is-an-event

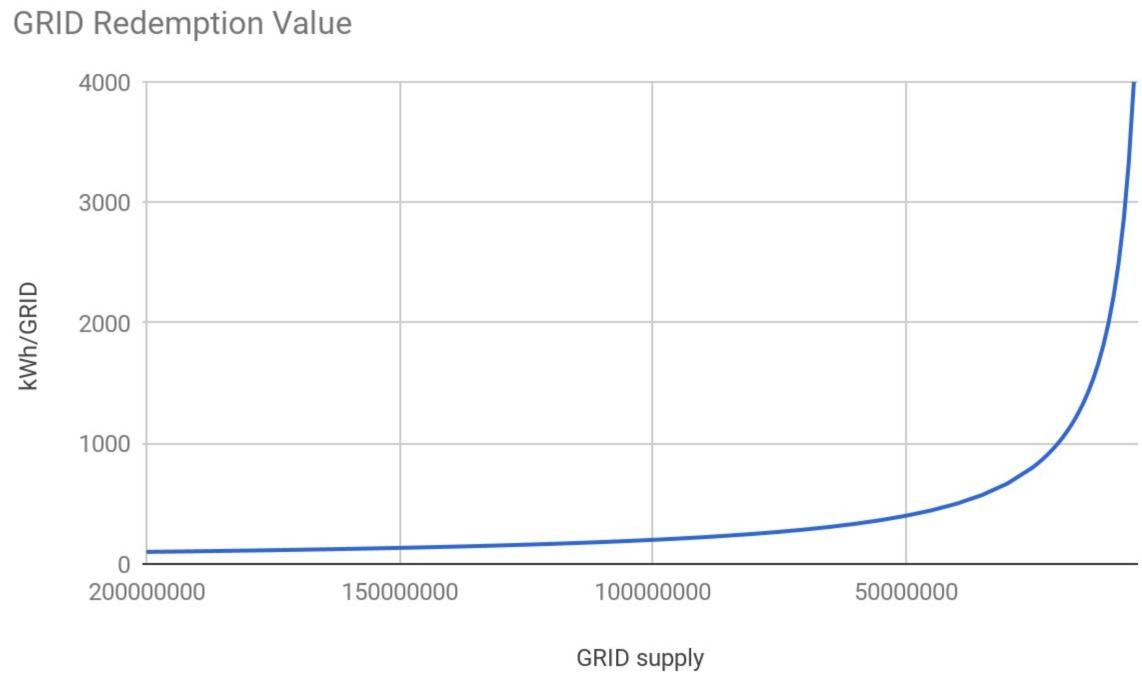

Figure 12: Expected GRID reward

5.3.2 Applying Wholesale kWh

Once GRID have been redeemed and an event emitted, the Grid+ hub reads that event and references it when billing the agent in the future. A typical bill[71] includes the following:

```
{
  price: 0.1,              // units of $/kWh
  wholesale_price: 0.08    // units of $/kWh
  amount: 1,               // units of kWh
}
```

In this simple billing example, the customer used 1 kWh of power. If the agent has recently redeemed GRID (recorded in the `Redemption` event), the wholesale price is passed to the customer and the customer pays $0.08, with no additional markup. If a customer has no amount of redeemed GRID associated with the agent, the customer pays the normal Grid+ price of $0.10.

For example, suppose a customer has redeemed GRID and been credited 10 kWh at wholesale price. If the above bill was issued to the agent, it would pay $0.08 and the wholesale credits would be reduced from 10 kWh to 9 kWh (because this bill used 1 kWh). This credit (now 9

[71] Note that there are other pieces of billing data irrelevant to this discussion.

kWh) would decrease with each subsequent bill until it hits 0 kWh, at which point the agent would return to paying the normal Grid+ price (wholesale + markup).

6 Business Model

Grid+ revenue will be generated from markup on wholesale energy prices, transaction fees, interest on capital backing BOLT tokens, and sales of agents. Grid+ will drive energy prices as low as possible and operate the energy business near-cost in the long-term (i.e. paying for expenses, but making little-to-no profit off of the energy fees charged).

6.1 Markup on Energy

Grid+ will charge its customers for the price of energy they purchase in the wholesale market, the fees associated with its distribution, as well as a percent markup over these latter two costs. Figure 13 shows the average wholesale cost of electricity in Texas over time. Note that in 2016 roughly half of the cost of residential electricity represented the markup by retailers.

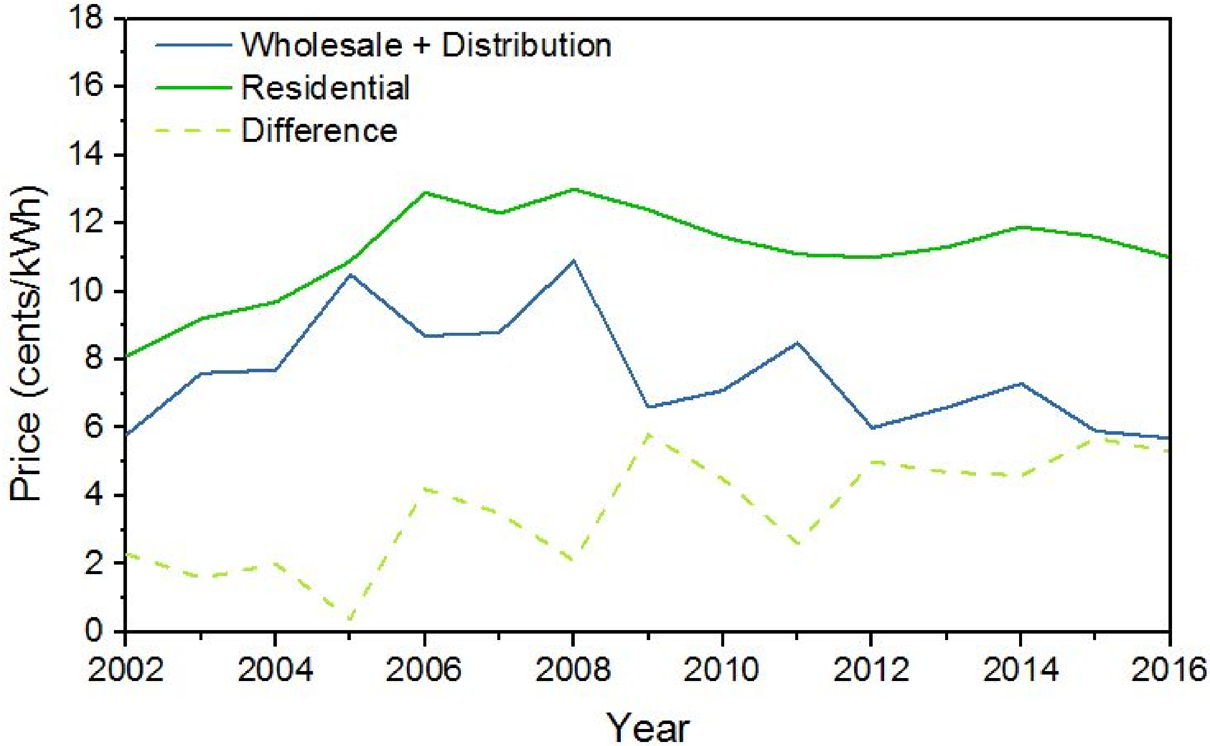

Figure 13: Wholesale vs Residential Pricing

Grid+ will charge 20% above the wholesale + distribution cost implying a cost of $0.068/kWh, for the Texas market, compared to the current average retail cost of $0.115/kWh. This would provide a customer savings of ~38%. Based on the projected number of customers during the Tesla Epoch (see Roadmap below), this would lead to $16 to 32mm in net revenue per year generated from electricity sales.

The mandatory use of deposits results in the complete removal of bad debt expenses, which creates a competitive advantage over incumbent retailers. The deposit model creates a somewhat hidden virtuous cycle. Customers who are likely to default on payments will be unwilling to post a deposit and join the Grid+ platform. Thus, high credit risk customers are pushed onto incumbent retailers, thereby increasing Grid+'s competitive advantage over time.

6.2 Raiden Network Transaction Fees

Given its system design, Grid+ is poised to become one of the largest stable-coin issuing entities on the public Ethereum network. Issuing large amounts of fiat tokens puts Grid+ in a unique situation to act as a central bazaar for a great deal of commerce on the public Ethereum network. Grid+ anticipates the ability to operate a large fiat hub on the Raiden network with a significant amount of liquidity. With this hub established, Grid+ foresees a secondary revenue source: charging fees on microtransactions inside the Grid+ Raiden hub.

These Raiden fees should not be conflated with Grid+ fees. The former is simply to pay for using the Grid+ Raiden hub to conduct commerce (outside of Grid+), while the latter is a markup on energy to pay for Grid+ costs. Note that no Raiden fees will be added to channels open for Grid+ services (i.e. Grid+ will not have double-fees). Also note that Raiden fees, like all other fees in Grid+, go to Karabraxos (which is intended to capture *all* revenue streams of Grid+).

Grid+ will work to capture market share in the early days of Raiden, rather than maximize short term revenue generated through the hub. Therefore, the fees charged will be extremely low (on the order of $0.0001 per tx). As of this writing, the average cost of a transaction on the Visa network is 2% of the transaction cost + $0.10, thus for a $10 transaction, the fee would be $0.30.[72] Although one could argue that Grid+ only needs to beat Visa, the team believes it must strive to beat the costs of the public Ethereum network as well. Currently, the median cost for a simple transfer is $0.11 on the public Ethereum network.[73] Thus, the expected transfer fee for a $10 payment in the Grid+ Raiden hub will be 0.033% the cost or the Visa transaction and 0.05% of the public Ethereum transaction. This means Grid+ Raiden hub transactions will be 2,000-3,000 times less expensive than typical payment costs. It is not inconceivable that other commerce will look to utilize BOLT inside of the Grid+ Raiden hub to capitalize on these extremely low costs.

6.3 Interest on BOLT deposits

The fiat currency backing BOLT will be used by Grid+ to pay for the wholesale electricity when BOLT is redeemed by a consumer for electricity. Note that any time fiat is used to pay for bills, a corresponding number of BOLT tokens will be burned within Karabraxos. If not enough BOLT tokens can be burned, the number of BOLT to be burned will be recorded and another burn event will be attempted after more fees have been collected.

In the time period between when the consumer buys the BOLT and the electricity is consumed, Grid+ will invest the monies in low-risk assets such as treasury bills. Assuming that US treasury

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[72] "Visa and Mastercard US Interchange Rates." *Helcim*. https://www.helcim.com/us/pricing/visa-mastercard-interchange-rates/
[73] ETH Gas Station, http://ethgasstation.info/

bills will yield 1% this will generate revenues of $272,000 - $544,000 per year during the Tesla Epoch (Q2 2018- Q1 2019).

6.4 Sales of Agents

All Grid+ customers will require an agent device, whose estimated manufacturing cost is near $50. This device offers substantially more functionality than a Trezor[74] or Ledger[75] hardware device at a lower price point. Although this is a potential revenue stream, Grid+ will sell agents at cost, as they are the gateway to the Grid+ platform and enable the revenue described above to grow.

6.5 Roadmap

The Grid+ roadmap starts by assuming relatively low battery and solar penetration and focuses primarily on developing the smart-energy agent and its software as well as rolling out utilities in targeted regions. In later phases, Grid+ will assume higher DER penetration.

6.5.1 Phase 1: Edison Epoch (Q4 2017 - Q2 2018)

During this period, Grid+ will establish a single utility in a targeted region and sign up 5,000+ customers. These customers will be charged electricity at cost in order to grow the Grid+ brand. This will also be a period of rapid improvement to Grid+ software and hardware components.

6.5.1.1 First Utility

Grid+ will begin the Edison Epoch by applying for creation of a utility in a deregulated market within the United States. At the time of writing this, no market has been selected, but the target markets have been narrowed down to a short list.

Grid+ will need to contract with a marketer who is familiar with marketing utilities. This sounds like a specialised task, but it is a fairly common skill in deregulated, competitive markets (because the churn rate is fairly high for utilities).

6.5.1.2 Agent Prototype

Before developing the software, Grid+ will need a stable hardware prototype of the agent to ensure the development environment will remain constant. This prototype should come from a

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[74] Trezor, https://trezor.io/
[75] Ledger, https://www.ledgerwallet.com/

production process that is at least scalable to a few thousand devices, but need not be scalable to millions.

During this phase Grid+ will hire three hardware engineers to finalize the first production hardware device. Karl Kreder will oversee the agent prototyping, testing, and production.

6.5.1.3 Establish Content Delivery Network

Before making upgrades to the agent device client[76], Grid+ needs to establish a process in which the agent device fetches updates from the hub. This is critical to streamlining upgrades and enabling fast iteration. The software team, led by Alex Miller, will spend much of this phase developing a content delivery network (CDN) - this will mostly be on the server side. The software team will also build the plumbing (remote logging, updates, etc.) for the client to operate in whatever agent environment is chosen.

6.5.1.4 Updates to the Client

The Edison phase will see rapid development in the client. Grid+ will hire two additional software engineers, primarily for development of the client. This client will have bare minimum functionality (signup, open payment channels, withdrawals).

The software team will also spend more time on the REST API of the Grid+ hub, which will be similarly limited in functionality. The end of this phase will be marked by a v1.0 release on the releases page[77] of the Grid+ client.

6.5.2 Phase 2: Tesla Epoch (Q2 2018 - Q1 2019)

During this period, Grid+ plans to acquire 100,000-200,000 customers in 2-4 markets and will increase the liquidity of the BOLT token by decreasing transaction fees through the establishment of a Raiden hub.

6.5.2.1 Scalable Hardware Production

After reaching a v1.0 of the Grid+ agent client, Grid+ will establish an improved production process for the hardware. This process will need to scale to 100,000 devices and will require at least two full time manufacturing engineers to ensure Grid+ can meet production quotas.

[76] Grid+ Client, https://github.com/GridPlus/client
[77] Grid+ Client, Releases, https://github.com/GridPlus/client/releases

6.5.2.2 More Utilities

During the Tesla phase Grid+ will create 1-3 more utilities in targeted regions. This will ensure the process to create utilities is scalable. Long term, Grid+ hopes to open many utilities worldwide, and this is only possible if with a sufficiently streamlined expansion process. Grid+ will need to contract with several more marketers who are familiar with the respective local regions.

6.5.2.3 Raiden Hub

Once Grid+ has acquired a sufficient number of customers, it will begin utilizing BOLT liquidity (BOLTs are only created when customers make deposits) by establishing a Raiden hub. This is both to introduce a new revenue stream (from generalized state channel fees) and also to make Grid+ more efficient (migrating simple, custom payment channels to the Raiden network).

This will make Grid+ a prominent hub for stable token (USD) commerce. This will be a big step in facilitating mass adoption of the Ethereum network for payments.

Alex Miller will oversee the software team’s phased migration to the Raiden hub. Grid+ will bring in subject-matter expertise from ConsenSys to assist in making a smooth transition. This is one of the biggest advantages of being a ConsenSys Formation - Grid+ will have continued access to some of the best developers in the Ethereum ecosystem.

6.5.2.4 Better Decisions from More APIs

During this phase, Grid+ will allow optional API data feeds to send encrypted information to the agent. This will allow better decision-making and more efficient energy usage. Grid+ will need to scale its software team to develop the client, expand the API, create an SDK, and make the web system more scalable.

The Tesla Epoch will be marked by a v2.0 release of the Grid+ client.

6.5.3 Phase 3: Musk Epoch (Q2 2019 and beyond)

This will be the final of the first three phases, during which Grid+ will globally expand its utilities network and sign up many more customers. At this point, Grid+ must have a scalable process in place to facilitate this expansion.

6.5.3.1 Full Hardware Production Scalability

During this phase Grid+ will need to establish a production process to allow for millions of devices to be manufactured. This must be extremely scalable and will require a large ramp-up in hiring hardware engineers and process managers. Because Grid+ will likely need to contract with multiple hardware manufacturers, it is important for the agent to be built from sufficiently commoditized parts.

6.5.3.2 Agent AI Optimization

With the client software at v2, Grid+ will now dedicate much of its software development time to optimizing agent decision-making by designing better artificial intelligence to leverage incoming API data from sufficiently abstracted data feeds. This will require scaling the software team to include data scientists and AI experts. This will likely happen in several stages and at that time Grid+ will likely draft an updated roadmap.

6.5.3.3 International Utilities Expansion

While Grid+ will be forming many more utilities in the U.S., it will also look to expand globally in targeted regions. This will require growth of the strategy team, which is overseen by Mark D’Agostino.

6.6 Use of Funds

Funds from the token sale will be used in several ways over several Epochs detailed in the roadmap. (Figures 14-16) It is estimated that Grid+ will spend ~$12mm through the Edison Epoch, $36mm during the Tesla Epoch, and $52mm during the Musk Epoch. While building a hardware and software product, Grid+ will also be required to put down deposits in order to form utilities in every region of operation. Once a Raiden hub is established, Grid+ will likely convert much of its ether to BOLT tokens in order to increase liquidity for stable coin commerce. However, it will also maintain ether liquidity in the same Raiden hub. If Grid+ has excess funds after setting up retailers in all targeted deregulated markets, it will increase both ether and BOLT liquidity in its Raiden hub.

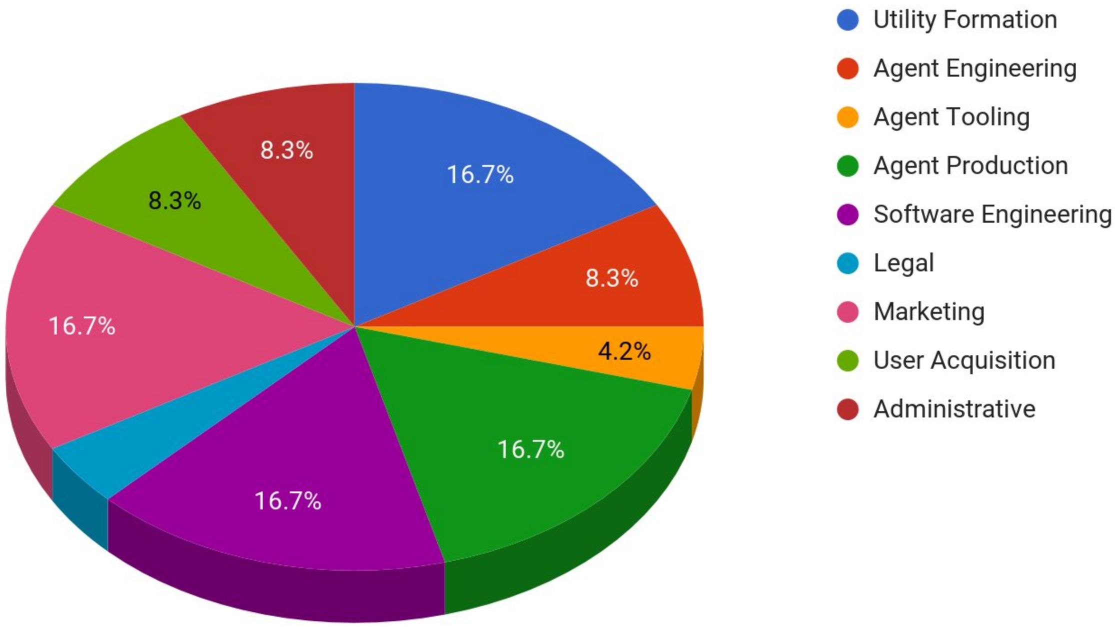


Figure 14: Use of token sale funds during Edison Epoch

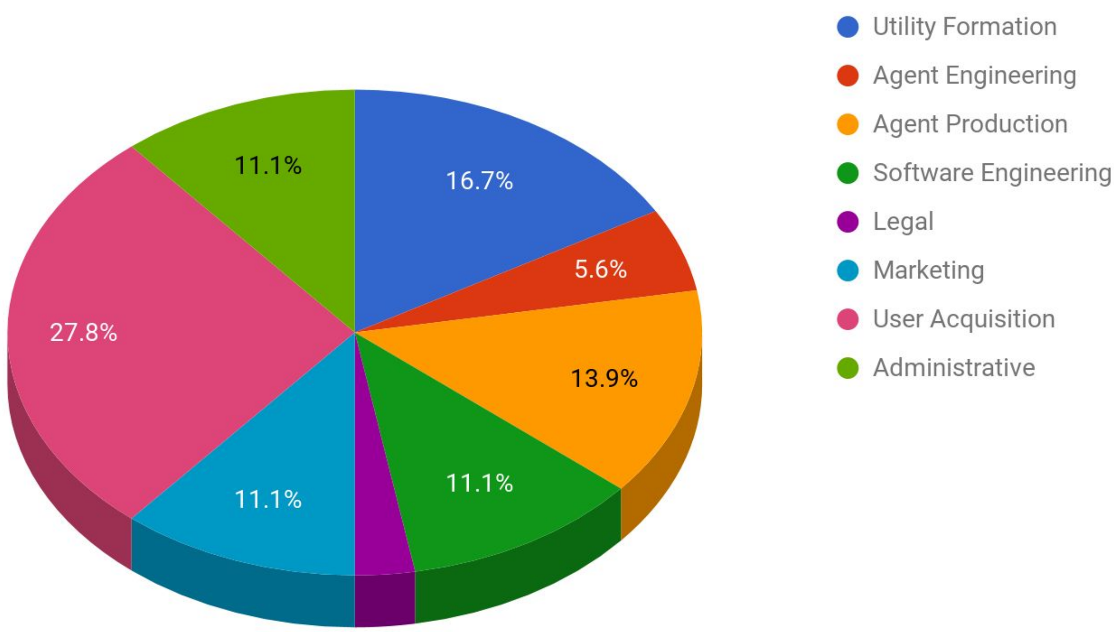


Figure 15: Use of token sale funds during Tesla Epoch

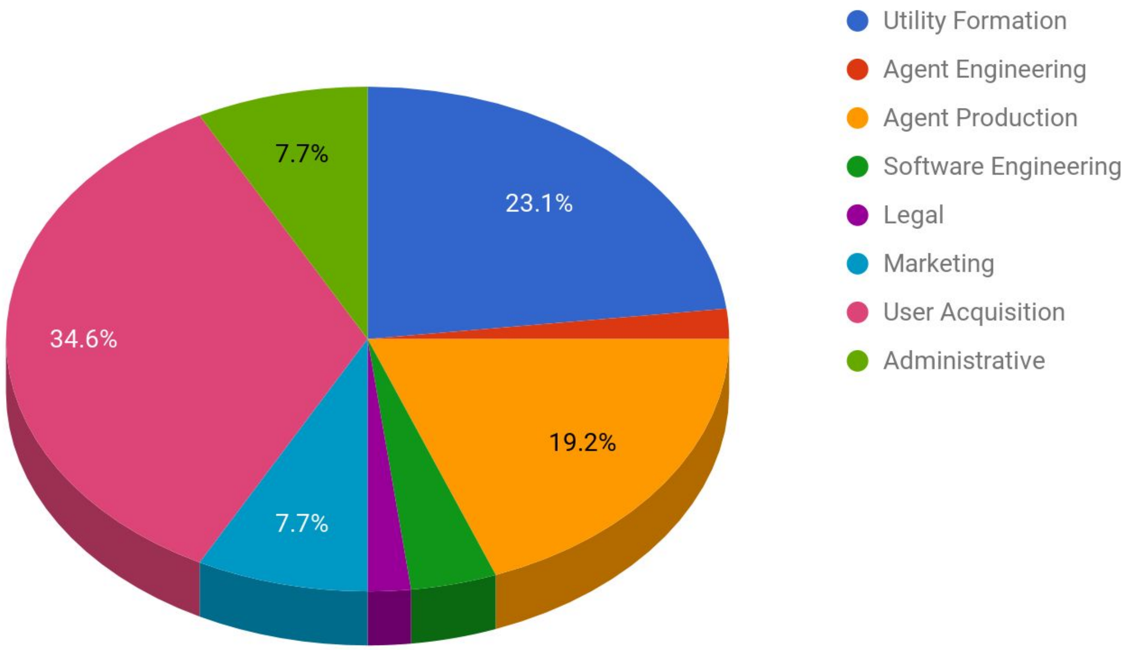


Figure 16: Use of token sale funds during Musk Epoch

6.6.1 Forming Utilities

It is contemplated that a plurality of ether accepted will go toward forming retailers in specifically identified deregulated markets. The first utilities will likely be in Texas, California, and New England. There are many factors that go into this decision, but the most significant ones are smart-meter penetration, regulatory friendliness, and price of electricity - higher prices means more room for competition (Figure 17). After starting in the US, Grid+ will seek to expand internationally to strategic regions. Right now, the best candidates are Australia, Germany and the UK but there are many other possibilities.

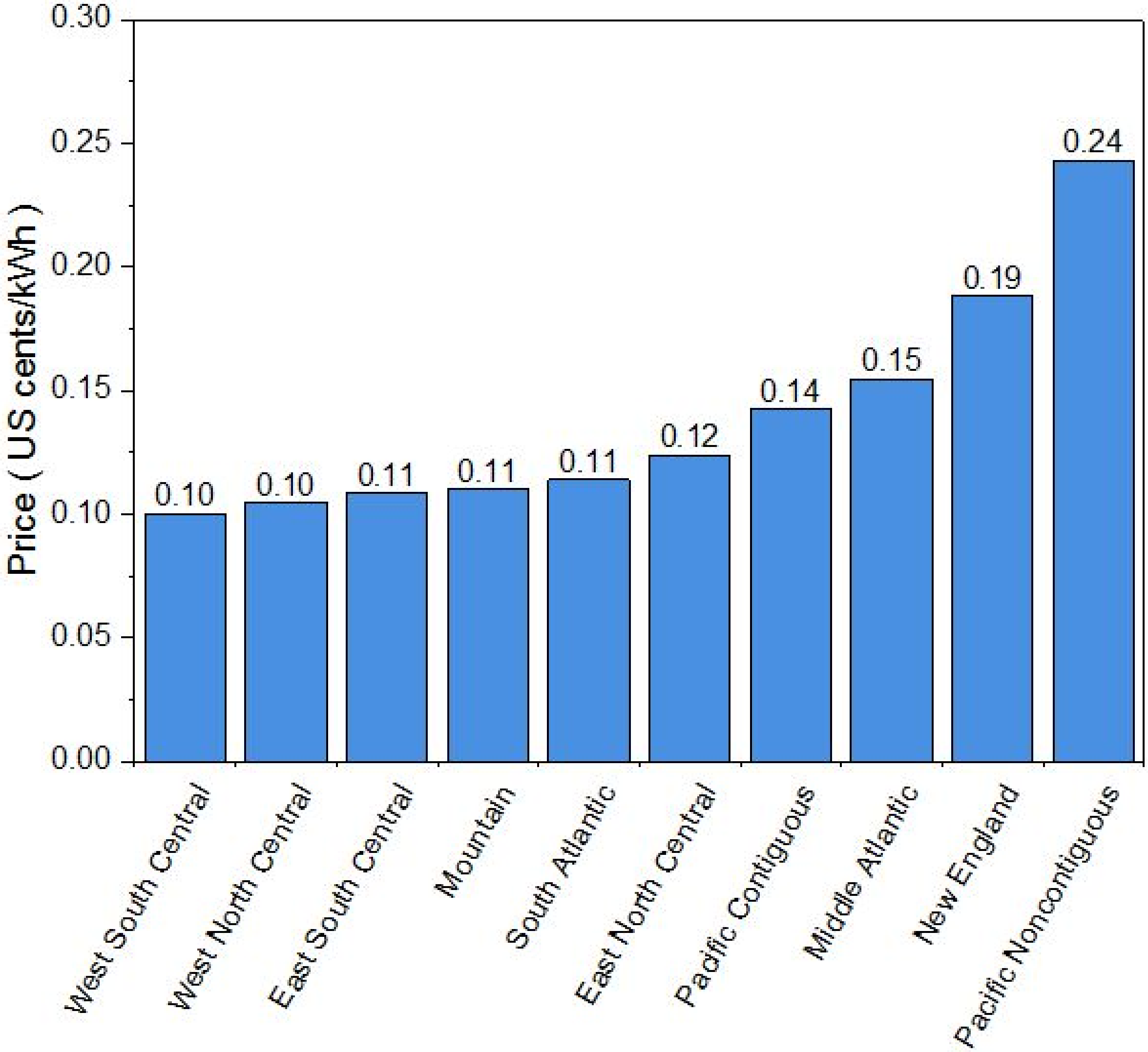


Figure 17: Regional Average Prices of Electricity in United States [78]

The creation of a retailer requires a large deposit, which sits in escrow. This number is greater than $1 million for many regions. It is important to reiterate that these funds are not be "spent", but rather deposited.

6.6.2 Legal Work

Grid+ has been working closely with Matt Corva, general counsel for ConsenSys. Matt has intimate knowledge when it comes to the tokenized ecosystem in Ethereum, having worked closely alongside Coinbase to draft "A Securities Law Framework for Blockchain Tokens".[79] Matt

[78] https://www.eia.gov/electricity/monthly/
[79] Corva, Matt. "A Securities Law Framework for Blockchain Tokens." *Coinbase*. (7 Dec. 2016) https://www.coinbase.com/legal/securities-law-framework.pdf

also led all of the legal work for the Gnosis team, along with top global law firms, to structure their two-token utility system in a legally compliant manner. Matt plans to help put together a legal team and provide guidance for Grid+ as it expands operations to ensure Grid+ is always compliant with all laws pertinent to the jurisdictions in which it operates.

6.6.3 Marketing

In the short term, Grid+ plans to spend a relatively large amount on marketing to acquire its initial customer base. Grid+ will advertise in a highly targeted geographic region and to a highly targeted demographic. As the brand gains more notoriety, Grid+ will move to minimal marketing/advertising and will let its low energy prices speak for themselves.

Many reading this white paper can attest to the evangelistic effects of a tokenized economy. Grid+ imagines GRID token holder-evangelists will do a better job marketing the Grid+ platform than Grid+ can do on its own. Even those who are not GRID holders, but are Ethereum enthusiasts, will help push the platform because Grid+ uses the Ethereum rails from start to finish. Adoption of Grid+ by definition means adoption for public Ethereum. Grid+ foresees a grassroots viral marketing craze propelling Grid+ into mainstream media.

6.6.4 Product

The final area where Grid+ plans to deploy substantial resources is in the further development of the Grid+ system. Grid+ has a working demo application and has prototyped the hardware product, but this will be an iterative process to create and test. Grid+ will need to grow its team and bring together hardware specialists, software engineers, and Ethereum experts to ensure it can build a safe, reliable, and desirable agent device.

7 Experience and Team

Prior to the advent of the Frontier[80] deployment of the Ethereum public chain on July 30th 2015, ConsenSys had already been building and testing applications for the energy ecosystem. The first project began in May of 2015, which was a ConsenSys-led joint venture to construct the TransactiveGrid.[81] Championed by ConsenSys Enterprise partner John Lilic and senior technologist Dr. Christian Lundkvisk, the TransactiveGrid proved that electrical energy could be tokenized on Ethereum and transacted across a distributed network.

Through the Brooklyn TransactiveGrid project of 2015, ConsenSys came to the realization that the public Ethereum blockchain infrastructure was seriously deficient, and thus discontinued the project in 2016. Since then, the ecosystem has experienced rapid growth in developer infrastructure. Tools such as Truffle[82], MetaMask[83], INFURA[84], and MyEtherWallet[85] allow

[80] Ethereum Frontier Guide, https://ethereum.gitbooks.io/frontier-guide/content/
[81] DEVCON1, TransactiveGrid, https://www.youtube.com/watch?v=kq8RPbFz5UU
[82] Truffle, http://truffle.readthedocs.io/en/latest/
[83] MetaMask, https://metamask.io/

developers to rapidly prototype Ethereum applications and seamlessly integrate them into the user's browser.

Since the TransactiveGrid, the ConsenSys Energy team has been engaged in a number of projects with various utilities around the world. ConsenSys began joint development on a platform called Co-tricity[86] alongside RWE Group[87], which was recently rebranded as Innogy.[88] This joint development helped validate assumptions about the energy markets and demonstrated the expanded roles utilities can play in a world with decentralized grid infrastructure.

For the past 12 months, the ConsenSys Energy and Enterprise teams have serviced multiple Fortune Global 50 Energy companies. ConsenSys has built models akin to the TransactiveGrid, albeit utilizing much more scalable design patterns. During these pilot projects ConsenSys developed two fully decentralized exchanges, one using a continuous auction model and the other using batch/uniform pricing. ConsenSys also explored the intersection of IoT and Ethereum, giving smart-batteries the ability to utilize ECDSA (Elliptic Curve Digital Signature Algorithm), specifically the secp256k1 curve, by signing and broadcasting Ethereum transactions on behalf of their owners. One Enterprise project, which involves swarms of smart batteries, is currently in the pilot phase with code running in a production environment in the homes of select participants in Europe.

The ConsenSys Enterprise group lives by the modus operandi of 'customer led development'. This ensures that ConsenSys enters engagements with open minds and that it learns from its clients, who are the true subject matter experts in their industries. Many startups, especially those in the blockchain ecosystem, fail to achieve increased efficiency by naively applying new technology to existing industry processes. ConsenSys brings Ethereum expertise to industry leaders and learns from their experiences. ConsenSys has spent two years working with some of the brightest minds in the energy space, which has culminated in the formation of Grid+. The Grid+ team leverages experience from other ConsenSys teams, Ethereum startups, and massive Fortune Global 50 energy companies to design a system that will fundamentally change the way consumers interact with their energy providers.

[84]INFURA, https://infura.io/
[85]MYEtherWallet, https://www.myetherwallet.com/
[86]DEVCON2, Co-Tricity https://consensys.net/static/devcon2/cotricity/Cotricity_Master_Slides.pdf
[87]RWE Group, https://www.rwe.com/web/cms/en/8/rwe/
[88]Innogy, https://iam.innogy.com/en/ueber-innogy

7.1 Team:

7.1.1 Alex Miller

Alex is a software engineer with a background in applied physics. He discovered Ethereum in 2015 when he was working for a fin-tech startup that moved ~$2 payments between users with traditional payments infrastructure. He left that world for the greener pastures of permissionless innovation and joined ConsenSys in 2016. He has been the technical lead on multiple Fortune 500 Enterprise energy client engagements and has a passion for developing Ethereum and IoT infrastructure.

7.1.2 Karl Kreder

Karl recently graduated from The University of Texas at Austin, where he received his PhD in Materials Science researching advanced battery technologies. Prior to attaining his PhD, Karl worked at Southwest Research Institute where he started the Energy Storage System Evaluation and Safety (EssEs) consortium which performed testing, characterization, and research on large format lithium ion batteries for >10 kWh energy storage. The EssEs consortium had 12 industry members from 3 continents with a budget of more than $3mm. Before joining full time, Karl served as a subject matter expert advisor for the Energy group at ConsenSys. He is now the resident energy guru for all energy-based projects.

7.1.3 Mark D’Agostino

Mark has spent the past decade in management consulting, specifically focused on the financial services industry. Prior to joining ConsenSys as a managing partner in the Enterprise group, Mark built out Deloitte’s blockchain market offering. He has successfully delivered Ethereum-based applications to Fortune 500 banks, global energy companies and governments. Over his career, he has served clients such as AIG, BlackRock, Citi, GE, JPM, Lehman Brothers, MasterCard, and Pfizer. He has been the ConsenSys lead for all Energy consulting engagements and has worked closely with a number of utilities and global energy companies. Mark has decided to step back from an Enterprise delivery role to spend more time focused on product development and strategic leadership within ConsenSys.

7.1.4 Claudia Pop

Claudia is a PhD student and a teaching assistant, at Technical University of Cluj-Napoca, Romania. She likes exploring the computer science world, thus she went from building sumo robots to implementing projects to digitize the local community and got involved in European research projects. She is passionate about her teaching role at the University and always tries to have an impact. Besides her interest in computer science, she enjoys hiking, cooking and singing.

7.1.5 Rachel Epstein

Rachel recently graduated from Cardozo Law School with a law masters degree specializing in Intellectual Property law. While at Cardozo she worked as a researcher for Professor Aaron Wright on a book about the legal implications of blockchain technology and assisted in providing legal help for NYC based startups as part of the Cardozo Tech Startup Clinic. Rachel is passionate about the legal policies developing around the implementation of blockchains and enjoys writing about the tokenization of securities. She joined ConsenSys's legal team in 2017.

7.2 Advisors

7.2.1 Joseph Lubin

Joe is a co-founder of Ethereum and the founder of ConsenSys. He has an academic background in Electrical Engineering and Computer Science from Princeton University and has research experience in the field of Robotics Learning. Joe is a former VP of Technology at Goldman Sachs in the Private Wealth Management Division.

7.2.2 Jeffrey Char

Mr. Char is a serial entrepreneur and investor. He is Founder and CEO of J-Seed Ventures, Inc. and Chief Mentor of Venture Generation, a Tokyo-based venture community. He is also Director of Corporate Venture Capital and a member of the Innovation Task Force at Tokyo Electric Power Company (TSE: 9501). Mr. Char is also an adjunct professor who teaches entrepreneurship at IE Business School in Spain. He founded and built several successful ventures including Sozon, an online marketing company sold to ValueCommerce (TSE Mothers: 2491), Solis, a domain registrar sold to GMO Internet (TSE: 9449), SSK Technology, an electronics component company sold to Suzuki Manufacturing, and Pario Software, a network security company sold to Lucent Technologies (NYSE: ALU). Prior to becoming an entrepreneur Mr. Char was a corporate attorney in Silicon Valley and securities research analyst in Tokyo. He studied economics at Sophia University in Tokyo and law at the University of California, Berkeley and Harvard Law School.

7.2.3 Rikiyai Abe

Professor Abe has a degree in Electronics Engineering from the University of Tokyo and a PhD from the University of Kyushu. Formerly, he has had roles at J-POWER, a Japan-wide wholesale power company; and the Electric Power Research Institute (EPRI) as a visiting researcher to the United States. Since 2008, Professor Abe has focused on Technological Management for Innovation (TMI). Since June 2012, Professor Abe has served as Co-Chair of the Presidential Endowed Chair at the Electric Power Network Innovation by Digital Grid, at the University of Tokyo. Professor Abe has developed the digital grid concept, which represents a "power Internet". He is also a Representative Director at the Digital Grid Consortium. His interests include renewable energy, energy storage and smart grid.

7.2.4 John Lilic

John has been working at the intersection of distributed energy resource development and blockchain technologies since 2013 with past projects that include the Brooklyn Microgrid, the TransActive Grid, Project Exergy, collaboration with RWE/Innogy as well as helping drive engagements and interactions with utilities and power companies around the world as they explore Ethereum and its value proposition to the grid.

7.2.5 Matt Corva

Matt Corva is General Counsel for ConsenSys. Matt is particularly interested in the disruption triggered by decentralizing technologies and the implications of that disruption on legacy legal frameworks. In addition to overseeing ConsenSys legal issues, Matt frequently speaks at conferences and educates large law firms on Ethereum and blockchain technology. Matt holds a law degree from Washington and Lee University and is licensed to practice in New York.

7.2.6 Igor Lilic

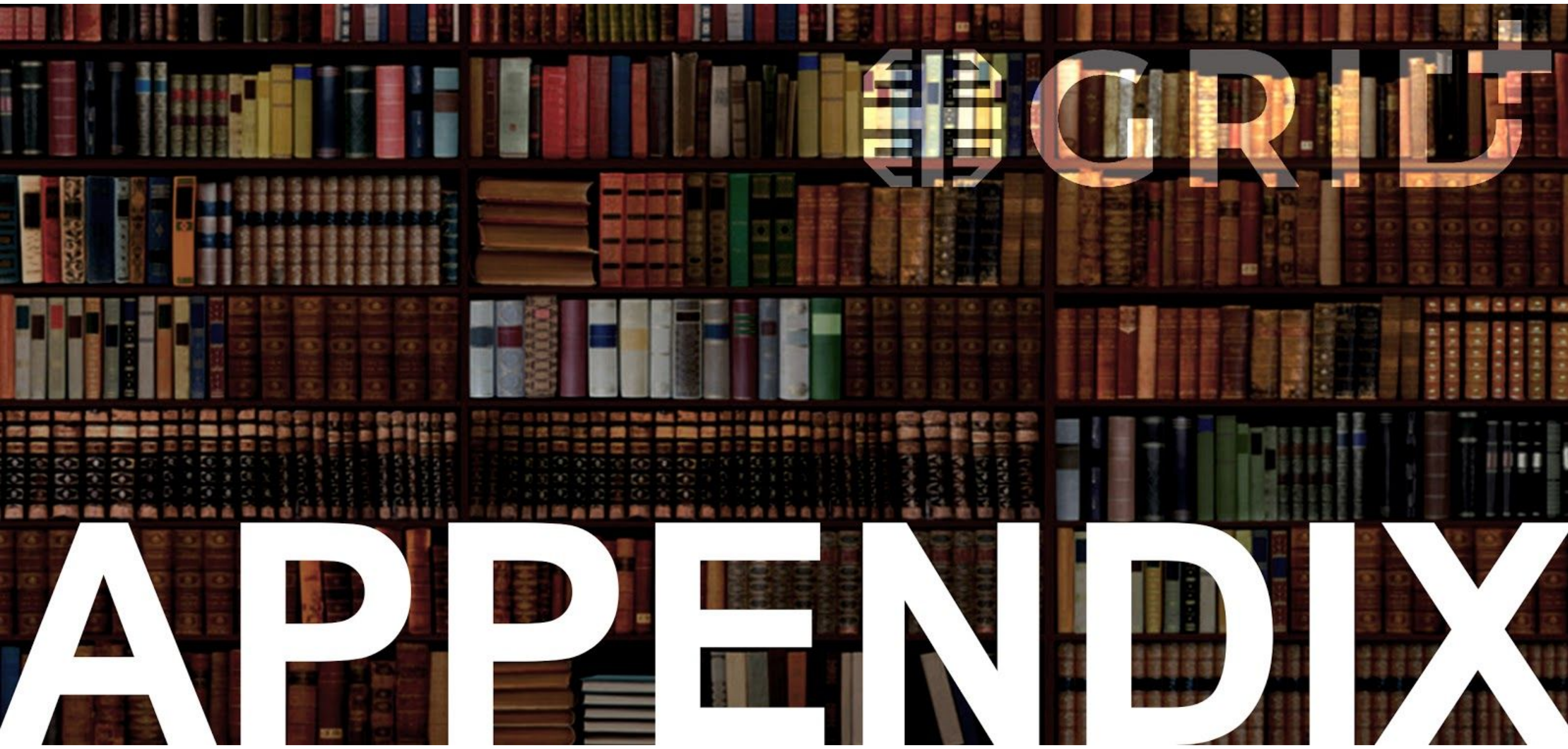
Igor is a full-stack software engineer at ConsenSys, formerly a senior consultant at ThoughtWorks, software development engineer at Amazon Web Services, OANDA, SAP and AMD. He is the CTO and co-founder of the Enterprise group at ConsenSys and has been active in the crypto space since 2012. Igor wrote the Proof of Physical Address (PoPA) system and has been integral in the delivery of most client engagements at ConsenSys. He helped structure ConsenSys' largest Energy delivery to date and is currently shifting focus to product development.

7.2.7 Mike Goldin

Mike began working on applications for the Ethereum blockchain during the summer of 2015 as an intern at ConsenSys, where he worked on the smart contract backend for Ujo Music. He joined ConsenSys full-time after graduating from Columbia University with a degree in computer science. He worked as a software developer and architect in the ConsenSys Enterprise group where he built complex simulations to be used in distributed energy applications. He is now the technical lead for ConsenSys AdTech.

7.2.8 Bashar Lazaar

Upon graduating from Babson College with a B.Sc., Bashar has focused his early career in structuring energy projects across the Middle East and North Africa combining knowledge in finance and renewable energies to deliver financial engineering for utility scale PV & Wind power plant development in the MENA region. While employed at SunEdison, Bashar took a keen interest in Ethereum's potential implementation within the energy sector, and made a shift to ConsenSys, where he contributed to launching its MENA operation and establishing the Dubai office. Bashar currently serves as an advisor and financial engineer for the Grid+ team.



8 Appendix

8.1 State Channels Research

[How offchain trading will work]()	Martin Koeppelmann
[Ethereum Lightning Network and Beyond]()	Robert McCone
[State Channels]()	Jeff Coleman
[Raiden: Scaling Out With Offchain State Networks]()	Heiko Hees
[Epicenter Bitcoin: State Networks]()	Jeff Coleman
[Universal Payment Channels]()	Jehan Tremback

Scalability via State Channels	Martin Koeppelmann
Ethereum: Platform Review (page 30)	Vitalik Buterin
Sparky: A Lightning Network in Two Pages of Solidity	Dennis Peterson
An Introduction to State Channels in Depth	Ameen Soleimani
State Channels Wiki	Jeff Coleman
Gamble Channels: Fast Verifiable Off-Chain Gambling	Denis Peterson
Toy State Channels	Jeff Coleman
Raiden Network	Brainbot
Machinomy	Sergey Ukustov

8.2 Tesla Powerwall Payback Calculations

ROI Overview					
Total Cost		Yearly Revenue		**Payback Period (Years)**	
14kWh Powerwall	$5,500				
Supporting Hardware	$700	Days/Year	365	Total Cost	$7,600
Average Installation Cost	$1,400	Revenue/Day	$3.50	Revenue/Year	$1,277.50
	$7,600		**$1,277.50**		**5.95**
Revenue Calculations					
6-8AM to Charge (Daily Revenue)		4-6pm Peak Sale (Daily Revenue)		**Combined Revenue**	
Energy Cost (kWh)	$ (0.10)	Energy Cost (kWh)	$0.15	Charge	$1.40
Powerwall Size	14 kWh	Powerwall Size	14 kWh	Sell	$2.10
	$1.40		$2.10	**Total**	**$3.50**