



Blockchain and the Grid

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Drivers of 21st Century Grid Transformation

Decarbonization

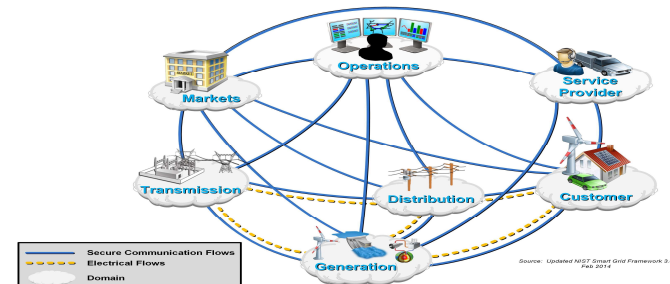
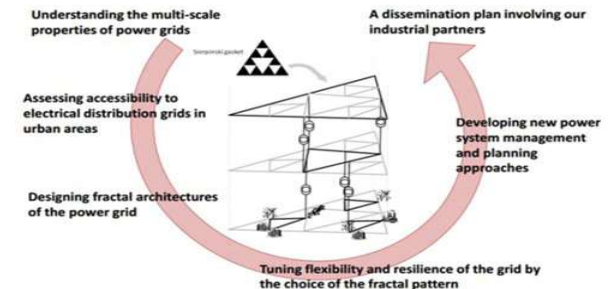
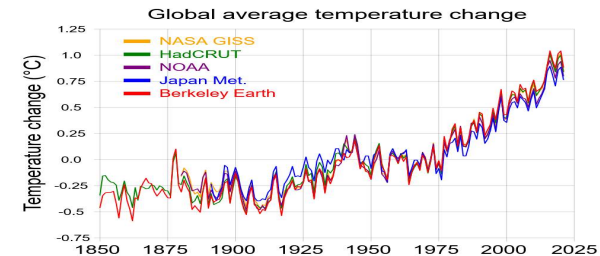
- Current and historical carbon emissions are on track to increase average global temperature above 1.5 degrees C by 2050.
- Since renewables offer a cost-effective path to grid decarbonization, the push to eliminate fossil fuels is to “Electrify Everything!”.

Decentralization

- Like small routers and PCs decentralized telcom networks in the 1990s, solar panels, EV and home batteries and flexible loads like heat pumps are decentralizing the grid today.
- These devices are challenging optimal control techniques that were designed for managing a few hundred large power plants serving a fixed load profile.

Digitalization

- After almost 20 years of almost no load growth, an NREL study in 2016 identified a high load growth scenario of 67% until 2050.
- New smart grid protocols and IoT devices combined with AI and blockchain provide the tools to manage this growth intelligently.



Source: wikipedia.org, researchgate.net, NIST Smart Grid Framework 2014

Transactive Energy

GridWise Architecture Council defines transactive energy (TE) as:

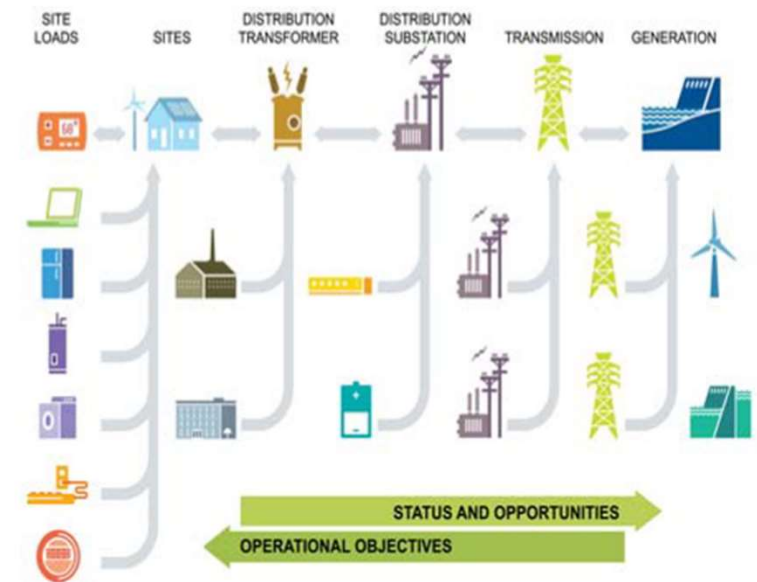
... techniques for managing the generation, consumption or flow of electric power within an electric power system through the use of economic or market-based constructs while considering grid reliability constraints. ([GWAC 2015](#))

Wholesale power markets in the US have had transactive features since the late 1990s/early 2000s.

- Day ahead and real time prices used to control amount of power on grid.
 - Energy price increases -> expensive fossil gas peaker plants are fired up.
 - Energy price decreases-> fossil gas peakers shut off.

But the retail market is still controlled by fixed prices set by regulatory authorities.

- Some jurisdictions now feature “time of use” tariffs to help mitigate late afternoon load peaks.



Blockchain Transactive Energy

Blockchain Transactive Energy (BCTE) replaces the TE centralized database with a distributed ledger/blockchain.

- Cryptographic verification ensures that transactions and records can be trusted.
- Technology for bringing TE to the retail market.

Where blockchain validator nodes run and store copies of the ledger depends on the use case.

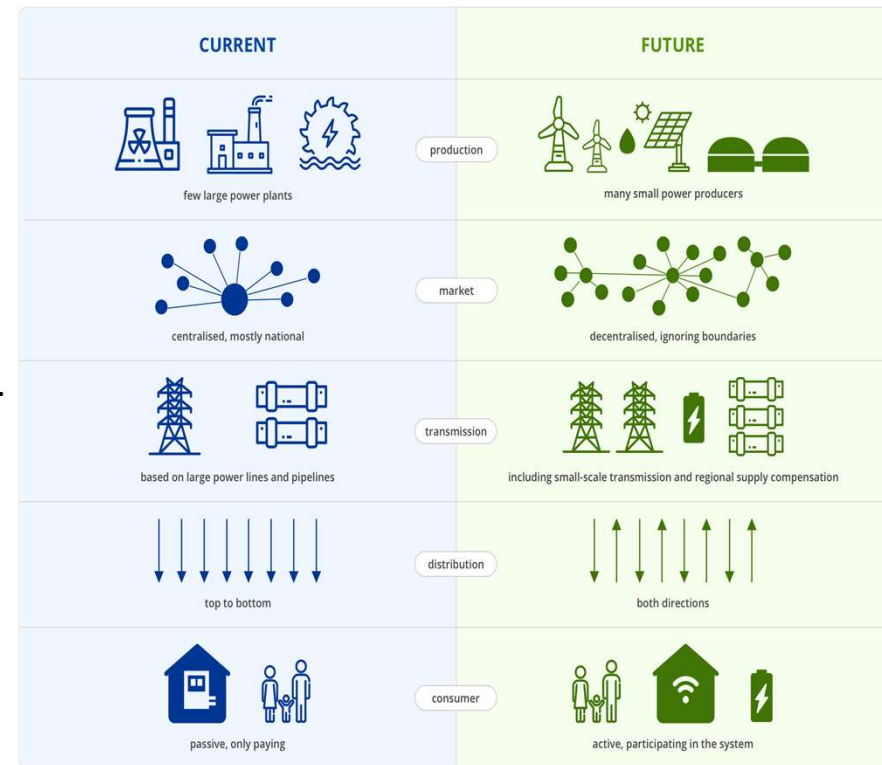
- Regulator, wholesale market operator (ISO), utility, aggregators, and/or every distributed energy resource (DER) deployment site could all run validator nodes.
- Transparency ensures every participant can view transaction records.

Need for identity and access management on validator nodes suggests a permissioned blockchain.

- Tight control over which nodes can join the network.

For real time transactions use a fast distributed consensus algorithm.

- Examples:
 - RAFT/Proof of Authority if private blockchain.
 - Proof of History if public blockchain.
- Many others - no need for Proof of Work energy hog!



Tokens

Tokens are digital assets or digital representations of physical assets with lifecycle on a distributed ledger.

- Created, tracked, and destroyed on a blockchain.

Two basic types of tokens:

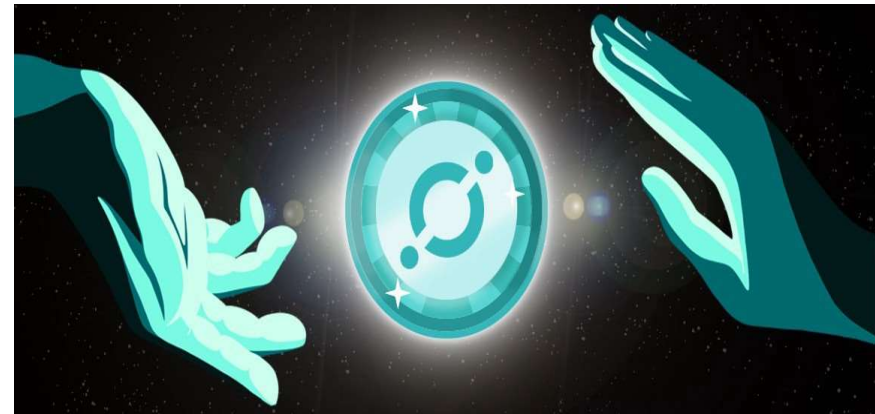
- Fungible Tokens (FT).
 - Can be subdivided down to a smallest unit like money
 - Each token is identical to any others
 - Example: Bitcoin or Ether (Ethereum)
- Nonfungible Tokens (NFT).
 - Each token is unique.
 - Cannot be subdivided.
 - Example: Tokenization of digital artwork.

Example uses of tokens in energy systems:

- A FT convertible to cryptocurrency used to incentivize distributed consensus validator nodes for PoS.
- A NFT representing 1 MWh of energy generated at a particular time and having a particular carbon content.

Note: Tokens should NOT be conflated with cryptocurrency!

- Cryptocurrency is a type of token but not all tokens are cryptocurrency.



Peer-to-Peer (P2P) Energy Trading

Consumers who also produce power (aka prosumers) trade energy with neighbors and record price and quantity on blockchain.

- Started with the [Brooklyn Microgrid Project](#) in New York City in 2017.
 - Exergy blockchain originally run by [LO3Energy](#).

Benefits to the grid:

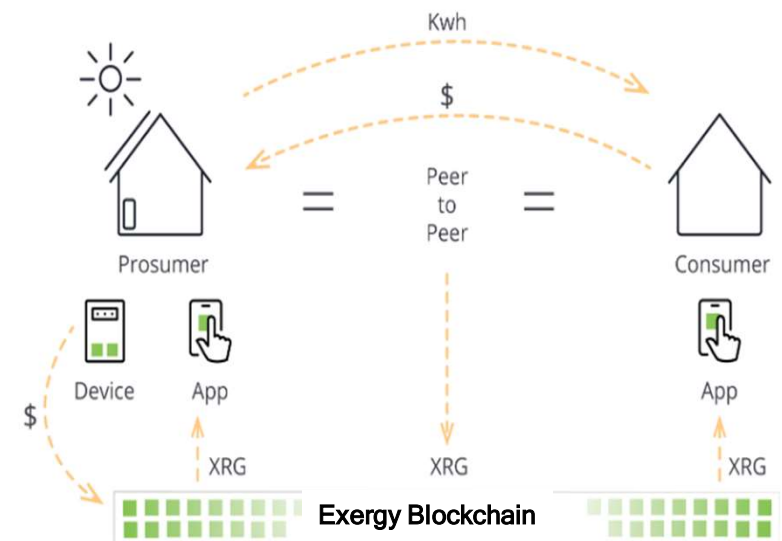
- Eliminates 6% power loss between transmission (high voltage) and distribution (low voltage) grids.
- Local energy markets can be more resilient to wide area disruptions like hurricanes, wildfires, and earthquakes.

2017 saw a bubble in transactive energy startups.

- \$184m raised for peer-to-peer transactive energy blockchain startups.
- 57% of total for energy blockchain startups in general.
- Mostly through initial coin offerings
 - Declared illegal by the SEC in late 2017.

Regulatory issues:

- Peer-to-Peer energy trading is possible in Europe and Australia
- Prohibited by utility franchise laws in Japan and most US jurisdictions with the exception of Texas
 - Utility has monopoly on selling electricity.



Source: lo3energy.com, frontlinegaming.org

Local Energy Markets on the Distribution Grid

Incumbent utility runs the market and acts as the market maker.

- Similar to wholesale market but at the distribution grid level.

Local energy markets on the distribution feeders :

- Producers sell energy to the utility at the real time market price.
- Consumers similarly buy energy at the real time market price.

Transactive nodes run on energy gateways at the customer premises and at the substation.

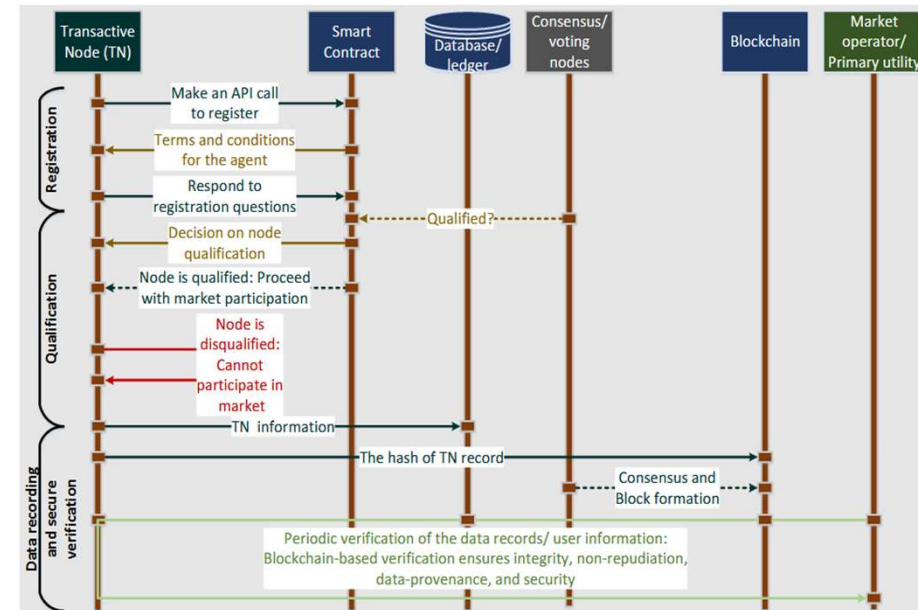
- Producer/consumer gateway is an add-on to smart meters.

Why not simply use a centralized database?

- Decentralized system can handle real time traffic from thousands of local nodes in a more scalable manner than a centralized database.
- If internet connection is arranged to keep traffic local, local transactive market can survive wide area grid outages.

Resilience benefit to the grid:

- If transmission grid connection is severed, distribution feeder could still stay up.
 - Acts like a microgrid.
- Controlling flexible loads could allow load reduction to match reduced power availability from local DERs only.



Source :https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29017.pdf

Microgrid Charging and Billing



Port of Long Beach sued by SCE to stop reselling energy purchased from SCE and stored in microgrid batteries to port customers.

- Port microgrid includes solar panels owned by the port and connection to SCE's grid.
- Utility monopoly franchise laws prevent reselling of energy.

Solution: Tokenize energy and track what energy comes from SCE and what comes from port's solar panels on a blockchain.

- Each party (SCE, the port, port customers) runs a blockchain node.
- Generate a token for each kwh stored in battery or consumed labelled with attributes
 - The origin of the kilowatt-hour (e.g. the SCE grid or the port microgrid authority's solar panels),
 - The date and time the kilowatt-hour was stored,
 - The date and time the kilowatt-hour was consumed.
- When a token is consumed, it is retired and the amount and source is recorded in the customer's smart contract.

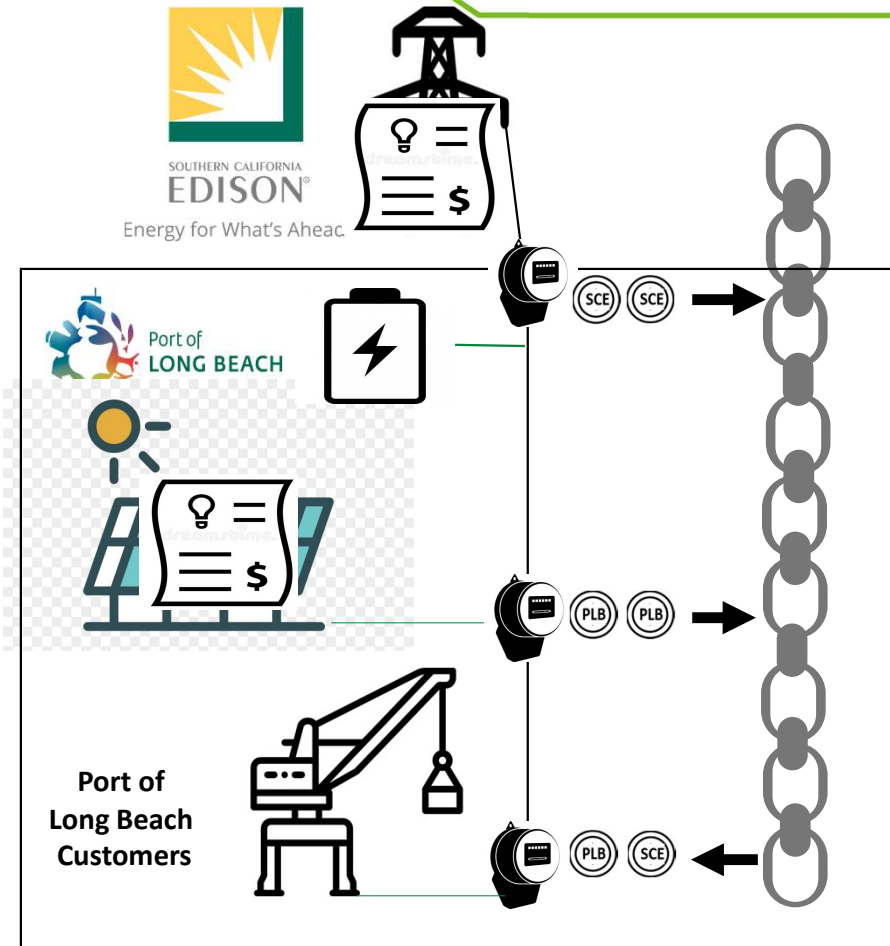
Tokens consumed on a first in-first out basis.

- If two tokens generated at the same time, use a randomization algorithm to select if an SCE token or a port token is consumed.

At the end of the month, SCE and the port each issue a bill to port customers for the amount of electricity (== tokens) they consumed.

[Whygrene](#) is building a virtual power plant based on this architecture.

- Also more detail in this [Medium.com post](#).



Source: freeiconspng.com, clipartmax.com, flaticon.com, thenounproject.com

Energy Web Foundation



Nonprofit spinoff from Rocky Mountain Institute.

- Based in Switzerland.

Energy Web Chain is an open source fork of Ethereum that uses Proof of Authority (low energy consumption) distributed consensus.

- Smart contract mechanism to store Decentralized Identifiers (DIDs).
 - Blockchain-based credentials that take the place of public key certificates.
- Executes smart contracts that implement decentralized applications deployed by utilities, startups and others.

Energy Web Token (EWT) trades on the international cryptocurrency exchanges.

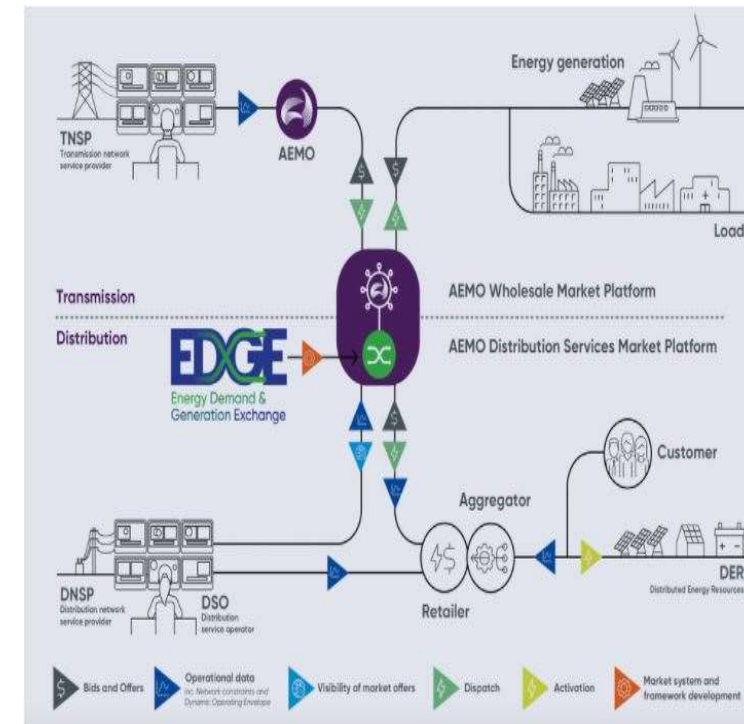
- Used to incentivize validator nodes.

Decentralized transactive energy concept:

- Decentralized Autonomous Area Agent (D3A) market model
- Reduces the distinction between the transmission and distribution markets.

EDGE proof of concept trial for D3A in Australia:

- Collaboration between AEMO transmission system operator, Mondo aggregator, and AusNet distribution system operator.
- Utilizes EWF's stack together with market intelligence software from PXiSE and runs in Microsoft Azure.
- Initially involves 50 residential customers in Victoria's Hume region, but then will scale up to 1000 residential, commercial and industrial customers.
 - 25% of Australia's homes nationally have rooftop solar.
 - 40% of the homes in South Australia have rooftop solar.
 - 70% of power on the grid is renewable on average.



Source: Energy Web Foundation

Power Ledger

[Power Ledger](#) is an Australian company founded in 2016 to develop a blockchain based, peer-to-peer energy trading platform.

Blockchain platform history:

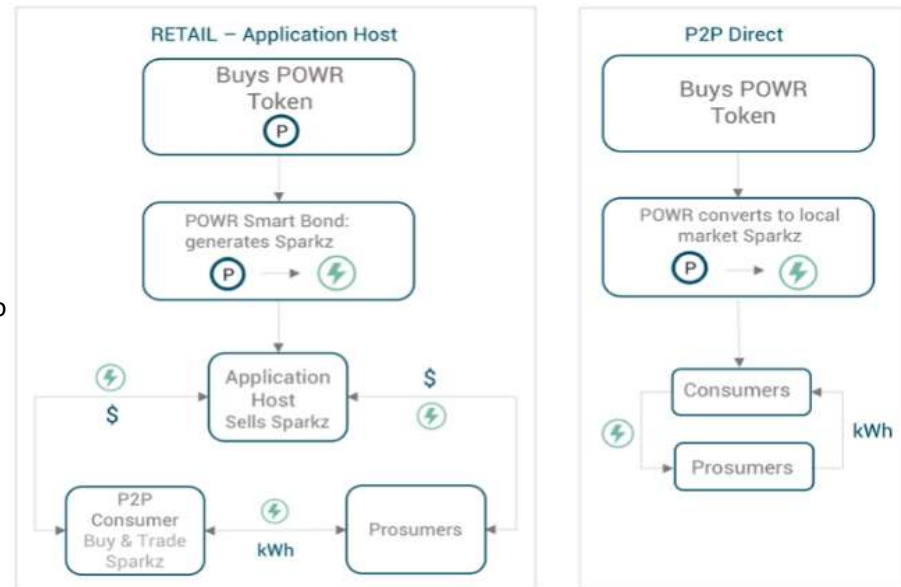
- Until 2021, Power Ledger deployed onto two platforms:
 - Ethereum 1.0 permissionless/public platform.
 - Ecochain private blockchain based on Proof of Stake distributed consensus.
- In 2021, switched public blockchain to Solana:
 - Ethereum transaction times were becoming too long and transactions costs too high.
 - Ethereum 1.0 uses energy wasting Proof of Work distributed consensus while Solana uses Proof of Stake and Proof of History.

To incentivize participation, Power Ledger uses two tokens:

- POWR ERC-20 token initial coin offering in 2018, peaked at \$1.79 in January 2018 and now worth about \$0.50 still trades on Ethereum
- Sparkz private token denominated in the local currency as a stablecoin and only trades on Ecochain.

Three peer-to-peer BCTE products:

- xGrid allows utility commercial and residential prosumers to trade energy directly with other customers.
- uGrid allows peer to peer trading between participants in microgrids, including shopping centers, housing estates, etc.
- PowerPort is similar to uGrid but for Electric Vehicle charging stations, allowing cheap and secure electricity metering, settlement, low-cost payment, user IDs, and integration with existing protocols.



Source: <https://medium.com/trivial-co/power-ledger-powr-analysis-of-the-token-and-business-model-7bee0ca1908a>

Summary and Conclusions



Transactive energy in general and blockchain transactive energy in particular holds promise to solve many of the problems in grid transformation.

- Allowing DERs in the distribution grid to participate in local energy markets.
- Co-ordinating DERs and flexible loads at scale.
- Increasing grid efficiency and resiliency.
- Support deployment of more distributed renewables, batteries, EVs, and flexible loads.

Despite promising proof of concept studies, widespread deployment has been lagging.

- In the US, regulatory issues and mismatch to utility's capital focused business model have hindered deployment.
- More progress in Europe and especially in Australia with the EWF EDGE study.

IEEE BCTE Initiative presented the results from 3 years of work at the IEEE GET Blockchain Forum Energy Symposium on November 8, 2022.

- Conference web page: <https://get.blockchain.ieee.org/symposia/energy/>
- BCTE Initiative will conclude at the end of this year.

*Thank you
for Listening!*