e⁻Lab Summit

welcome pre-read

NEW MEXICO 2017

welcome

to New Mexico and to our second annual e-Lab Summit — the most expansive convening hosted by Rocky Mountain Institute as part of our Electricity Innovation Lab (e-Lab). Over the next 48 hours, you'll be joining 150 fellow decision makers and practitioners from across the U.S. and around the world to advance the most critical questions we face in transitioning to a cleaner, more distributed, and more resilient electricity system.

As the name suggests, e-Lab is a laboratory, a forum for working together in the spirit of experimentation and co-creation. We will be addressing eight timely topics for transforming the electricity system through discussion "pods." You have been invited to participate because you and your organization bring a unique perspective, critical expertise, and important resources to advance the concepts we will be working to develop.

This year's e-Lab Summit is designed to:

- Frame and advance actionable strategies to address the most pressing industry needs
- Support key individuals and teams to address and affect change
- Create and strengthen relationships amongst industry leaders and innovators to support meaningful action

e-Lab Summit is a unique event, but even more so a unique process. We invite you to be curious, to question your assumptions (and others'), to seek the unique perspectives of your fellow participants, and to critically and honestly assess the strengths and weaknesses of our collaborative work.

We wish you a productive three days and great success, both for work here at e-Lab Summit and beyond.

The e-Lab team

agenda

MONDAY OCT. 2ND

11:00 am / registration
1:00 pm / kickoff
2:00 pm / pod session #1
3:30 pm / break
4:00 pm / plenary
5:00 pm / networking
6:30 pm / dinner
8:30 pm / optional activities

TUESDAY OCT. 3RD

6:30am / optional activities
7:30 am / breakfast
8:30 am / plenary
9:00 am / case clinics
10:00 am / break
10:30 am / pod session #2
12:00 pm / learning sessions
1:00 pm / lunch & paired walk
3:00 pm / pod session #3
5:00 pm / plenary
6:00 pm / break
7:00 pm / dinner
8:30 pm / optional activities

WEDNESDAY OCT. 4TH

6:30am / optional activities
7:30 am / breakfast
8:30 am / plenary
8:45 am / shift & share
10:00 am / break
10:15 am / pod session #4
12:00 pm / plenary close
1:00 pm / adjourn

logistics

TRANSPORTATION — You will be provided a complimentary Uber ride from the airport to the Tamaya Resort (specific instructions were emailed to you). Return shuttle service will be provided to the airport.

REGISTRATION — After checking in with the hotel, please proceed to our registration desk in front of the Tamaya Ballroom. Registration starts at 11 am.

DRESS CODE — e-Lab Summit is a casual event (think: jeans). Mornings and evenings will be chilly and some activities are outdoors, so please plan accordingly.

PARTICIPANT CONTACT BOOK — A full list of participants is included at the end of this document. We will be distributing contact information after the event.

QUESTIONS — For any logistics questions beforehand or en-route, please contact our event services company, Black Badger Events, blackbadger303@gmail.com or (603) 714-0124.

pod topics

- Smart Heating Electrification
- Infrastructure Planning and New Mobility
- Blockchain and Transactive Energy
- Rate Design Pathways
- Value Stacking for DERs
- Distributed Grid Infrastructure
- Utility Business Model Pathways
- LMI-Focused Utility Business

your pod's pre-read is in next section

blockchain and transactive energy

A Blockchain Breakthrough for DER and Transactive Energy?

introduction and objectives

context

Our hypothesis is that DER, smart grid technology, the internet-of-things, and emerging approaches to cybersecurity have matured to the point that they put an idealized electricity system design within reach. By "idealized", we are referring to the following characteristics:

- Lowest total system cost;
- Deep decarbonization; accomplished via a combination of energy efficiency, high penetration of renewables, and increased demand side flexibility;
- Resilience against physical and digital threats ;
- Increased options for customer participation and choice.

Despite the existence of many of the building blocks of this idealized system, several challenges hold us back. Managing an order-of-magnitude larger number of assets is complex and expensive; much of our electricity system remains "dumb" (i.e., most of our electrical devices are incapable of communicating with the grid and responding to price signals); and our market and regulatory structures are designed for a 100-year-old paradigm.

questions to explore

- **Is a transactive energy system (devices, buildings, and industrial assets trading with each other at the grid-edge) the best way to achieve an idealized electricity system (lowest-cost, decarbonized, resilient, and customer-centric)?**
- **Could blockchain technologies be a critical enabler for such a system?**
- **How can we move from theory to action; what are the key elements needed to deploy a transactive energy system at scale (and what role would blockchain play, if any)?**

pod objectives

Gaining a better understanding of the technology and its potential

- “Good discussion that raises the important questions in the transactive paradigm, and helps to understand whether blockchain is the right ‘hammer’ for the ‘nails’ that need to be pounded”
- “Better understand intricacies involved with effectively trading energy on blockchains (and) a clear appreciation of the incentive structures required to motivate the diverse set of stakeholders to participate”
- “Practical use cases for utilizing block chain in energy markets, with value quantification”
- “Background on how blockchain is being considered in the energy sector today and a robust discussion and rough consensus on the questions you have asked”
- “See whether others, particularly utilities and RTO/ISOs, also see the technology as an opportunity or if they view it as competition”
- “Technical understanding of how blockchain will enable a transactive energy network, and whether the value will outweigh the costs of implementation”

pod objectives

Laying the groundwork for "proof-of-concept" implementation

- "Spark collaboration on a real-world demonstration project that shows the potential for transactive energy and blockchain to help deliver a lower-carbon, lower-cost, more secure system"
- "Form a team that will produce a PoC for one or two specific areas (e.g., cybersecurity and p2p trading)"
- "Understand technical path forward for realizing a scalable system that 'fits'"
- "Concept that could be explored by one or more attendees through a development program."
- "Understand what may be needed to get utilities and other market participants to buy in to a strategy of working together to implement blockchain and advocating for regulatory changes that may be required"
- "Clear picture of the road forward for blockchain in the energy space, and how I can help to foster the development of transactive energy systems"
- "See the mechanism between energy, capacity and reserve products roll up to a transactive market"

transactive energy and blockchain basics

what is transactive energy?

From *"A society of devices"*, Koen Kok and Steve Widergren
(IEEE Power and Energy Magazine, April 2016)

...Smart homes, buildings, and industrial sites engage in automated market trade with others at the distribution system level and with representation of the bulk system. Communications are based on prices and energy quantities in a two-way negotiation.

Operation of devices is optimized economically by a local intelligent controller (or agent) under the control of the end user. This controller receives price information and takes the device state and user preferences into account to operate local demand and supply resources.

Before the price reaction takes place, the local controller communicates the available flexibility combined with their preferences and conditions to an electronic marketplace through a market transaction (price/quantity bid). Consuming devices communicate their willingness to pay, while producing devices communicate the price for which they are willing to produce.

Since all resources participating in the market communicate their intended reaction to a range of price levels, the pool reaction to a range of price signals is known up front and the market mechanism can determine the price for an appropriate balance of supply and demand.

From the end user's or energy consumer's point of view, the local energy management system agent acts on behalf of the user or consumer to bid into the market and reacts to the resulting market price signals. No direct outside control is involved here. However, from a system perspective, the participants engage in coordinated control actions. With this approach, demand response moves from influencing, with an uncertain overall response, into market-based control with a collaboratively derived dynamic price as a control signal to trigger a predictable system reaction.

When properly implemented, the market bids sent by the end users' energy management systems can be aggregated together. When this is done for two devices, the resulting bid represents the preferences of the two devices together. The message size of the aggregated bid curve is a simple combination of the individual device bid curves. Using this property, a highly scalable system can be obtained when, in a response cluster, bids are aggregated together. The processing and communication time then scales with the height of the aggregation tree instead of with the number of devices participating.

In summary, TE approaches are able to access the full response potential of flexible devices, provide greater certainty about the momentary system reaction, realize an efficient market with proper incentives, and protect the privacy of the end user whose devices participate in the energy management task.

"A set of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter."

- Gridwise Architecture Council

Olympic Peninsula Demonstration, 2006-2007

Objective

Test the potential for flexibility offered in coordinating distributed energy resources to postpone or remove the need for a transmission upgrade.

Project description

The project used a 5-min double- auction market technique to coordinate four large municipal water pumps, two backup diesel generators, and residential demand response from electric water and space heating systems in 112 homes.

The market received supply bids from the utility based upon a markup of the wholesale price of energy in the area. The diesel generators' bid was based on the actual fixed and variable costs incurred for operation. The pumps' bid into the market was based on water-reservoir levels that they were designed to regulate. And the residential demand-response equipment allowed the households to specify their automatic price-response preferences (from "most comfortable"/ non-price-responsive to "greatest economy"/ highly price-responsive). The 5-min market determined the clearing price for energy and broadcast that to the market participants. Each participant's bidding equipment would operate based on whether their bid was higher or lower than the market-clearing price.

Results

The project established the viability of TE to achieve multiple objectives: system peak load and distribution constraint management; wholesale price purchases by the utility; and residential, commercial, and municipal energy cost savings.

The system also managed congestion on a distribution circuit, by managing all of the devices as if they were on one circuit and seasonally adjusting the capacity setting of that circuit to exercise constrained operating conditions. The project controlled the imported capacity of the circuit below the constraint for all but one 5-min interval over the entire project year.

Source: Koen Kok and Steve Widergren, *"A society of devices"*, IEEE Power and Energy Magazine, April 2016

transactive energy projects

AEP Ohio gridSMART Real-Time Pricing Demonstration, 2010–2014

Objective

Test the potential for devices to respond to peak-shaving conditions.

Project description

The project used a 5-min double-auction market to dispatch participating responsive loads on four distribution circuits. the preferences of household occupants were reflected in software agents that developed an overall price flexibility curve for the household and coordinated device control actions (HVAC units).

A market-clearing engine at the operations center aggregated the bids from all households to form a price-sensitive demand curve for the distribution circuit and calculated a clearing price and a supply bid, which incorporated PJM's 5-min wholesale locational marginal price (LMP). The clearing price was broadcast back to the households and captured in the billing system according to a tariff approved by the regulator.

Results

Wholesale purchases and household bills each reduced by about 5%.

Source: Koen Kok and Steve Widergren, *"A society of devices"*, IEEE Power and Energy Magazine, April 2016

Pacific Northwest Smart Grid Demonstration, 2010-2015

Objective

Improve reliability, energy conservation, efficiency, and demand responsiveness. Mitigation of renewable energy intermittency and flattening of system load.

Project description

Coordination of a regional response across 11 utilities, involving interaction between multiple nodes (each representing one or more electrically connected resources) to exchange information about the quantity of energy estimated to be produced or consumed and the cost of that energy. A time series of information is exchanged so that the nodes negotiate operation not only in the next interval but optimize their operation over the time horizon of the time series.

Internally, the node manages the resources under its purview to see that their needs and flexibility are properly reflected in the negotiation. the system of nodes iterates exchanging information for each operation's time step until the difference in incentive price and energy exchange between each neighbor converges.

In addition, the project used a simulation model of the regional system to assess the impact of a scaled-up deployment of the transactive system

Results

The simulation showed that the region's peak load might be reduced by about 8% if 30% of the region's loads were responding to the transactive system. Project also demonstrated that distributed assets can respond dynamically on a wide scale.

Source: Koen Kok and Steve Widergren, *"A society of devices"*, IEEE Power and Energy Magazine, April 2016

transactive energy projects

PowerMatcher

Objective

The two main application fields of the PowerMatcher technology are in market operations and in active distribution network management. The operations of these two subsystems are highly separated in Europe, and PowerMatcher approaches these as two separate control objectives.

Project description

The project has been installed in approximately 1,000 households and industrial sites to integrate numerous small electricity-consuming and -producing devices in the operation of the electricity infrastructure.

End-customers who own the domestic appliance, electrical car, and/or industrial installation offer the operational flexibility needed for a smart and sustainable electricity grid. This selling is completely automatic using a piece of intelligent software installed at the premises of, and running under the authority of, this end customer. This intelligent agent trades on behalf of the end customer. Uniformed data messages exchanged are stripped of specific local information. Only aggregated information regarding power levels and prices is exchanged, protecting privacy.

Results

Across different projects: wind imbalance reductions of 40-80%; distribution system peak load reduction of 30-50%; making 20% of water pump power consumption shiftable in time. Based on project results, the value of end user flexibility in The Netherlands may reach an estimated €3.5 billion.

Source: Koen Kok and Steve Widergren, *"A society of devices"*, IEEE Power and Energy Magazine, April 2016

What is blockchain?

From "A gentle introduction to blockchain technology"
Bits on Blocks, Antony Lewis, 2015

People use the term 'blockchain technology' to mean different things, and it can be confusing. Sometimes they are talking about The Bitcoin Blockchain, sometimes it's The Ethereum Blockchain, sometimes it's other virtual currencies or digital tokens, sometimes it's smart contracts. Most of the time though, they are talking about distributed ledgers, i.e. a list of transactions that is replicated across a number of computers, rather than being stored on a central server.

The common themes seem to be a data store which:

- usually contains financial transactions
- is replicated across a number of systems in almost real-time
- usually exists over a peer-to-peer network
- uses cryptography and digital signatures to prove identity, authenticity and enforce read/write access rights
- can be written by certain participants
- can be read by certain participants, maybe a wider audience, and
- has mechanisms to make it hard to change historical records, or at least make it easy to detect when someone is trying to do so

I see "blockchain technology" as a collection of technologies, a bit like a bag of Lego. From the bag, you can take out different bricks and put them together in different ways to create different results.

What's the difference between a blockchain a a normal database? Very loosely, a blockchain system is a package which contains a normal database plus some software that adds new rows, validates that new rows conform to pre-agreed rules, and listens and broadcasts new rows to its peers across a network, ensuring that all peers have the same data in their databases.

What are smart contracts?

From "A gentle introduction to smart contracts"

Bits on Blocks, Antony Lewis, 2016

What are people talking about when they talk about smart contracts? In the context of blockchains and cryptocurrencies, smart contracts are:

- pre-written logic (computer code),
- stored and replicated on a distributed storage platform (eg a blockchain),
- executed/run by a network of computers (usually the same ones running the blockchain),
- and can result in ledger updates (cryptocurrency payments, etc).

… In other words, they are little programs that execute "if this happens then do that", run and verified by many computers to ensure trustworthiness.

If blockchains give us distributed trustworthy storage, then smart contracts give us distributed trustworthy calculations. Smart contracts are one of the functionalities that sets Ethereum apart from other blockchains. I've found three helpful ways to bring them to life:

- Bank accounts with embedded instructions
- Replacing legal-ese with computer code
- An actual smart contract example

1. Bank accounts with embedded instructions: There are some elements of bank accounts that behave like smart contracts. My bank account has a balance. Every month, I have an automated payment that deducts a fixed amount and sends it to my landlady. If there isn't enough money in my bank account, the payment fails, I get fined, and another workflow is triggered. There are instructions I have set up which are associated with the account. This is similar to what a smart contract can do, except that a smart contract running on a blockchain is run by many parties rather than being controlled by a single one.

2. Replacing legal-ese with computer code: A smart contract is some code which automates the "if this happens then do that" part of traditional contracts. Computer code behaves in expected ways and doesn't have the linguistic nuances of human languages. Code is better, as there are less potential points of contention. The code is replicated on many computers: distributed/decentralised on a blockchain (more on that later) and run by those computers, who come to an agreement on the results of the code execution. The idea is that you can have a normal paper contract with all the "whereas" clauses that lawyers enjoy, and then a clause that points to a smart contract on a blockchain, saying "this is what we both agree to run and we will abide by the results of the code."

3. An actual smart contract example (on the Ethereum blockchain):

```
contract token {
    mapping (address => uint) public coinBalanceOf;
    event CoinTransfer(address sender, address receiver, uint amount);

  /* Initializes contract with initial supply tokens to the creator of the contract */
  function token(uint supply) {
        if (supply == 0) supply = 10000;
        coinBalanceOf[msg.sender] = supply;
    }

  /* Very simple trade function */
    function sendCoin(address receiver, uint amount) returns(bool sufficient) {
        if (coinBalanceOf[msg.sender] < amount) return false;
        coinBalanceOf[msg.sender] -= amount;
        coinBalanceOf[receiver] += amount;
        CoinTransfer(msg.sender, receiver, amount);
        return true;
    }
}
```

blockchain applications in the energy sector

demand response

Challenges and opportunities with demand response today...

Demand response (DR) resources produce a number of benefits in the electricity sector: reduced total capital spending on generation, transmission and distribution infrastructure; increased renewable energy penetration; and a wider pool of flexible resources for grid operators. In simple terms, DR resources can be more nimble (Korea procured over 1 GW of DR capacity in less than a year), more cost-effective (capital investment on a per-watt basis is a fraction of generation), and more precise (capable of location-specific services), than centralized supply-side resources.

In the U.S., DR capacity represents approximately 9% of peak demand but the majority of energy-using devices are unable to participate in existing markets. Globally, DR adoption is much lower. There are several structural problems that prevent the full potential of DR from being realized:

- **High overhead costs.** Manual processes feature prominently across the DR value stream and costs related to these processes represent between 40%-50% of operating expenses and 10%-30% of gross margin for utilities and aggregators. Historically as DR programs grow in size and complexity so do administration costs related to enrollment, manual management of bids, measurement and verification, and error correction.
- **Promised value often not delivered.** DR programs often rely on subjective decision-making and manual response. Utilities and grid operators have little to no visibility into how loads are behaving immediately prior to an event. Program economics become distorted by over-enrollment, a hedge against the probability that a some loads will not respond to a given event.
- **Lack of standardization and poor interoperability.** Despite standardization efforts like OpenADR, there isn't a single leading global platform or provider for device connectivity. Large enterprises, often representing the most energy-intensive industries, with facilities spread across multiple geographies, are unable to deploy a streamlined solution but rather must conform to the standards of each market separately.
- **Increasing cyber-vulnerability.** As more load is integrated into DR programs under the control of conventional software programs, the consequences of a cyberattack increase. There are physical and financial risks associated with the specter of a hostile agent taking control of a demand response platform and simultaneously shutting down or turning on thousands of devices in a single location.

demand response

...and how blockchain can help

Blockchain technologies have the potential to address each of the challenges identified here:

- **Reduce overhead costs.** It is extremely difficult to tamper with information on a blockchain, and even if a particular node is compromised it cannot "contaminate" others. A blockchain can provide both DR program participants and utilities greater visibility into and confidence in data, obviating the need for complex enrollment, M&V, and auditing. The U.S. DR market poised to grow to $2.9B by 2023 under existing frameworks; a blockchain solution that improves margins would attract could significantly increase the expected size of the market.

- **Ensure DR results**. Smart contracts will ensure results and enable sophisticated rate design. In the context of DR, decisions about dispatch and response can be programmed into operator and participant devices, respectively, thus removing the element of real-time human decision-making and eliminating the lag between time of service (response) and compensation. This automation would eliminate the unpredictability from programs that rely on manual intervention (i.e., curtailment that requires somebody to "press a button"). It would also allow rate structures to be altered quickly and easily, and for sophisticated rate designs to be quickly brought to market.

- **Create an open-source, global standard for DR systems architecture.** The promise of a near-universal global platform will serve as a forcing mechanism for device manufacturers to coalesce around a common set of standards. This will reduce or eliminate the costs incurred by automated DR companies to reverse-engineer the means of controlling devices. This would, in turn, result in the integration of many more of these devices -- including smaller loads that are currently excluded from participation by program economics. Expanding DR participation to this new segment of energy-using devices would tap a new global market worth an estimated $4B per year.

- **Mitigate financial and physical risks of cyberattacks.** Blockchain's "immutability" and reliance on distributed consensus allows it to improve data integrity and enhance cybersecurity.

utility billing

Challenges and opportunities with utility billing today...

Utility billing (defined here as the full process from metering to payment completion) is a critical pillar of the electricity system. Utility billing provides the mechanism for data exchange between customers, utilities and generators and the foundation for the utility-customer relationship. As the utility business model and the electricity system undergo significant transition, billing system platforms are being called on to become more responsive, connected, bidirectional, and personal. There are several limiting factors preventing current billing processes from adapting to the new challenges and opportunities in the electricity system:

- **Data security risks.** Data transmission and processing can be insecure; cryptography is rarely employed, and data are usually stored and processed centrally, opening them up to significant losses or denial of service in the case of cyber attack. Hackers have reportedly attacked multiple electric utility IT systems looking for credit information in several instances world wide.
- **High transaction costs.** Billing costs (including debt collection) are a perennial concern for many utilities, ranging between 5-15% of total operating expenses. Current data management systems such as SAP and Oracle are expensive and often incomplete. Transaction processes are slow and cumbersome. Superfluous bill generation; inaccurate (and often still paper-based) bill delivery; and manual accounting processes causing a credit lag for utilities and losses from unpaid bills. Existing systems are error prone, adding error-fixing and customer-compensation costs to an already expensive system.
- **Low functionality**. Customers and regulators are looking for three improved functionalities that current systems do not provide; sophisticated and adaptable rate application; creating a single customer billing identity across multiple meters or devices; tracking customer preferences between multiple metering locations; and simplified provider switching
- **Lack of standardization**. Billing systems (from manual to automatic, from prepaid to credit) vary drastically across geographies , and common standards are not applied. Lack of standardization results in poor interoperability and difficulty in API access by equipment manufacturers and other market players. Inconsistent data cleaning and data quality procedures creates challenges for customer data access, provider switching, and integration with demand response or other ancillary services/programs..

utility billing

...and how blockchain can help

Blockchain technologies have the potential to address each of the challenges identified here:

- **Blockchain's immutability allows it to serve as a common record**, reducing transaction cost, improving data integrity, and enhancing cybersecurity. Utilities and customers would have more confidence in the integrity of data on a blockchain, and costs caused by inaccuracy and auditing could be avoided.
- **Blockchain's smart contracts could enable a variety of applications,** reducing transaction costs and improving system functionality. In the context of utility billing, this would mean transactions between electricity users and electricity providers are automatically executed when usage/ supply information conforms to the contract conditions, which are predetermined by users and providers. Transaction speed would be significantly improved by eliminating redundant accounting process, and time lag between billables and receivables would be greatly shortened - or even eliminated. Commercial losses from unpaid bills could be avoided with smart contract-based automated transactions. Smart contracts also make it possible to quickly apply sophisticated rate design.
- **Blockchain's decentralization empowers customers**, enabling customer centric capabilities and improving system functionality. If connected to the blockchain, customers could gain direct access to their own data. Having more information about usage history and bills, customers could become more empowered and more conscious of energy efficiency. They could also grant trusted third parties in the market (e.g., energy efficiency contractors, electricity aggregators) selective access to their data to provide better customer service. Customers would be active participants on the blockchain and could conveniently switch providers or even initiate transactions (e.g., switching from user to provider and selling electricity or green attributes to neighbors).
- **A global, open-source blockchain would encourage standardization.** Development of a more secure, more efficient, more functional, and lower cost utility billing system presents an opportunity to standardize the management of electricity transactions across geographies. This would help integrate DER and provide a more competitive market environment, eventually facilitating a scalable transactive energy system.

Challenges and opportunities with renewable energy certificates (RECs) today...

Customers increasingly want the ability to choose and trace the origin of each unit of electricity generation—including by whom, how, where, and when a given MWh of electricity was generated. Across the globe, a number of compliance and voluntary markets have been created for certificates of origin (guarantees of origin in the EU, renewable energy certificates in the US, etc.) to measure and verify renewable electricity generation and enable customers to meet their renewable energy purchasing goals. There are, however, several challenges facing renewable energy certificates (RECs) markets today, and the opportunity for blockchain technology to help these instruments realize their full potential :

- **Buying and selling RECs is complicated and costly**. The current REC process includes many steps—a MWh of renewable energy is generated, a record of its generation is translated into a REC, that REC is then added to a registry, multiple RECs are bundled for sale, ownership may be transferred between different buyers, the green attributes are publicly claimed or redeemed, and the REC is finally retired. Renewable generators and REC buyers face transaction and administration costs associated with each existing step, including fees from brokers and other intermediaries that typically translate to 5% of REC value. These high costs effectively shut out smaller renewable generators and REC buyers—constraining market size and ultimately limiting renewables development.

- **The integrity of the system is low.** RECs are prone to double-counting and/ or double-claiming due to time lags and loopholes in the system (i.e., the green attributes of a given certificate are claimed more than once). The sheer number of steps involved and organizations that touch each certificate also introduce doubt amongst current and prospective certificate buyers—again limiting market development.

- **There are too many markets.** There are many different compliance and voluntary markets, with each possessing unique attributes. These inconsistencies present challenges for current and prospective market participants, especially in terms of reporting among organizations that buy certificates in multiple markets.

...and how blockchain can help

This represents an opportunity that that we estimate amounts to at least $1 billion annually worldwide based on the avoided 5% broker margins for REC sales. This does not include the potential for a lower-cost, more secure system to significantly expand the market for RECs—the impact of which would be far greater.

- **Blockchain could radically simplify and lower the cost for a REC system** by enabling renewable generators and certificate buyers to interact directly. With a secure data uplink to a blockchain established for verified renewable generation assets, generators and buyers can, respectively, offer and purchase certificates in any quantity without working through intermediaries. This peer-to-peer system for REC trading would simplify the process—enabling real-time settlement, eliminating the need for intermediaries, and lowering internal administration and auditing costs. This streamlined, lower-cost system would also encourage the participation of smaller renewable generators and certificate buyers.

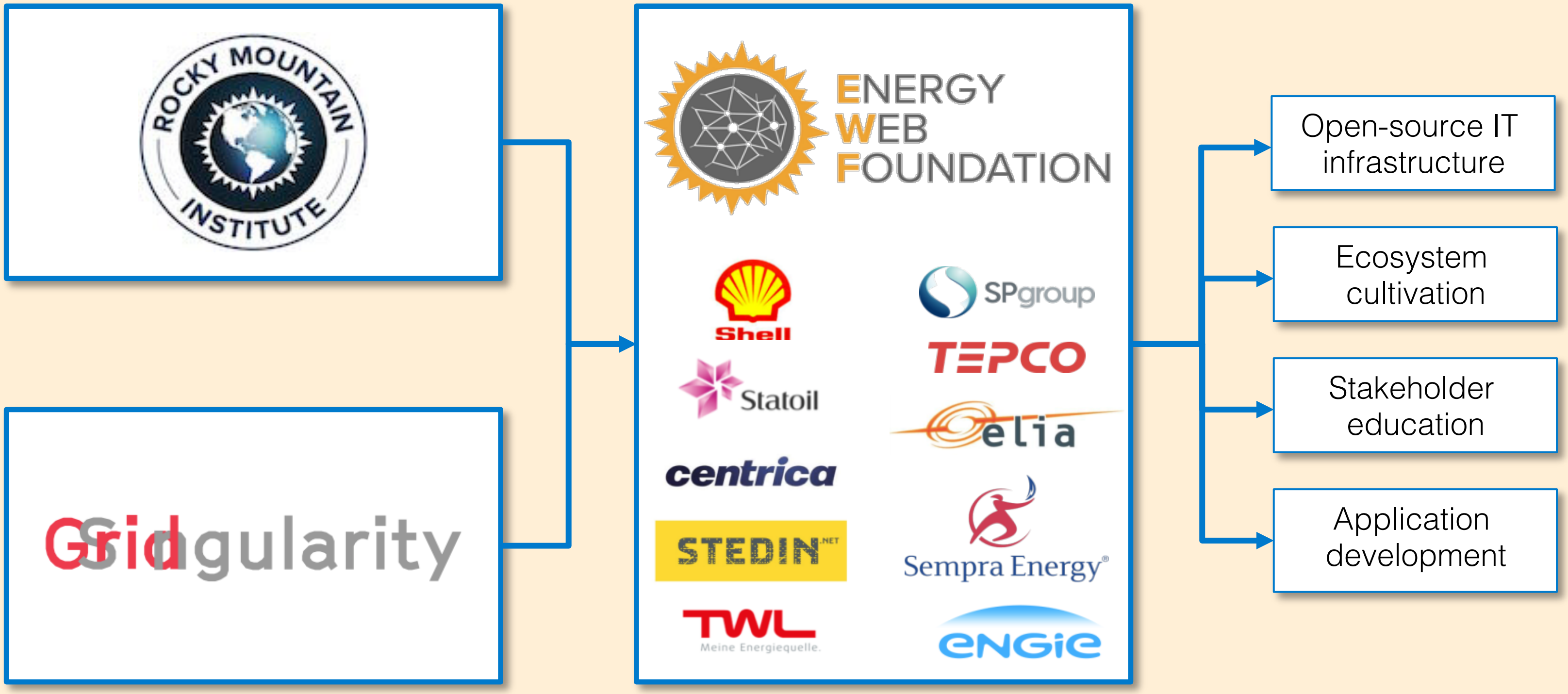
- **Smart contracts can enable streamlined reporting.** In the context of certificates of origin, this means a REC is automatically issued as each MWh is generated, data is sent to a REC registry as REC ownership changes, and each REC is retired when its owner claims its green attributes. This would eliminate the risk of double-counting. In some cases all of these steps - from renewable energy generation through certificate retirement - could be executed instantaneously.

- **Data on a blockchain-based REC registry would be extremely difficult to tamper with** due to a combination of strong cryptography, the interdependent relationship between each bundle of data, and distributed consensus. In sum, once valid data is put on the blockchain, certificate buyers and regulators can be confident that it has not be altered in any way.

- **A global, open-source blockchain would encourage standardization across markets.** By developing a simpler, lower cost, and real-time system for RECs, there is an opportunity to standardize the way the systems function in separate markets—and potentially create a single, integrated global market. This would enable frictionless buying and selling of certificates across the world, opening new markets for renewables generators, and allowing buyers to purchase certificates from wherever in the world they believe they can achieve the greatest impact.

background on the Energy Web Foundation (EWF)

The Energy Web Foundation (EWF)

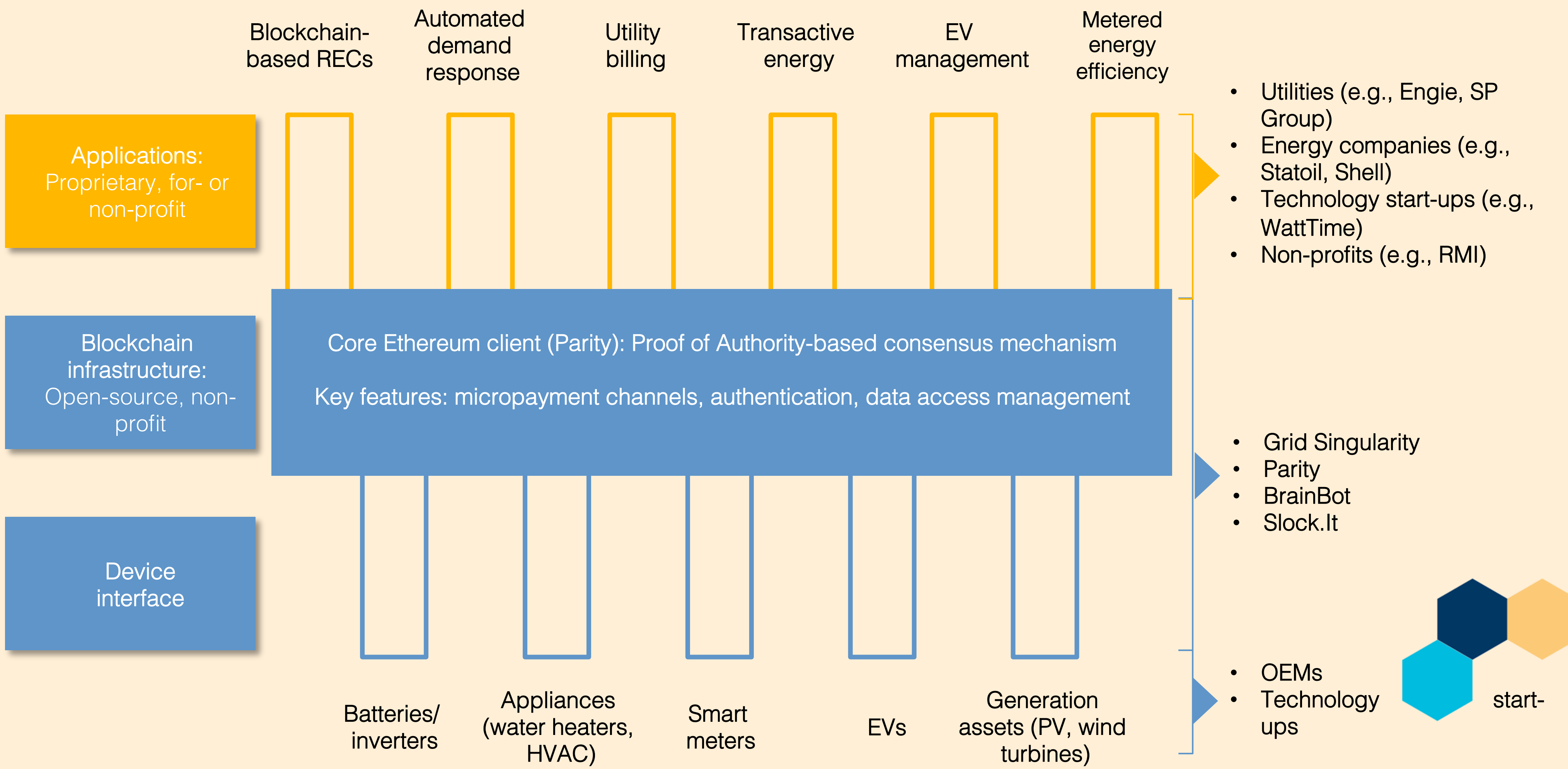


The Energy Web Foundation (EWF) is a non-profit joint venture between the Rocky Mountain Institute (RMI) and Grid Singularity focused on accelerating the adoption of blockchain technology across the energy sector. We believe blockchain technology has the potential to reduce transaction costs in the energy sector, enable active participation of a larger number of market participants (consumers and devices), enhance resilience against digital threats,, and, as a consequence, accelerate the transition towards a cleaner, more resilient, and more cost effective system.

To unleash this potential, EWF will identify, document, and assess the most promising applications of blockchain technology in the energy sector and launch a new energy-focused blockchain platform ("Energy Web Platform") that provides the functionalities needed to implement these use cases at scale.
The intent of EWF, through its Energy Web Platform, is to develop a market standard that ensures interoperability, reduces costs and complexity, aligns currently dispersed blockchain initiatives, and facilitates technology deployment through easy-to-implement applications.

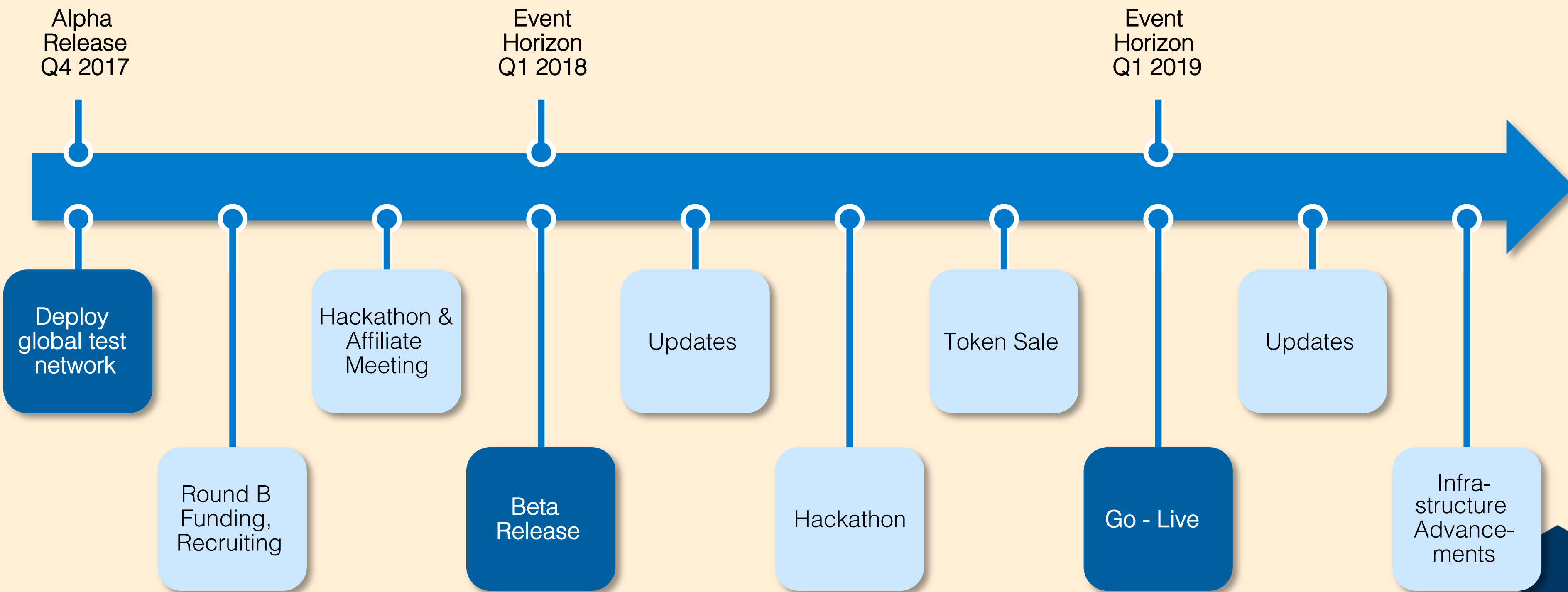
EWF's activities are funded by corporate Affiliates – a set of leading companies from across the energy sector. Corporate Affiliates drive initial application development (via demonstration projects) and receive privileged access to our research, technology, education efforts, and ecosystem.

EWF's IT architecture



Nobody should "own" the technology. As a mission-driven non-profit want blockchain to be used to lower system costs and increase DER/ RE penetration. We believe an open-source best way to achieve this. Developing a private, closed blockchain would cost a company 100s of thousands of dollars. Doing it well would cost millions. It would also entail much duplication – the same work done many times (analagous to every email or e-commerce platform recreating the internet). A proprietary approach would also fail to leverage the best programmers – there is war for talent in the blockchain/ crypto-currency world – and would result in no shared learning. A collaborative, open-source approach will also enable us to create concentrated pressure for regulatory changes and standardization.

EWF's technology development timeline



Agile development approach: monthly "sprints" to build critical features, constant feedback loop with taskforces

contact book

Blockchain and Transactive Energy

eLab Summit

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Distributed Grid Infrastructure

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