UCL Energy Institute

Transactive energy: Turning the energy system outside-in

David Shipworth

Professor of Energy and the Built Environment

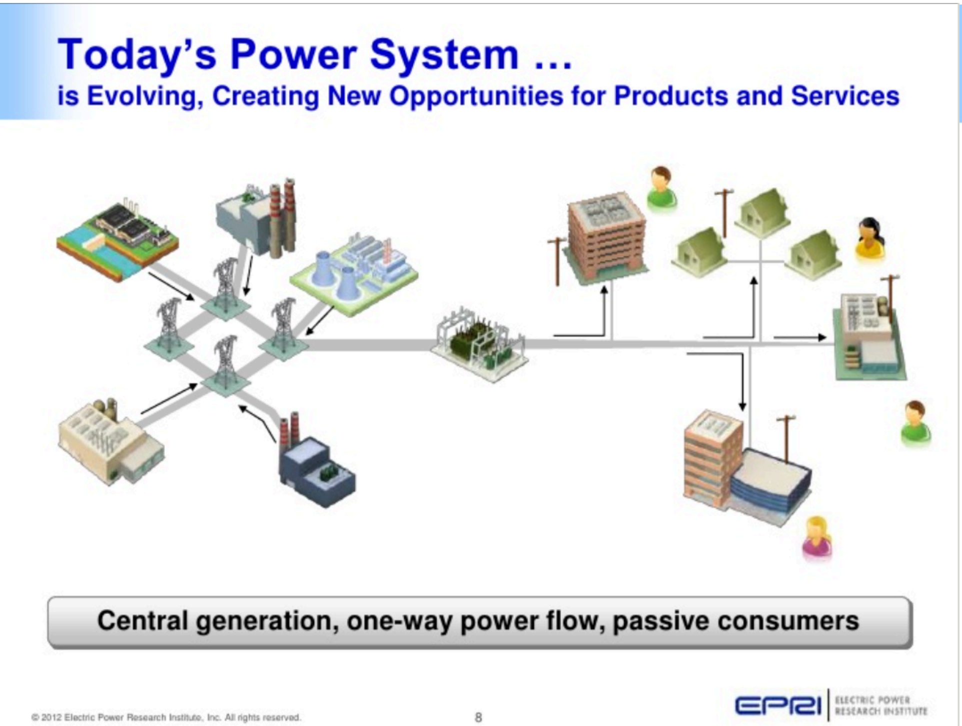
<d.shipworth@ucl.ac.uk>

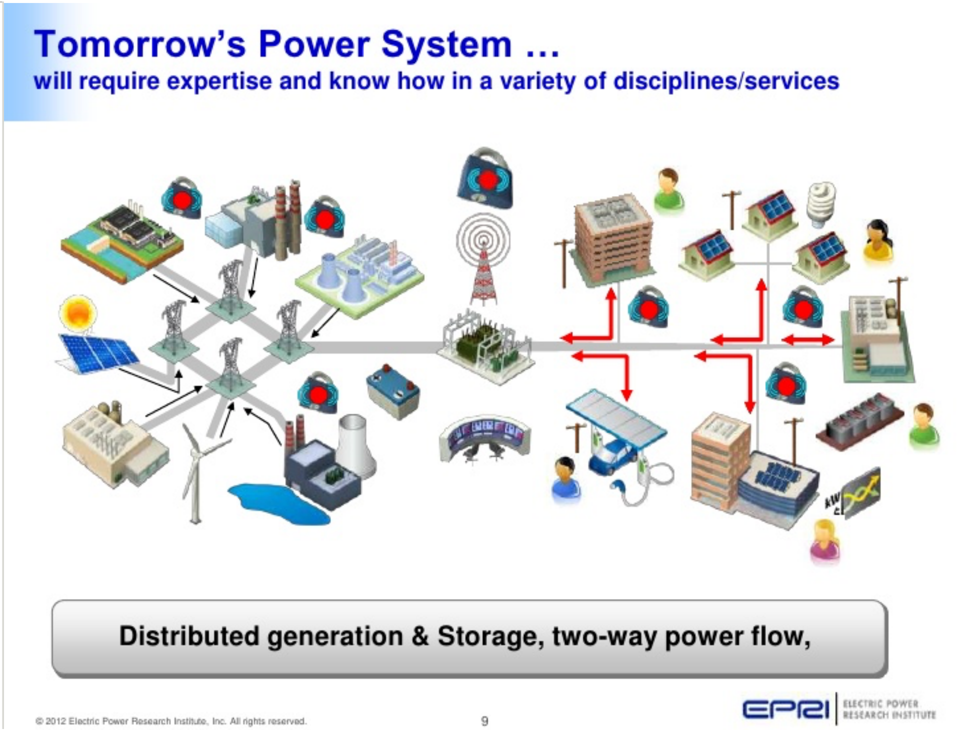
"A professor is someone who talks in someone else's sleep." W.H.Auden

Part 1: Context:
The energy transition

Turning the energy system inside out: the shift to grid edge balancing services

- "The recent rise of new connection requests is astounding."
  (Commons Energy and Climate Change Committee)
- "Trading flexibility locally has potential to optimise the matching of supply and demand…" (BEIS)
- "Half-hourly settlement, it will also allow domestic consumers themselves to become providers of system services in new ways" (Ofgem)

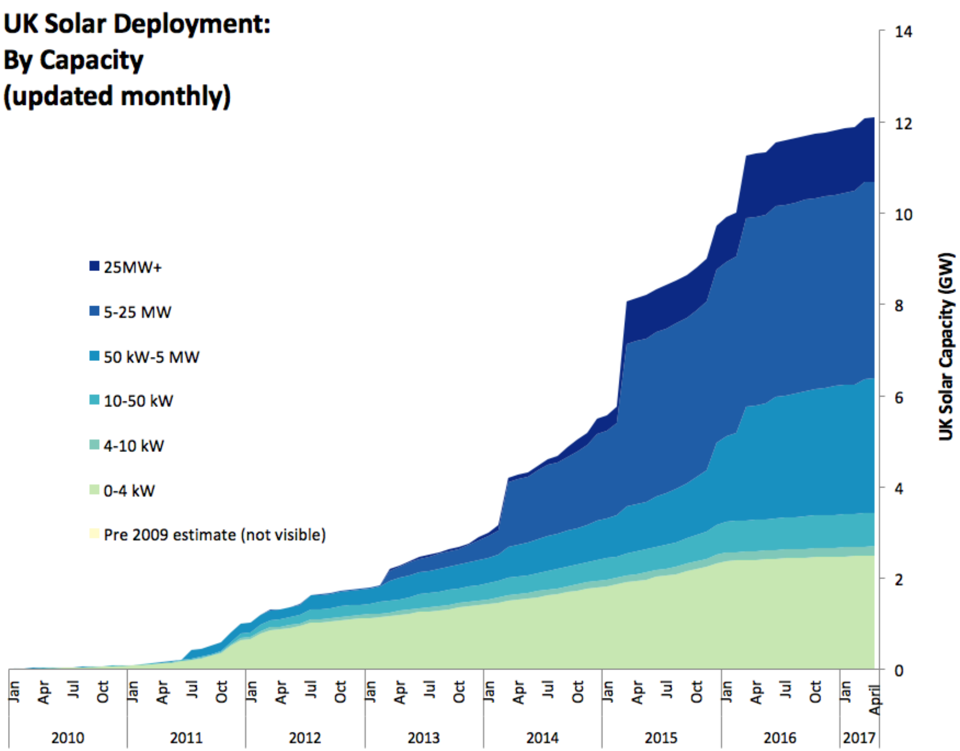


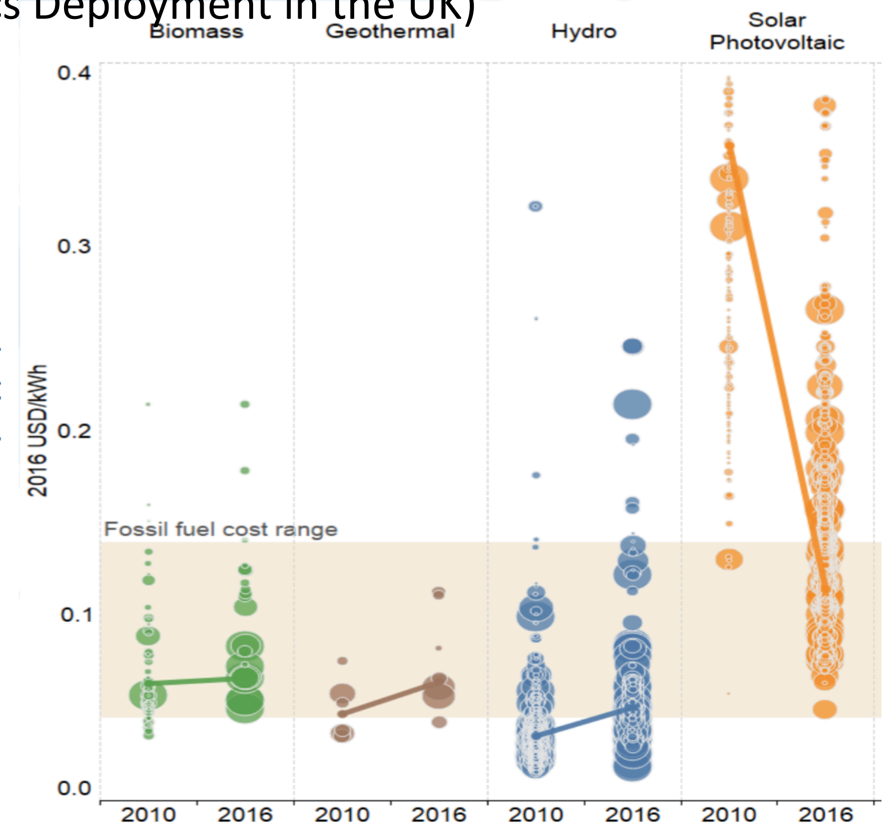


https://www.slideshare.net/webgoddesscathy/emerging-energy-generation-and-storage-technology-by-mark-tinkler

UK solar PV capacity 2010 - 2017

- ~ 11GW PV capacity in ~900,000 installations across the UK
- ~ 90% are domestic size (0 to 4kW)
  - (BEIS (January 2017) Solar Photovoltaics Deployment in the UK)



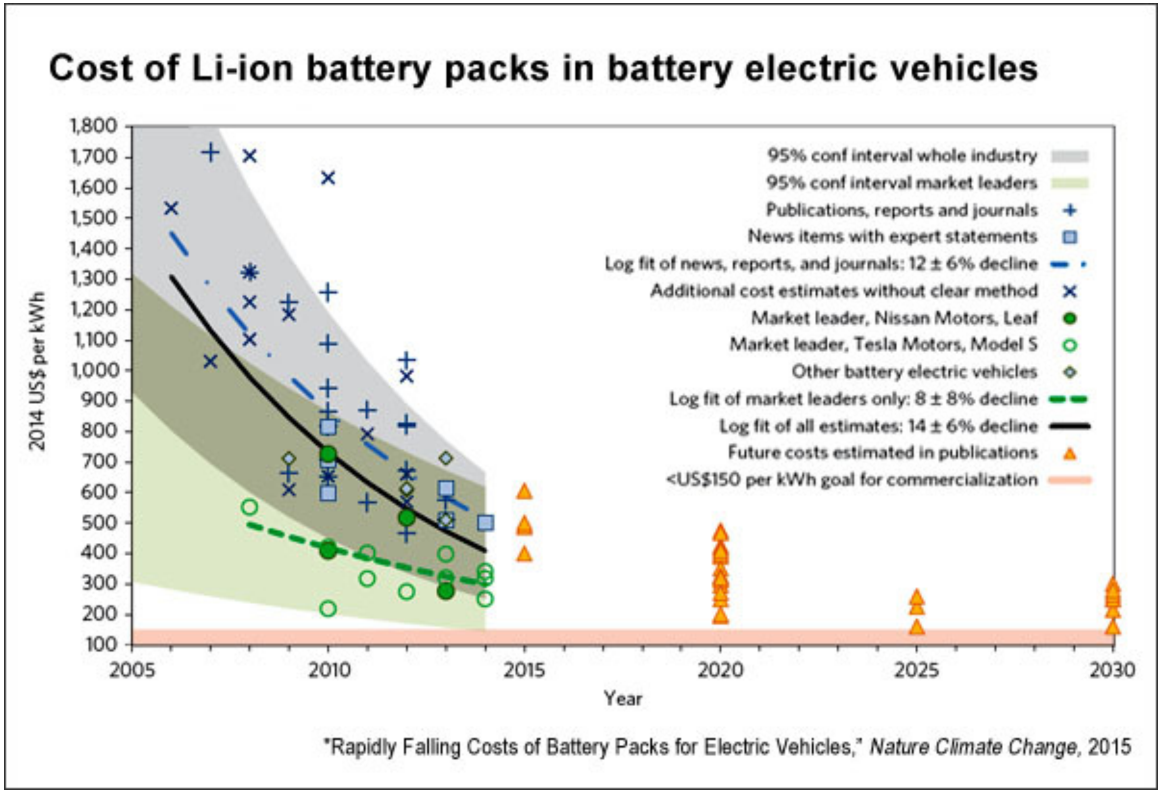


- Ref: National Statistics (2017) Solar photovoltaics deployment

[Ref: http://costing.irena.org/media/11386/TAYLOR-WB-MENA-workshop-Ouarzazate-7-Feb-2017.pdf]

Battery storage

- IEA's 'Tracking Clean Energy Progress: 2017' lists three technologies on track for a 2˚C goal
  - Electric vehicles
  - Energy storage
  - Solar PV & onshore wind



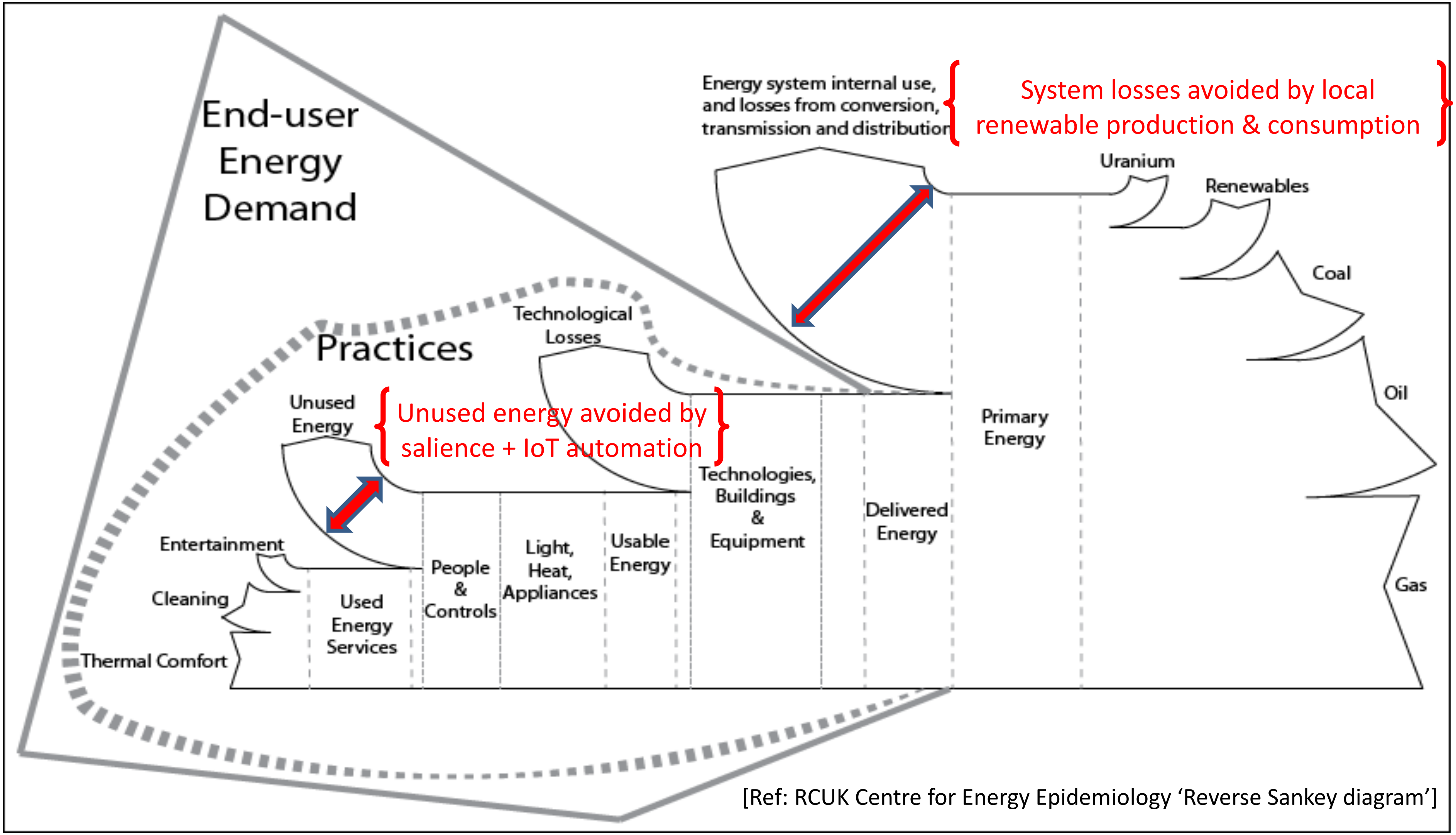
From energy to power

- Power drives cost in a decarbonised energy system
  - Decarbonising heat and transport increases electricity demand
  - Renewable generation is high capital and low operating cost
  - Generation is intermittent, driving up ‘loss of load’ probability
  - Network costs are determined by peak power
  - **Therefore enhanced balancing services are essential for cost minimisation**

- The DNO-DSO transition
  - “A Distribution System Operator (DSO) securely operates and develops an active distribution system comprising networks, demand, generation and other flexible distributed energy resources (DER).
  - It acts as a neutral facilitator of an open and accessible market, enabling competitive access to markets and the optimal use of DER on distribution networks to deliver security, sustainability and affordability in the support of whole system optimisation.
  - It enables customers to be both producers and consumers; enabling customer access, customer choice and great customer service.”
    - [Ref: ENA Open Networks Project - June 2017]

Ref: http://www.energynetworks.org/news/press-releases/2017/june/energy-industry-defines-future-of-electricity-networks-in-major-step-towards-smart-grid.html

Benefits of local renewable supply/demand matching



[Ref: RCUK Centre for Energy Epidemiology ‘Reverse Sankey diagram’]

Community energy initiatives

DECC estimated that community energy projects could generate 0.5 to 3 gigawatts by 2020

- Benefits to local communities
  - Building stronger communities.
  - Providing skills, education and work experience
  - Creating financial benefits for communities.
    - [Ref: Community energy in the UK: A review of the evidence, Call for Evidence responses.]

- [Ref: http://communityenergyengland.org/wp-content/uploads/2015/10/Infographic_2015_Combined.pdf]

Salience and self-consumption

- The ‘double-dividend’ of self-consumption: energy saving + energy shifting [Ref: Keirstead, 2007]
- Evidence that both household and community self-consumption, at can increase energy salience, engagement and perceived relevance of energy in some groups.
- Increasing salience is key to consumer engagement from supplier switching to energy efficiency, conservation, and investment.

From cost minimisation to value maximisation

- Whole energy system cost minimisation is predicated on product homogeniety – it is a legacy of 1960's socialised, centralised energy system planning.
- We need consumer power value differentiation to drive system change
- Who pays, why they pay, and what they get matters.
- Consumers investing in autonomy, resilience, communality, charity, social status etc. is part of "*putting consumers at the heart of the energy system*".

Part 2: Concept: Transactive energy

Transactive Energy – Introduction

- Term coined by US lead 'GridWise Architecture Council' (U.S. DoE) in 2015.
  - Similar to 'peer-to-peer energy trading' and 'Community self-consumption'.
- "[Transactive energy] aims to balance supply and demand in a real-time, autonomous, and decentralized manner."
  - "…distributed flexible resources are directly controlled by their owners.
  - "Transaction mechanisms are designed to align individual behaviors with the system's interests."
    - (Chen 2017)
- Requires smart metering as an enabling technology

French ‘Community self-consumption’

- Legislation implemented in France last month.
  - *“The self-consumption operation shall be collective when the supply of electricity is contracted between one or more producers and one or more final consumers linked together within a legal entity and whose import and export points are located on the same low voltage feeder of the distribution network.”*
    - [Ref: https://www.jechange.fr/energie/electricite/news/projet-ordonnance-autoconsommation-28-07-2016-4007]
- DNOs must facilitate self-consumption operations.
- New network charging protocols for self-consuming installations to be established this Summer (2017)

Transactive energy – the community benefits

- Keeping money in the local community
- Collaborative economy models
- Local energy resiliency
- Local economic benefits - buying local clean energy - supply-demand matching from rooftop PV to local businesses consuming power during the day, etc

Part 3: Mechanisms: Blockchains in energy

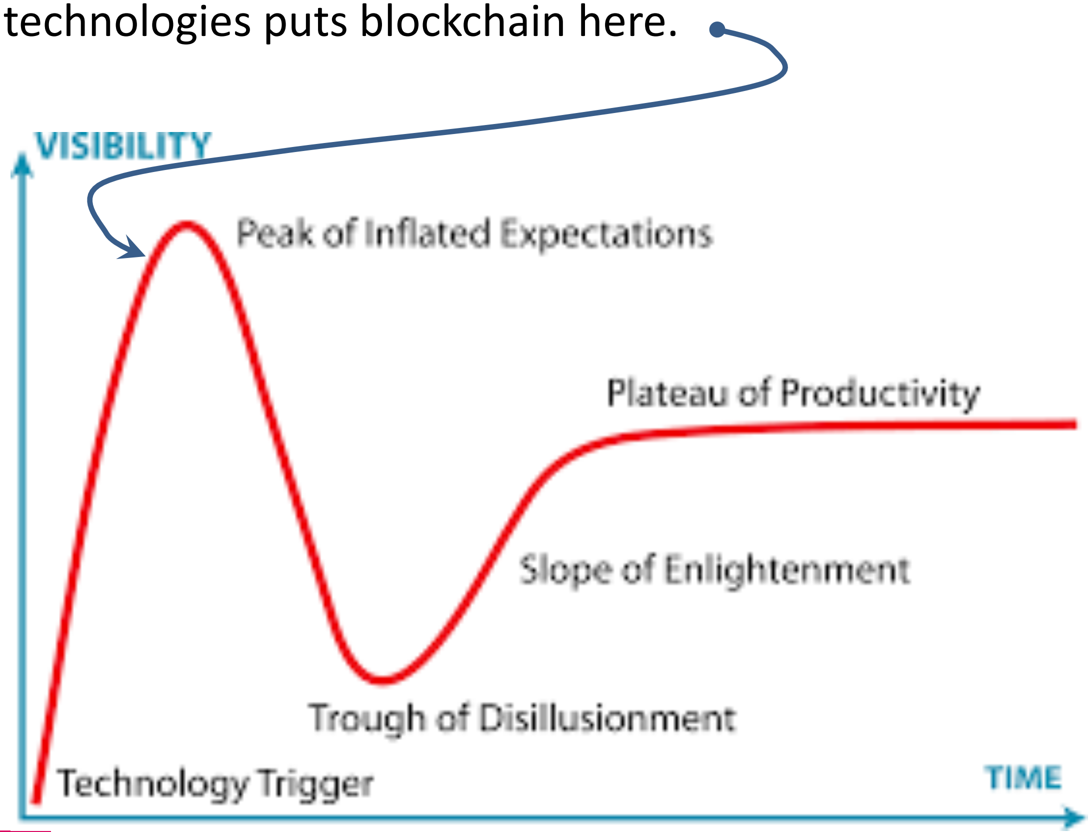
Distributed Ledgers or 'Blockchains'

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

EventHorizon 2017 YouTube channel < https://www.youtube.com/channel/UCeb-0aG78n_wZMZaRMUb3Zw/videos >

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.



- Key architecture concepts:
  - Distributed
  - Disintermediating
  - Trustless
  - Secure
  - Immutable
- Key cryptography concepts:
  - SHA256 hash functions
  - Nonces
  - Public-private key encryption protocols

Blockchain overview

- "The blockchain makes information look like a thing. It creates the scarcity that you couldn't do on the internet."
  - [*Joe Ito - MIT Media Lab*]
- Used to account for ownership of digital & physical assets
- Open to all participating parties (public, permissioned or private).
- 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
  - Collectively secured through mining energy and scale
- The 'three phases' of blockchain evolution
  - Cryptocurrencies (e.g. Bitcoin)
  - Smart Contracts (e.g. Ethereum)
  - Decentralised Autonomous Organisations (DAOs)

Blockchain smart-grid rationale

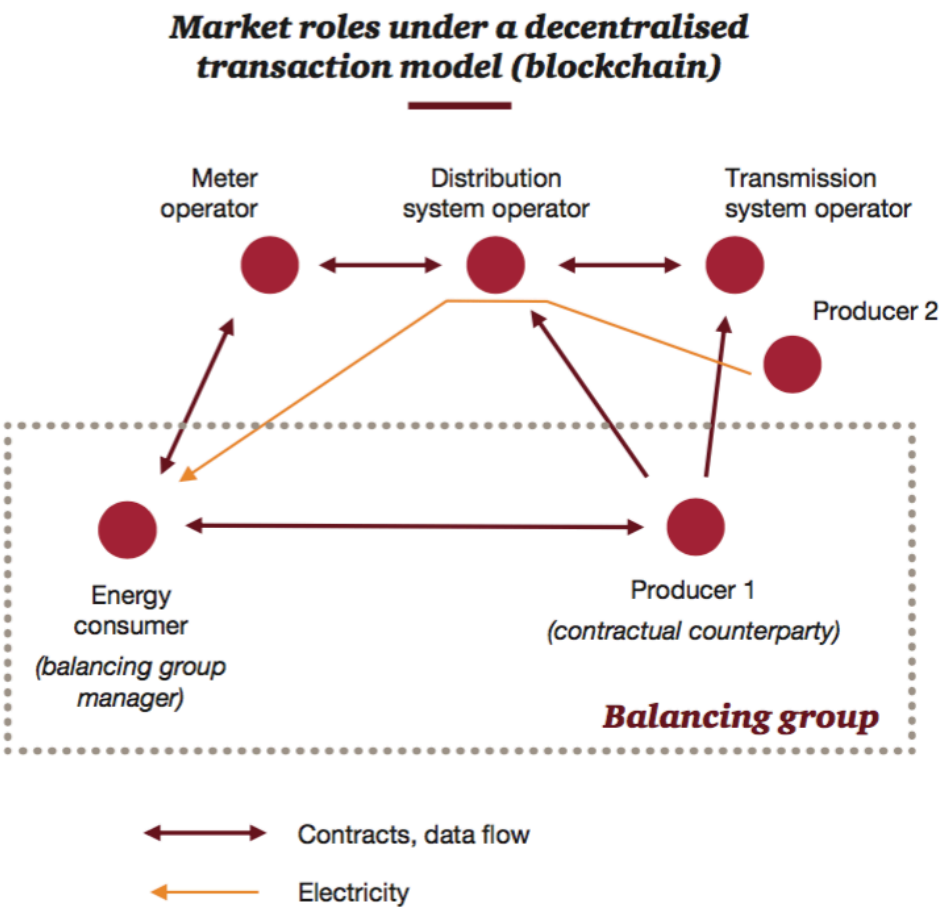
- A smart-grid requires:
  - A data infrastructure that:
    - Can be used by mutually competing and distrustful entities
    - Ensures integrity, authenticity, commercial secrecy and customer privacy
    - Cannot be compromised by any single entity
  - A financial transaction layer that:
    - Supports 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.
- Blockchain could provide the transaction and control layer for the smart-grid

Use cases

- RWE Innogy's Carsten Stöcker reports:
  - ~200 use cases;
  - ~90 start-ups;
  - dozens of PoCs;
  - a few physical trials; and
  - almost no business models.
    - (as of April 2017).

- 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

Existing energy system architecture:
The PwC P2P / RWE Innogy model

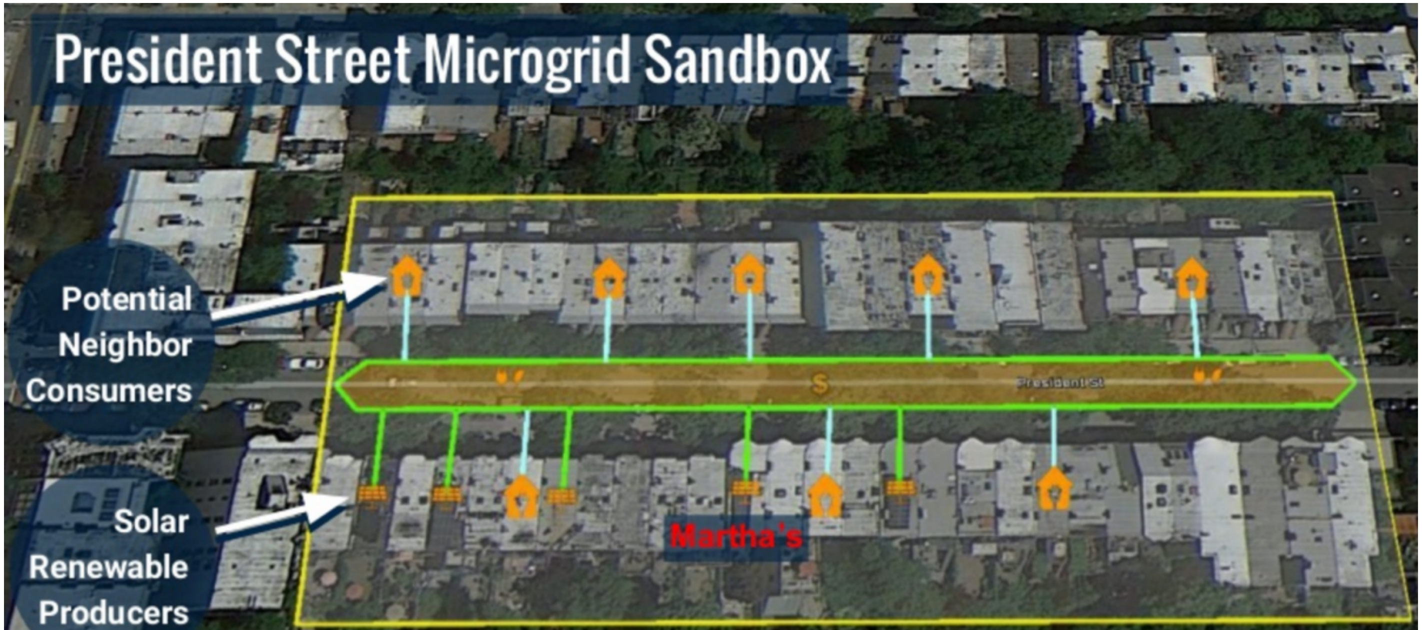


- P2P traders form balance groups
- Balance schedules sent to the grid operator
- Imbalances settled through wholesale market
- Utilities provide legal wrapper and interface services to the system

- Figure 15: 'Current market roles vs. market roles in a blockchain-based system' in PwC (2016) Blockchain - an opportunity for energy produces and consumers? Price Waterhouse Cooper global power & utilities, p.20

LO3 Energy

- 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.



Power Ledger

- Power Ledger
  - Q3 2016 - White Gum Valley microgrid - 30 homes – behind the meter
  - Q4 2016 – Mixed use estate (residential & commercial) – Across the meter.
  - Q1 2017 – New Zealand project with Vector & Tesla - 500 sites identified for development in 2017
  - Q3 2017 – 11,000 smart meter participants in Aust, DSO + Utility + Fed.Gov. support. All software solution.

Part 4: Challenges & Opportunities

Key blockchain challenges

- Throughput/scaling (transactions per second)
  - Bitcoin ~7tps; VISA ~2,000tps; Twitter ~5,000tps.
- Latency (time per verified transaction)
  - Bitcoin ~10 min.; Ethereum ~3 min.; Visa ~3 sec.
- Security: (51% attacks; Selfish Mine attacks; Verifier's dilemma, etc)
- Standards: (Increasing calls for standards but no work yet.)
- Size and bandwidth (Existing tech doesn't scale well)
  - Bitcoin ~110 GB (at April '17). To match Visa needs ~ 200 PB/year
- Privacy: (Blockchain data can reveal users' identities)
- Smart contracts: (Correctness, predictability, legal status across jurisdictions)
- Energy intensity: ('Mining') Bitcoin uses ~300MW (at April '17)
- 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)

Key energy system challenges

- Policy
  - The DNO to DSO transition and sub grid supply point balancing
  - Integration with the smart metering implementation programme and the DCC
  - Restructuring network charging and tax in bills to charge power progressively
- Regulatory
  - Revision of the Balancing and Settlement Codes
  - Revision of customer information sharing between suppliers
  - Revision of SMETS II to facilitate smart meter firmware upgrades
- Business
  - Energy IoT cybersecurity needs to move to ‘secure at all depths’ design
  - Design and consumer acceptability of product offerings
  - Customer value propositions and business cases
- Energy system technology issues
  - IoT for distributed generation asset control
  - API control integration with batteries and PV
  - Many legacy FIT PVs aren’t on net metering

Key research challenges

- Research issues:
  - Whole energy system architectures and identification of blockchain entry points.
    - [Ref: ESC & IET 'Future Power Systems Architecture work']
  - Designing blockchain system architectures to deliver different government, industry and consumer objectives (e.g. grid balancing vs product innovation)
  - Data privacy and governance in public and permissioned blockchains
  - Demand Side Response identification and authentication using smart metering and IoT sensing, actuation and control
  - Designing desynchronization of demand within balance groups
  - Integrating automated DSR into Building Energy Management systems

Key consumer challenges

- Designing transactive energy schemes to maximise consumer engagement.
- Identifying the social, psychological and financial value to consumers.
- Deliver automated DSR without annoying or confusing building occupants.
- Working out how to equitably socialise the cost of a robust universal energy service.
- Avoiding social marginalisation arising from product differentiation and ‘energy gated’ communities.
- Design one platform that delivers multiple value streams (social, psychological and financial)

The Opportunity

- The energy transition shifts focus from energy to power.
- Global trends in generation (PV + wind) and storage (incl. 2^{nd} life EV Li-ion batteries) will drive rapid change.
- Putting consumers at the heat of the power system means moving from cost minimisation to value differentiation and maximisation.
- Transactive energy can deliver both energy system and consumers benefits.
- Blockchains make value transactable, transparent, auditable and aggregable at very low transaction costs.
- Blockchains support both transactions and control.
- Transactive energy + blockchains + IoT can help minimise waste of both primary and delivered energy.

Recommended reading

- **Videos:**
  - EventHorizon 2017 YouTube channel <https://www.youtube.com/channel/UCeb-0aG78n_wZMZaRMUb3Zw/videos>
  - Blockchain 101 - A Visual Demo by 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
- **Consultancy reports:**
  - Burger, C., A. Kuhlmann, P. Richard and J. Weinmann (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.
  - PwC (2016). Blockchain - an opportunity for energy producers and consumers?, Price Waterhouse Cooper global power & utilities**:** 46.
  - Mattila, J., T. Seppälä, C. Naucler, R. Stahl, M. Tikkanen, A. Bådenlid and J. Seppälä (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:**
  - 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.
  - Dimitriou, T. and G. Karame (2013). Privacy-Friendly Tasking and Trading of Energy in Smart Grids. Proceedings of the 28th Annual ACM Symposium on Applied Computing.
  - Green, J. and P. Newman (2017). "Citizen utilities: The emerging power paradigm." Energy Policy **105**: 283-293.
  - Mihaylov, M., S. Jurado, N. Avellana, K. V. Moffaert, I. M. d. Abril and A. Nowé (2014). NRGcoin: Virtual currency for trading of renewable energy in smart grids. 11th International Conference on the European Energy Market (EEM14).