UCL Energy Institute

UCL

~~Blockchain~~ Distributed Ledgers in the energy transition

David Shipworth

d.shipworth@ucl.ac.uk

Professor of Energy and the Built Environment, UCL Energy Institute

IEA Demand Side Management TCP Vice-chair and BEIS Industry and Academic Delegate

PACE Research group: https://www.ucl.ac.uk/bartlett/energy/PACE

Characterising the transition

- **Decarbonised**
  - Renewables are low density & intermittent, making the energy system more 'supply-led'
- **Distributed**
  - Low energy density necessitates distributed generation and bi-directional energy flows
- **Digitialised**
  - Controlling supply-led, distributed, intermittent generation requires a smart grid
  - This requires a very low cost transaction layer to support energy exchanges at the grid edge
- **Disintermediated**
  - Lowering transaction costs requires automation and disintermediation
  - Growing societal demand for collaborative economy models and 'localism'.
- **Democratised**
  - Supply-led distributed generation & control requires actively/passively engaged consumers
  - Expectations of service delivery & consumer engagement are shifting in the digital economy
  - Thus engaged consumers are at the heart of the new services based energy system
- **Differentiated**
  - By value. Energy services have multiple social and economic values
  - By place. Each of these values change by network, social and environmental context
  - By time. Each of these contextual values change over time from milliseconds to decades

Democratised: The EU 4th Electricity Directive

3RD ELECTRICITY DIRECTIVE	PRODUCTION	WHOLESALE MARKET COMMODITY		WHOLESALE MARKET SERVICES		RETAIL MARKET	
		DIRECT	INDIRECT (AGGREGATOR)	DIRECT	INDIRECT (AGGREGATOR)	DIRECT	INDIRECT (AGGREGATOR)
INDIVIDUAL PROSUMERS	✓ (access without special provisions)	✗ (no access)	✗ (no access)	✗ (no access)	✗ (no access)	✗ (no access)	✗ (no access)
COLLECTIVE PROSUMERS	✓ (access without special provisions)	✓ (access without special provisions)	✗ (no access)	✓ (access without special provisions)	✗ (no access)	✓ (access without special provisions)	✗ (no access)

4TH ELECTRICITY DIRECTIVE	PRODUCTION	WHOLESALE MARKET COMMODITY		WHOLESALE MARKET SERVICES		RETAIL MARKET	
		DIRECT	INDIRECT (AGGREGATOR)	DIRECT	INDIRECT (AGGREGATOR)	DIRECT	INDIRECT (AGGREGATOR)
INDIVIDUAL PROSUMERS	✓ (access with special provisions)	✓ (access with special provisions)	✓ (access with special provisions)	✓ (access with special provisions)	✓ (access with special provisions)	✗ (no access)	✓ (access without special provisions)
COLLECTIVE PROSUMERS	✓ (access with special provisions)	✓ (access with special provisions)	✓ (access with special provisions)	✓ (access with special provisions)	✓ (access with special provisions)	✓ (access without special provisions)	✓ (access without special provisions)

✗ NO ACCESS ✓ ACCESS WITHOUT SPECIAL PROVISIONS ✓ ACCESS WITH SPECIAL PROVISIONS

A. Butenko (2017, forthcoming) "User-centered Innovation in EU Energy Law: Market Access for Electricity Prosumers in the Proposed Electricity Directive" (OGEL, ISSN 1875-418X) October 2017, www.ogel.org

Democratised: European legislative changes

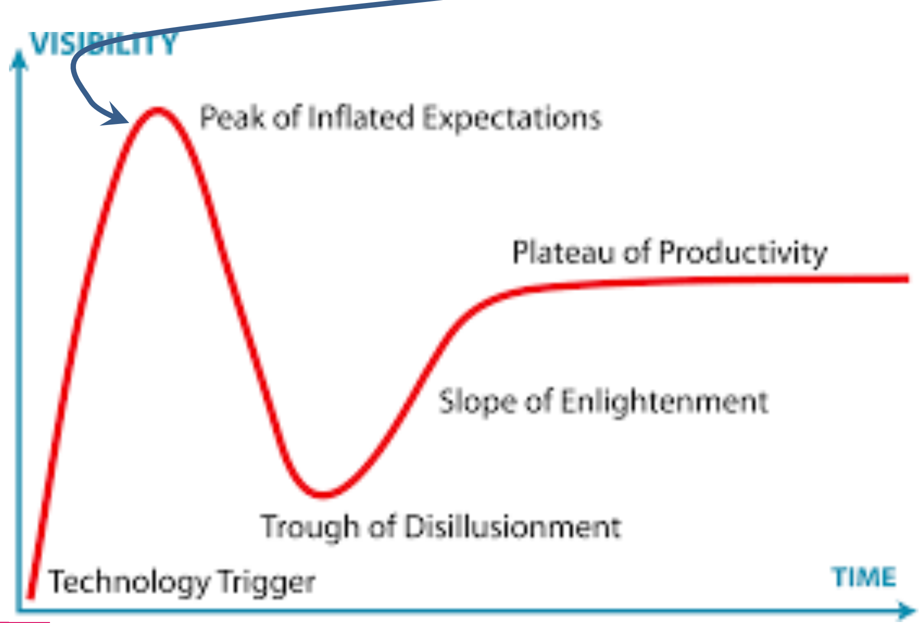
- France (April 2017) amended Article D of their Energy Code to support electricity self-consumption at the grid edge.
- Germany (June 2017) amended their German Renewable Energy Sources Act (EEG 2017) to explicitly include PV tenant electricity consumption.
- Austria (August 2017) likewise begun changing its legislation to better support self-consumption.
- Luxembourg (March 2018) adopted draft legislation regulating self-consumption and promoting the active role of prosumers.
- Spain - Balearic regional government (2018): law under consultation to incentivise residents to participate in community RES projects, and share prosumer energy between residents.

Distributed Ledgers 101

(The most exciting thing since double-entry book keeping.)

Blockchain 101 - A Visual Demo by Anders Brownworth < https://www.youtube.com/watch?v=_160oMzblY8>

Gartner's latest 'Hype cycle' for emerging technologies puts blockchain here.



- Distributed Ledgers ≠ Blockchain ≠ Bitcoin
  - Cryptocurrencies are one application of blockchains
  - Blockchains are one class of Distributed Ledgers
  - Graphical structures will probably supersede blockchains for most applications.
    - e.g. IOTA; Hashgraph; Spectre, etc

DLT-101: fundamental properties

- Distributed nature – allowing system resilience:
  - *Social resilience* through distribution of political/economic control;
  - *Cybersecurity resilience* through avoiding a central point of failure;
  - *Physical system resilience* through distributed asset control and subsystem independence.
- From trust in actors - to trust in the system – allowing:
  - Trading between unknown parties;
  - Fair trading between parties of unequal knowledge/power;
  - System action transparency.
- Immutable accountability – allowing:
  - Fair and transparent trading
  - Tracking Guarantees of Origin of renewables and carbon
  - Evidencing and authenticating Demand Side Response
- Digital asset scarcity – allowing:
  - Trading in a zero-sum pooled resource systems like money and energy
  - Creating value for non-monitised social goods

Distributed ledgers 101

(The political economy of Distributed Ledgers)

- Distributed ledgers enable users to agree on the historical record in a way that is (ideally) fast, fair and final.
- Approaches to achieving consensus
  - Controlling the means of production (Proof of Work)
    - Bitcoin; Etherium (current), etc
  - Electing/Appointing leaders (incl. Proof of Authority)
    - Paxos, Raft, Hyperledger, etc
  - Trusting free markets (Proof of Stake)
    - Etherium (future)
  - Referenda (Voting systems)
    - Hashgraph ('virtual' voting)

Distributed ledgers 101

- The 'Internet of Value'
  - Internet makes copying & distributing information easy, but protecting & exchanging information assets hard.
  - Distributed ledgers create scarcity value for information assets, and protocols to support an 'Internet of value'.
  - "The blockchain makes information look like a thing."
    - [*Joe Ito - MIT Media Lab*]
- Why use distributed ledgers for energy trading?
  - DLTs made *digital* coins behave like *physical* coins.
  - Currencies require coins (e.g. £) to be recorded (in ledgers), balanced (i.e. zero-sum), and settled – ***i.e. just like electricity trading*.**

Distributed ledgers 101

- Open to all participating parties:
  - Permissioned blockchains can only be accessed by authorised users
  - Public blockchains are open to anybody (e.g. like Bitcoin)
- Distributed:
  - Ledger held by all parties & changes agreed by consensus
- Trustless & Disintermediating:
  - Require no centralised/trusted intermediary
- Cryptographically secured:
  - Privately secured with public/private key encryption

Distributed Ledgers & Smart Grids

- A smart-grid requires:
  - A data infrastructure that:
    - Can be used by mutually competing and distrustful entities
    - Ensures integrity, authenticity, commercial secrecy and customer privacy
    - Cannot be compromised by any single entity
  - A financial transaction layer that:
    - Supports product and service innovation
    - Minimises or eliminates transaction costs
  - An IoT control architecture that:
    - Is compatible with component APIs
    - Supports an ecosystem of smart-controls (smart-contracts; distributed computing, fog computing)
    - Is distributed to minimise latency and energy, and enhance privacy.
- Distributed ledgers can provide the transaction and control layer for the smart-grid

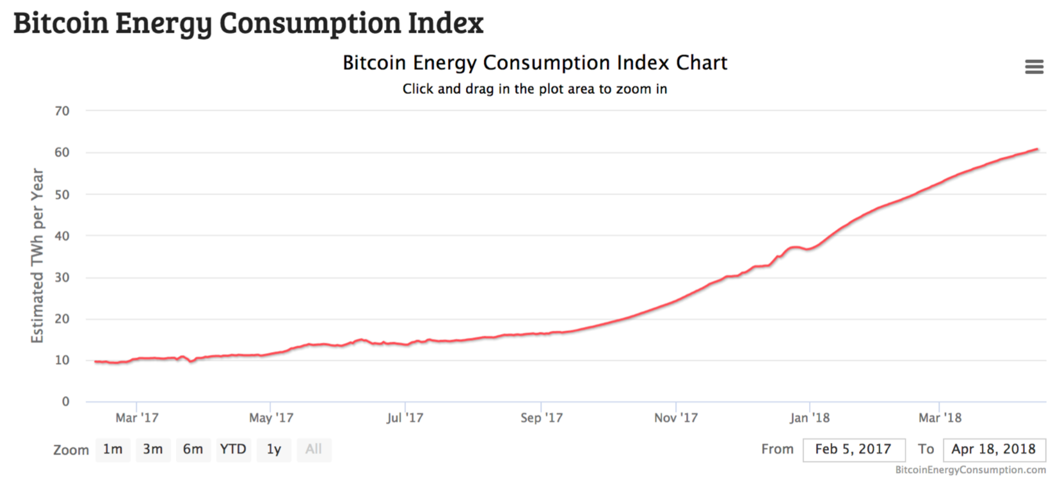
Challenges: Distributed ledgers

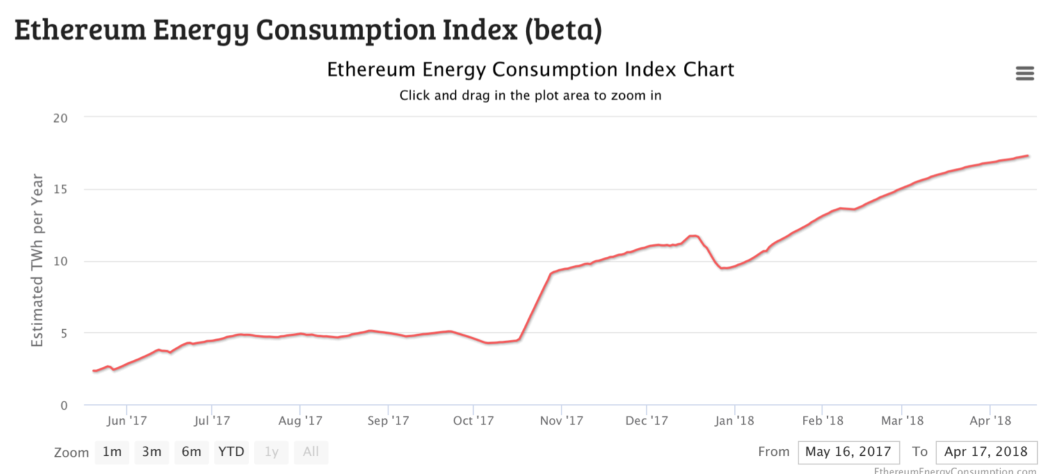
- Throughput/scaling (transactions per second)
- Latency (time per verified transaction)
- Security: (Inputs, coding flaws; consensus mechanisms)
- Size and bandwidth (Existing tech doesn't scale well)
- Privacy: (reidentification and GDPR compliance)
- Smart contracts: (Correctness, predictability, legal status)
- Energy intensity: (varies widely by system)
- Usability: (Current APIs and apps are not user friendly).
  - (Ref: Yli-Huumo J, D, Choi S, Park S, Smolander K (2016) Where Is Current Research on Blockchain Technology?—A Systematic Review. PKo LOS ONE 11 (10):e0163477. doi:10.1371/journal.pone.0163477)

DTL Energy consumption

<Ref: https://digiconomist.net>

- Energy use depends on security and consensus mechanisms.
- ‘Mining’ = energy
  - Bitcoin ~ 60 TWh/year (~30MtC)
  - Ethereum ~ 15 TWh/year
- New ‘graphical’ DLTs like Hashgraph & IOTA use orders of magnitude less.
- Bitcoin is a dinosaur – but dinosaur’s evolved into birds. That’s what’s happening now





Challenges: Distributed ledgers

- Blockchain governance
  - Who agrees changes to the rules governing the blockchain. Is it done by proof of work (miners); proof of stake (coin holders); or proof of authority (founders)?
  - Decred; e.os and others are working on this
- Multichains and parachains – accommodating a diversity of distributed ledgers
  - There are many blockchain and distributed ledger architectures with different functionalities. How can interoperability best be delivered?
  - Polkadot and others are working on this.
- Standards
  - Increasing calls for standards.
  - The EC is working on standards in FinTech and cryptocurrencies
  - No work yet in energy
- Regulation of Initial Coin Offerings/Token Generation Events
  - US Securities and Exchange Commission adjudication on the DAO
  - The Howey test of securities and investments

Challenges: Governance

- **Policy**
  - **Key UK Opportunities: Smart Metering Implementation Programme**
  - Moving to outcome based policies and metrics
  - Mitigating distributional impacts (e.g. grid defection)
  - Mitigating whole energy system impacts (e.g. balancing the legacy grid)
  - Building trust, salience and social value in the energy system
  - Avoiding energy data siloing - building open platforms of analysable but encrypted data
- **Regulatory**
  - **Key UK Opportunities: Ofgem Innovation Link and Regulatory Sandbox**
  - Moving to principles based regulation
  - Reducing barriers to market entry
  - Ensuring customer protection to all groups
  - Balancing economic efficiency and fairness
- **Energy codes**
  - **Key UK Opportunities: Elexon BSC P 362 Electricity Market Sandbox and BSCP 550 Shared SVA Meter Arrangements**
  - Balancing and Settlement Code alterations
  - Master Registration Agreement alternations
  - Evidencing demand response and flexibility services

DLT Use cases

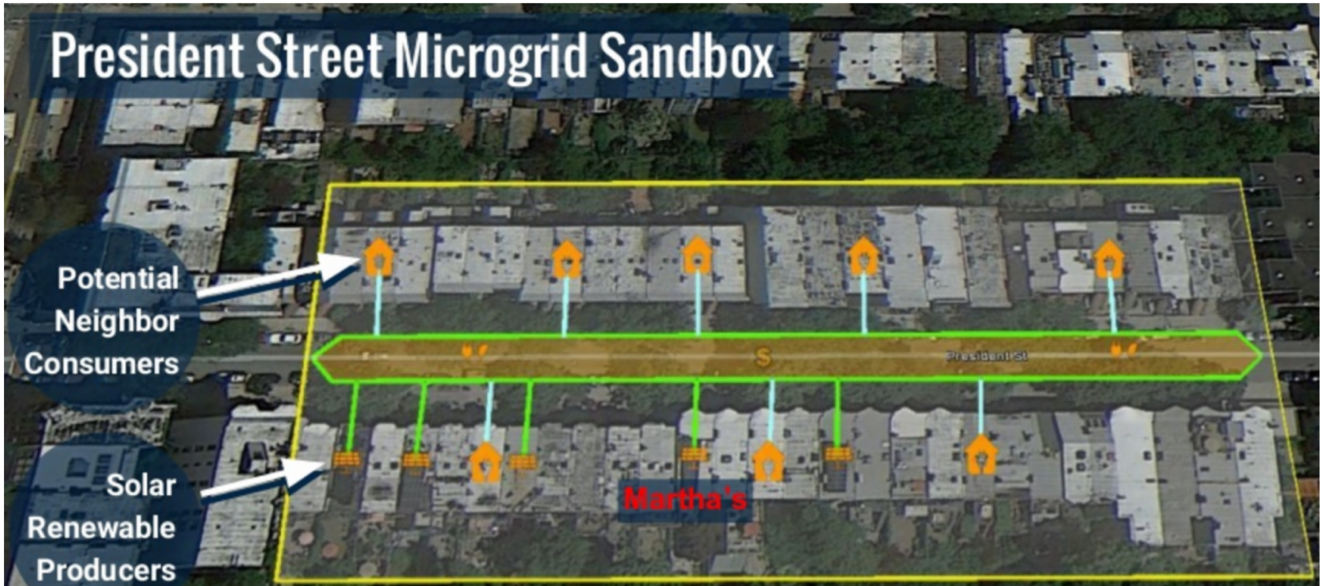
- ~ 1000 use cases;
- ~100 start-ups;
- ~10s of PoCs;
- A few physical trials;
- Very few working business models.

- Figure 7 'Results of potential use cases of Blockchain in the energy sector', p.20 in Burger C, Kuhlmann A, Richard P, Weinmann J (2016) Blockchain in the energy transition: A survey among decision-makers in the German energy industry. ESMT European School of Management and Technology GmbH Deutsche Energie-Agentur GmbH (dena) - German Energy Agency

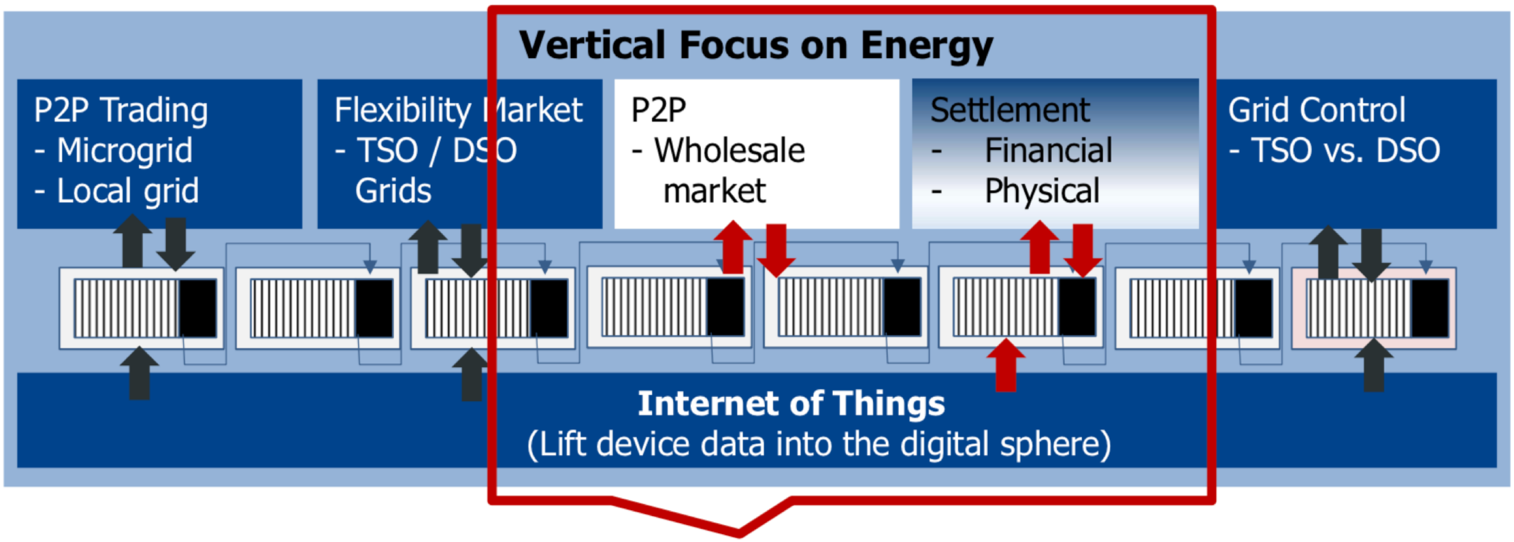
LO3 Energy

http://lo3energy.com/

- Brooklyn Microgrid (~130 sites)
  - Apr 2016 - P2P energy trading
  - Feb 2017 – P2P energy + efficiency trading through IoT device activation on the blockchain.
  - Environmental, resiliency, community and financial consumer value propositions.



Wholesale energy trading: PONTON Enerchain



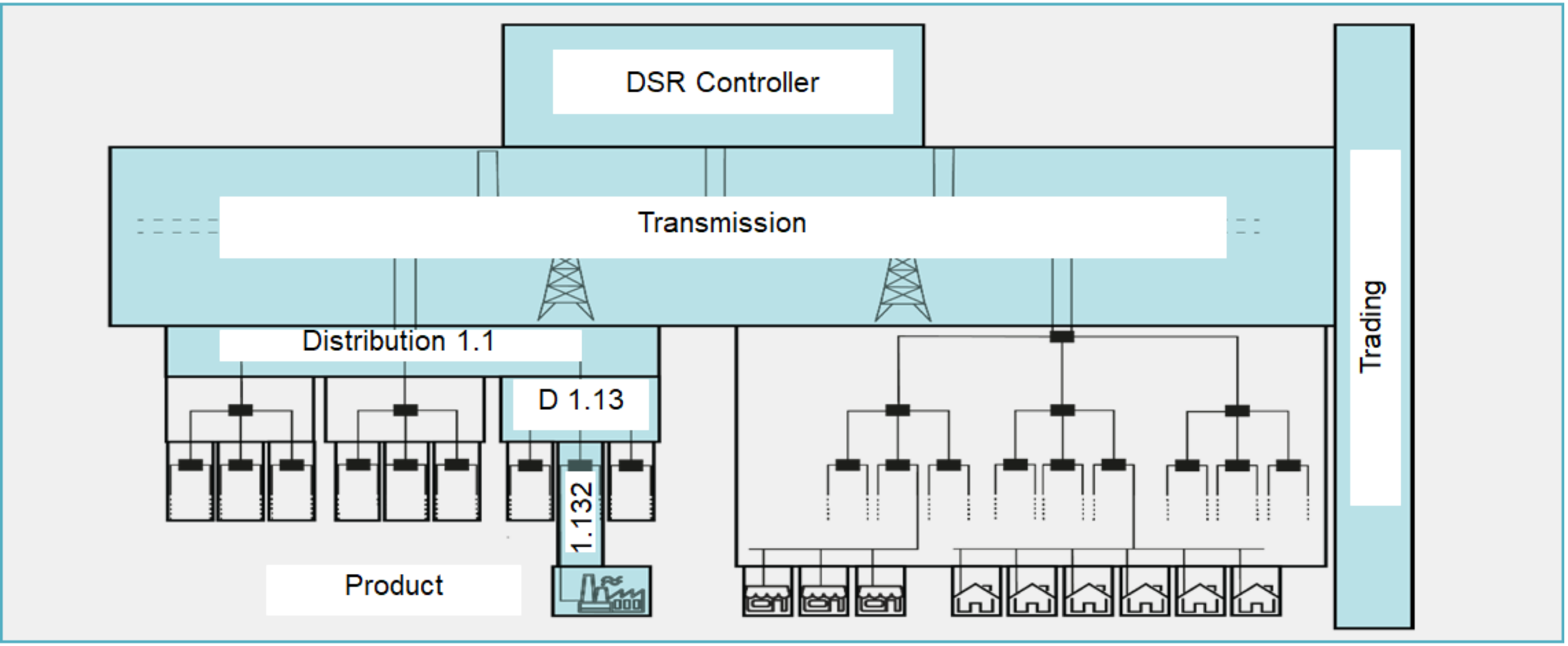
- Horizontal Features & Challenges
  - Access; Identity Management; Archive historic blocks
  - Load; Performance; Stability; Security; Privacy
- PoC phase 2 ends March 2018, 38 companies, hand-over to new governance structure underway

- Ref: <https://ponton.de>

Electron <electron.org.uk>

- Currently, bilateral trading in the DSR market precludes value aggregation across multiple beneficiaries.
- Electron are looking to release value through collaborative trading of DSR as a non-rival good.
- They disaggregate the components of DSR into its non-rival elements, and allow companies to price them individually.
- They then use blockchain to record all the trading commitments from the industry and enforce the trading protocols of the platform.

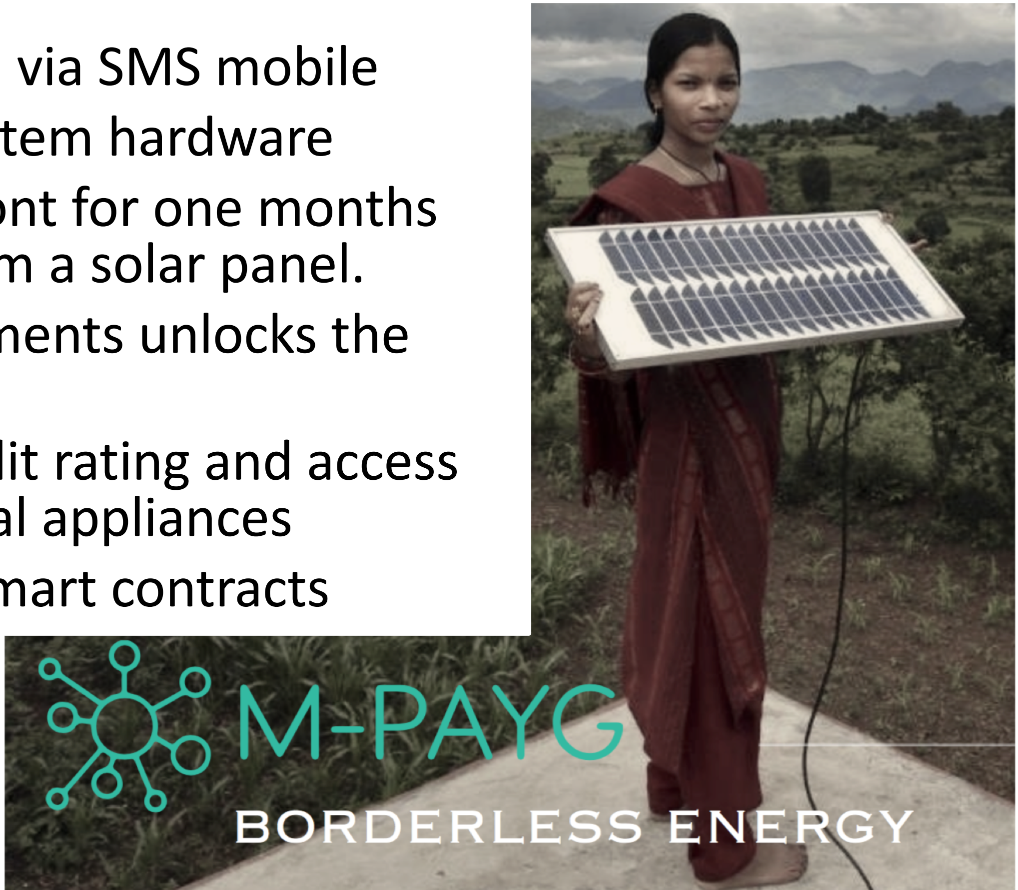
- This then:
  - creates fair and transparent DSR value allocation;
  - facilitates trades that wouldn't otherwise happen;
  - Encourages greater liquidity and participation in DSR;
  - generates significant cost savings;
  - leads to better investment decisions; and
  - lowers carbon emissions across the energy industry.



M-PAYG

http://www.mpayg.com

- Microfinance + renewable energy company
- Allows low-income households in developing countries access to solar energy
- Cryptocurrency microfinanced via SMS mobile
- 50w PV + battery + control system hardware
- Users pay 5 USD/month up front for one months unlimited access to power from a solar panel.
- Lease to own model – 36 payments unlocks the panel
- Repeated payments build credit rating and access to credit purchase of additional appliances
- Microfinance payments and smart contracts executed on blockchains.
- Rolling out in Tanzania, Uganda & Kenya



UCL Energy Institute

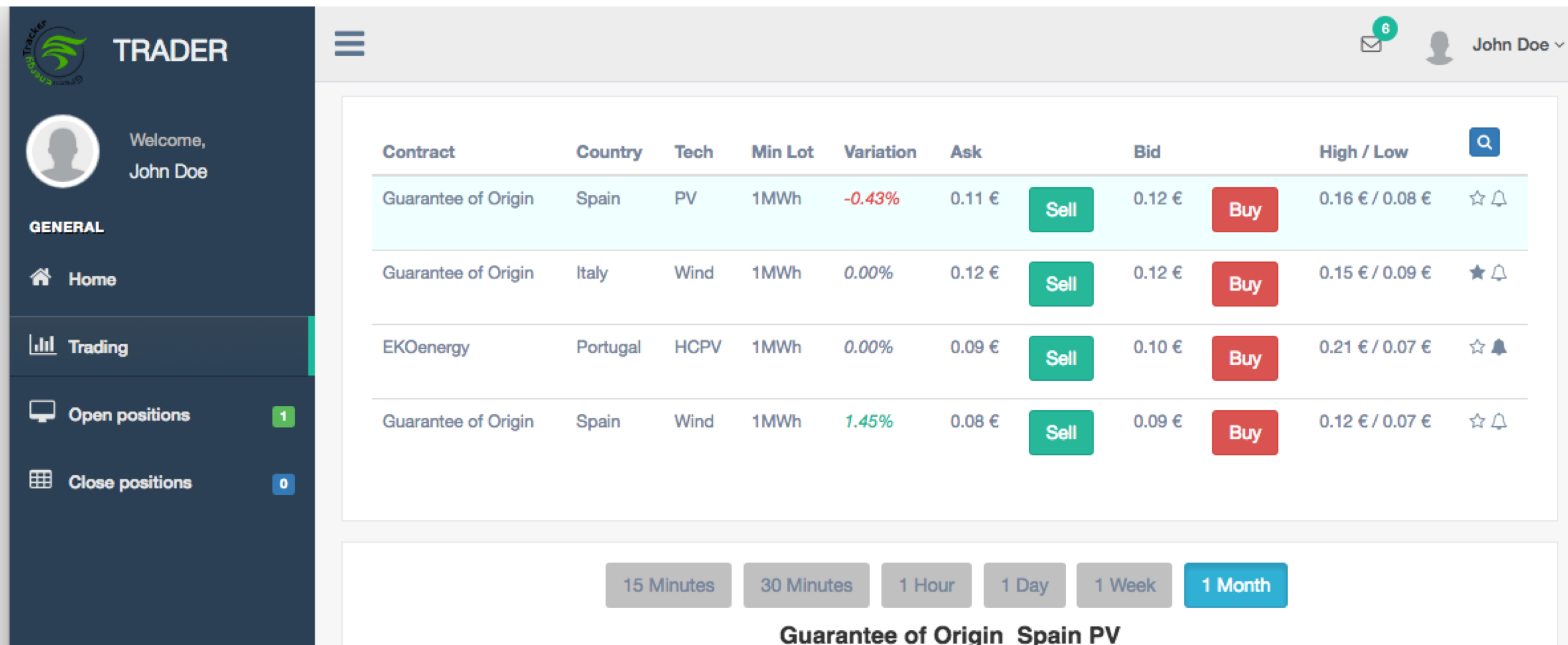
UCL CENTRE FOR BLOCKCHAIN TECHNOLOGIES

UCL

Green Energy Tracker

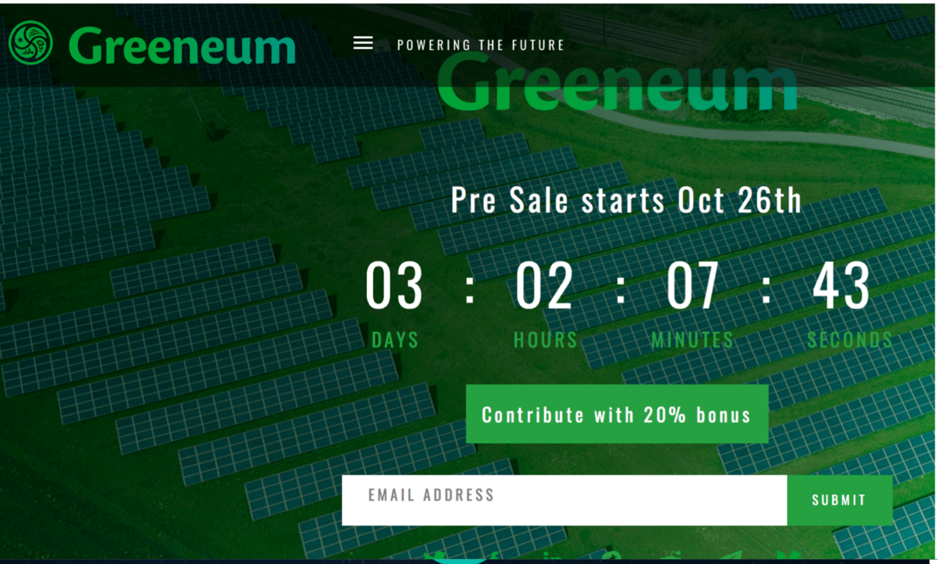
<https://greenenergytracker.eu>

- Green Energy Tracker uses DLTs to verify and track Guarantees of Origin for EU Renewables.



Start-up finance

https://www.greeneum.net; https://gridplus.io
https://powerledger.io; http://lo3energy.com



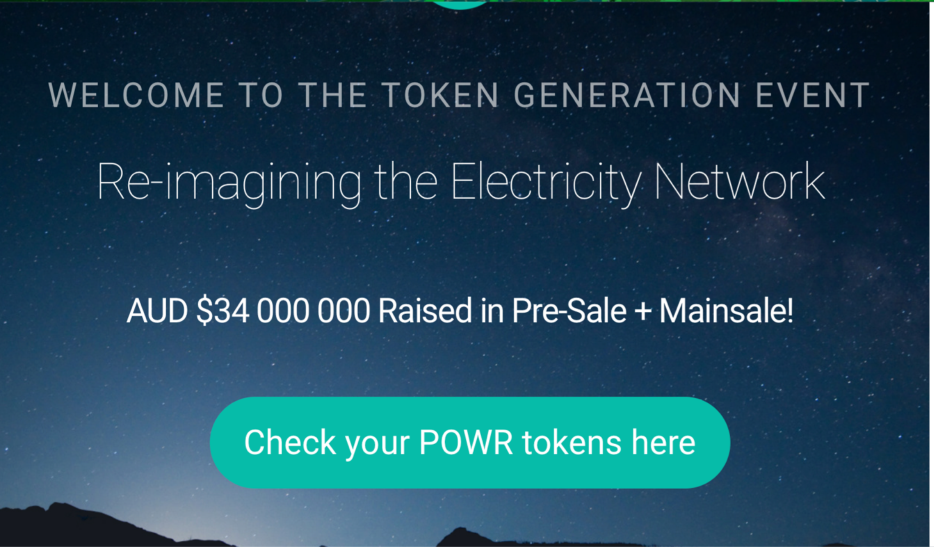
GRID+

During the GRID token pre-sale, Grid+ sold **36,422,909 GRID tokens** and currently holds the following assets:

- **85,407.0 ether**
- **584.8 bitcoin**
- **$125,000.00 USD**

Using today's prices, these assets sum to roughly **$27.7M**. In terms of USD collected at the time of sale, the total is **$29.0M**.

With the pre-sale officially finalized, this leaves **53,577,091 GRID tokens** for sale in the **public token sale on October 30**.



LO3 ENERGY

UCL: Research approach

- Pre-competitive research – 2 to 5 year outlook
- Focus on the academic value-add
- Deep engagement with stakeholders
  - Communities (Brixton; Hackney)
  - Companies (EdF; BP; Verv; etc)
  - Governance (IEA; BEIS; Ofgem; Elexon)
  - Academia (UKCRED; PETRAS; BIEE; etc)
- Empirical approach (think->measure->model)

UCL: What we do

- Physical layer
  - Measuring (Mloduchowski)
  - Modelling (TBC)
- Social layer
  - Measuring (Johnson + Huebner)
  - Modelling (Ala-Kurikka + Huebner)
- Governance layer
  - Mechanisms (Schneiders + Fell)
  - Impacts (Fell + Schneiders)
- Global layer
  - Case studies (Shipworth)

How we do it

- Modelling & simulation
  - Signal detection
  - P2P balance group optimisation
- Social research
  - Participant co-design workshops
  - Social survey experiments
- Physical model
  - Hardware: Generation; metering; loads
  - Software: BC/DLTs; smartphone apps/interfaces
  - Customers: P2P field trial participants
- Field trials
  - Hardware + Software + Customers
  - Experimental/observational research design

Recommended reading

- **Videos:**
  - ‘Peer-to-peer energy trading on blockchains’ – David Shipworth <https://www.youtube.com/watch?v=AcufQeaOK1U>
  - ‘Blockchain 101 - A Visual Demo’ – Anders Brownworth < https://www.youtube.com/watch?v=_160oMzblY8>
- **Podcasts:**
  - Epicenter episode 174 – Carsten Stoker: ‘How blockchains will power the energy grids of tomorrow’, Epicenter – Weekly podcast on Blockchain, Ethereum, Bitcoin and Distributed Technologies, Duration 1:05:53
  - Epicenter episode 206 – Karl Kreder: ‘Grid+ – Unlocking Direct Access to Wholesale Energy Markets’, Epicenter – Weekly podcast on Blockchain, Ethereum, Bitcoin and Distributed Technologies, Duration 1:00:47
- **Consultancy reports:**
  - Burger, C., et al. (2016). Blockchain in the energy transition: A survey among decision-makers in the German energy industry, European School of Management and Technology GmbH Deutsche Energie-Agentur GmbH (dena) - German Energy Agency.
  - PwC (2016). Blockchain - an opportunity for energy producers and consumers?, PWC Global Power & Utilities: 46.
  - Mattila, J. et al. (2016). Industrial Blockchain Platforms: An Exercise in Use Case Development in the Energy Industry. ETLA Working Papers. Finland, The Research institute of the Finnish Economy.
- **Academic articles:**
  - Morstyn, T. *et al.* (2018) ‘Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants’, *Nature Energy*. Nature Publishing Group, 3(2), pp. 94–101. doi: 10.1038/s41560-017-0075-y.
  - Mengelkamp, E. et al. (2017) ‘Designing microgrid energy markets: A case study: The Brooklyn Microgrid’, Applied Energy. doi: https://doi.org/10.1016/j.apenergy.2017.06.054.
  - Chen, S. and C.-C. Liu (2017). "From demand response to transactive energy: state of the art." Journal of Modern Power Systems and Clean Energy **5**(1): 10-19.
  - Yli-Huumo, J., D. Ko, S. Choi, S. Park and K. Smolander (2016). "Where Is Current Research on Blockchain Technology?—A Systematic Review." PLOS ONE **11**(10): e0163477.
  - Green, J. and P. Newman (2017). "Citizen utilities: The emerging power paradigm." Energy Policy **105**: 283-293.