Opportunities for Energy Systems Flexibility

Scottish Enterprise

Scottish Enterprise

Green Heat Accelerator

Powered by CLT CARBON LIMITING TECHNOLOGIES

Workshop 11. 6th December 2022

Agenda

1) Current Issues in the Energy System
2) What is Flexibility, and how does it help?
3) Why does the energy system need flexibility?
4) How does it buy this flexibility?
5) How does this translate into value for the end customer?
6) How can heating systems help deliver this value?
7) What type of business models can this enable?
8) What do the supply chains look like?

Current issues in the energy system

- Affordability
- Security of Supply
- Decarbonisation
- Pace of Investment
- Consumer / Customer / Citizen Trust & Value

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Flexibility

"modifying generation and/or consumption patterns in reaction to an external signal such as a change in price, to provide a service within the energy system"

Flexibility can enable

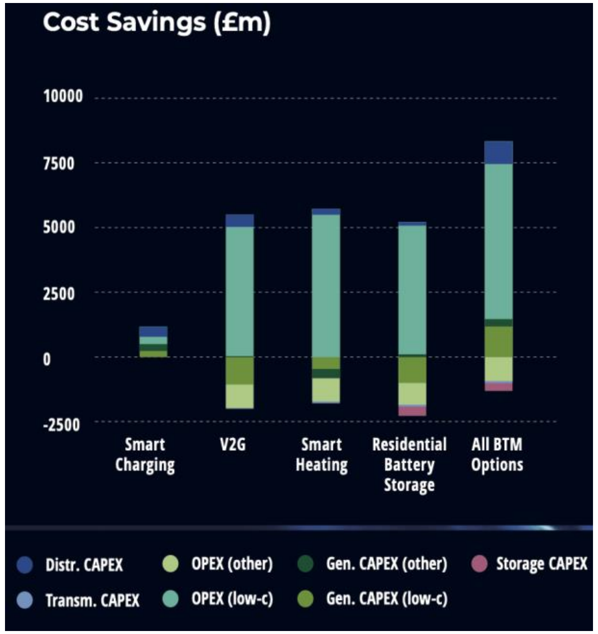
Affordability	• Shift demand to times when energy is cheap / export when expensive • Earn additional revenues by providing services to ESO & DSO • Hedge against risks in wholesale markets
Security of Supply	• Reduce demand / increase generation when energy is scarce • Store energy (batteries, thermal inertia, etc) for times of scarcity • Earning revenue from ESO or DSO enables investment in generation
Decarbonisation	• Shift consumption to times when energy is clean
Pace of Investment	• Reduce peak demand / flow, reducing need for generation & network • Increase utilisation of generation & network • Defer investment until greater certainty, avoiding risk of stranding
Consumer / Customer / Citizen Trust & Value	• Enable products based on broader value (convenience, locality, community ownership, …) • Enable people and community to participate more actively

Flexibility is key to a net-zero energy system

Numerous energy system models estimate that flexibility could reduce whole system costs by between **£3.2bn - £16.7bn p.a.**[1,2,3,4], due to reduced need to invest in generation, lower system balancing costs and reduced need to reinforce transmission and distribution networks.

"The transition to a smarter and more flexible energy system is an opportunity. It will be delivered by UK businesses and will benefit consumers across the country. It will reduce the costs of our system by up to £10bn a year by 2050, by reducing the amount of generation and network we need to build to meet peak demand. It will create jobs, perhaps 24,000 by 2050, and drive investment across the UK."

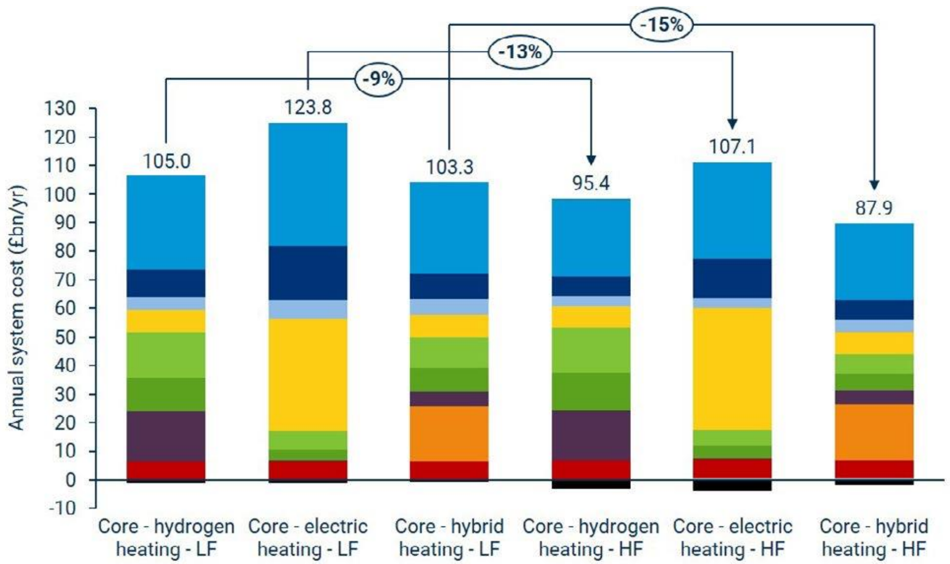
BEIS / Ofgem Smart Systems & Flexibility Plan[5]



Ovo Energy et al[2]

"Investing in flexibility is a no-regrets decision as it delivers material net savings of up to £16.7bn/yr across all net zero scenarios analysed in 2050"

Carbon Trust et al[3]



Carbon Trust et al[3]

[1] https://www.theccc.org.uk/wp-content/uploads/2017/06/Roadmap-for-flexibility-services-to-2030-Poyry-and-Imperial-College-London.pdf
[2] https://www.ovobyus.com/m/612ecb9594ebe581/original/blueprintforapostcarbonsociety-2018.pdf
[3] https://www.carbontrust.com/news-and-events/news/groundbreaking-analysis-reveals-a-fully-flexible-energy-system-could-cut-the
[4] https://nic.org.uk/app/uploads//Power-sector-modelling-final-report-1-Aurora-Energy-Research.pdf
[5] https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

Why is this an issue now?

- Energy system was essentially built on assumption that flexibility is an inherent property of generation – *Need more power? Throw more coal into the furnace.*
- This is more true for some types of generation than others. (e.g. Gas > Nuclear)
- No-one has yet found a way to turn up the sun or wind when we need it

Why does the energy system need flexibility?

Explicit Flexibility

- National balancing
- System operability
  - Response (frequency)
  - Reserve (energy)
  - Reactive (voltage)
  - Restoration
- Network constraints
- Network losses
- Investment timing & optionality

Implicit Flexibility

- Wholesale trading to optimise energy pricing & risk
- DUoS & Triads reduce network constraints & losses

How does it buy this flexibility?

Who buys flex?

1) **ESO** – reasonably well developed markets for ancillary services, BM, capacity market

2) **DSO** – emerging markets for 4 products defined via ENA

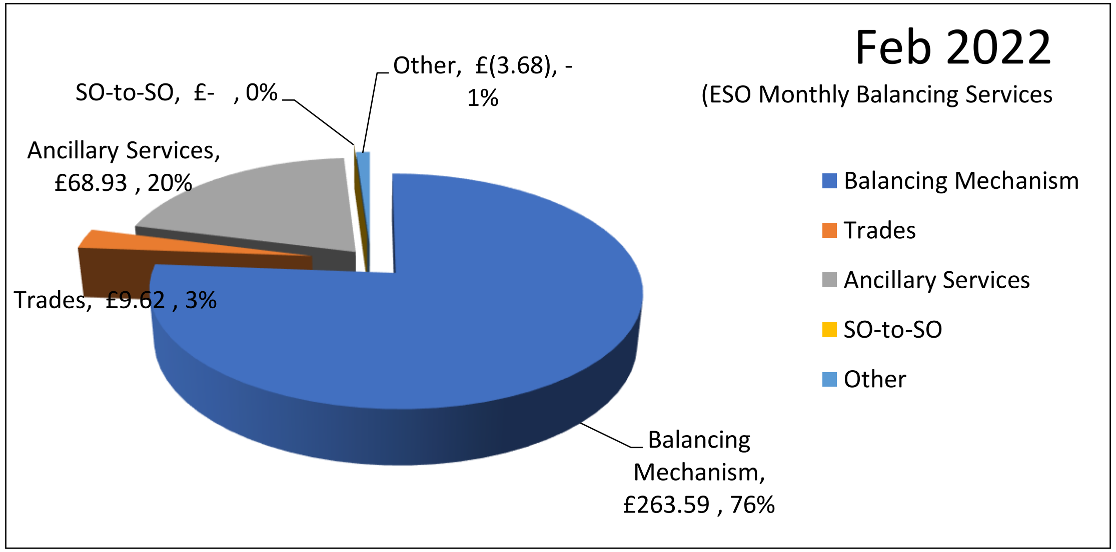
3) **Suppliers & Traders** – manage / hedge their position on wholesale & imbalance markets

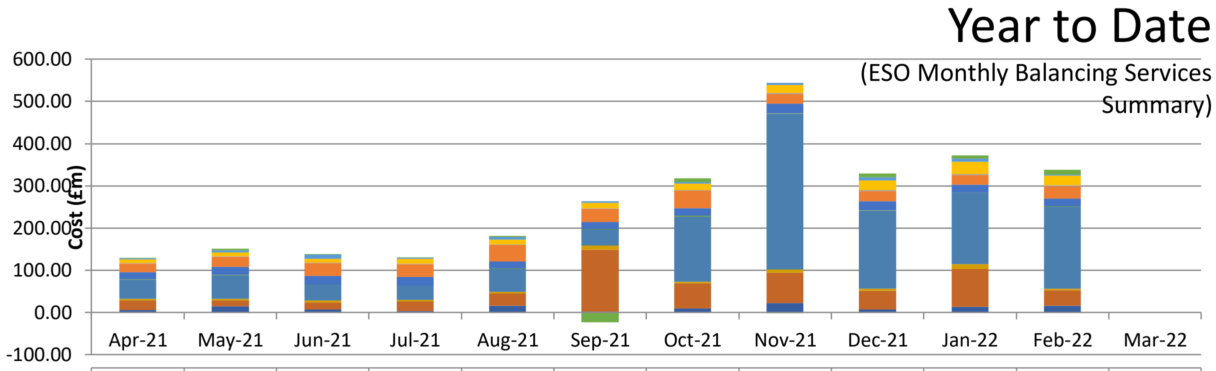
4) **Customers** – Consumers & generators optimise the price they pay / receive for energy

ESO Flex Markets – BM, Ancillary Services & Capacity Market

- Balancing Mechanism
  - Energy System Balance
  - Network Constraints
- Ancillary Services
  - Response – FFR (static & dynamic), DC, DM & DR to start soon
  - Reserve – STOR, Fast Reserve, new products in pipeline
  - Smaller products, e.g. Black Start
  - Pathfinders for Reactive, Constraint, Stability
- Capacity Market

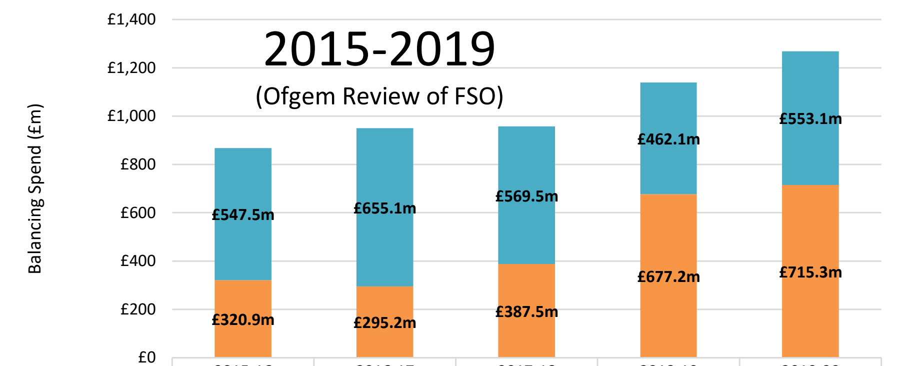
ESO Flex Markets – BM, Ancillary Services & Capacity Market





	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22
Minor Components	0.82	4.73	0.65	1.11	2.03	-23.07	8.62	-1.96	9.44	6.74	11.79	
Black Start	3.70	4.06	9.62	2.64	5.92	2.96	3.30	4.88	6.83	8.34	2.60	
Reactive	7.73	8.95	9.25	10.88	12.05	12.51	14.68	19.30	23.67	28.42	22.70	
Other Reserve	1.40	1.32	1.18	0.96	1.27	1.52	1.96	2.81	1.77	2.18	1.86	
Response	20.43	24.02	30.28	30.23	38.28	32.14	41.22	22.15	23.91	23.35	29.65	
Fast Reserve	17.15	19.64	19.88	21.10	16.90	16.51	17.40	23.08	21.62	18.89	18.18	
Negative Reserve	0.34	0.36	0.08	0.13	0.90	0.47	3.40	1.24	0.83	0.55	0.25	
Constraints	45.35	56.22	38.75	33.96	55.17	38.02	153.68	368.59	185.30	168.65	195.25	
STOR	4.35	3.69	4.36	3.35	3.20	9.91	4.35	7.18	4.53	11.23	3.73	
Operating Reserve	22.71	13.67	16.74	22.30	28.82	146.79	58.49	72.34	44.70	90.44	36.12	
Energy Imbalance	5.93	14.95	7.07	3.85	16.50	2.22	10.22	22.29	6.99	12.96	16.30	

Figure 3.3. Increasing system balancing spend between 2015/16 and 2019/20[30]



	2015-16	2016-17	2017-18	2018-19	2019-20
Energy Costs	£547.5	£655.1	£569.5	£462.1	£553.1
Constraint Costs	£320.9	£295.2	£387.5	£677.2	£715.3

Constraint Costs Energy Costs

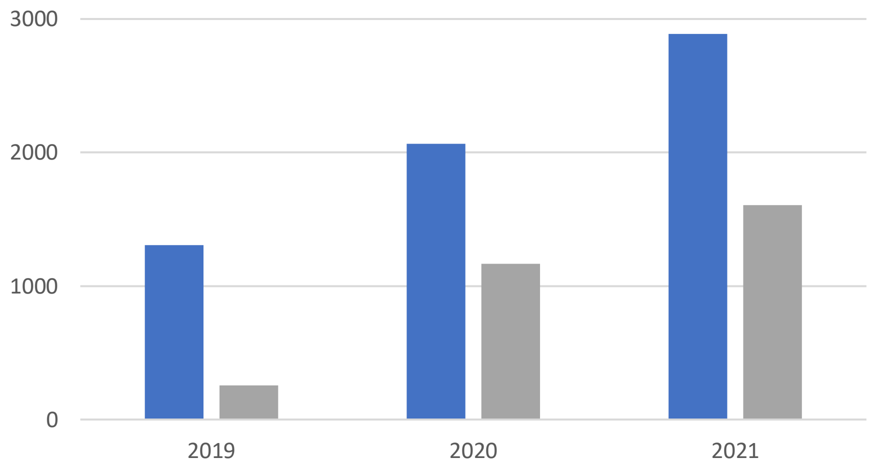
ESO Flex Markets – BM, Ancillary Services & Capacity Market

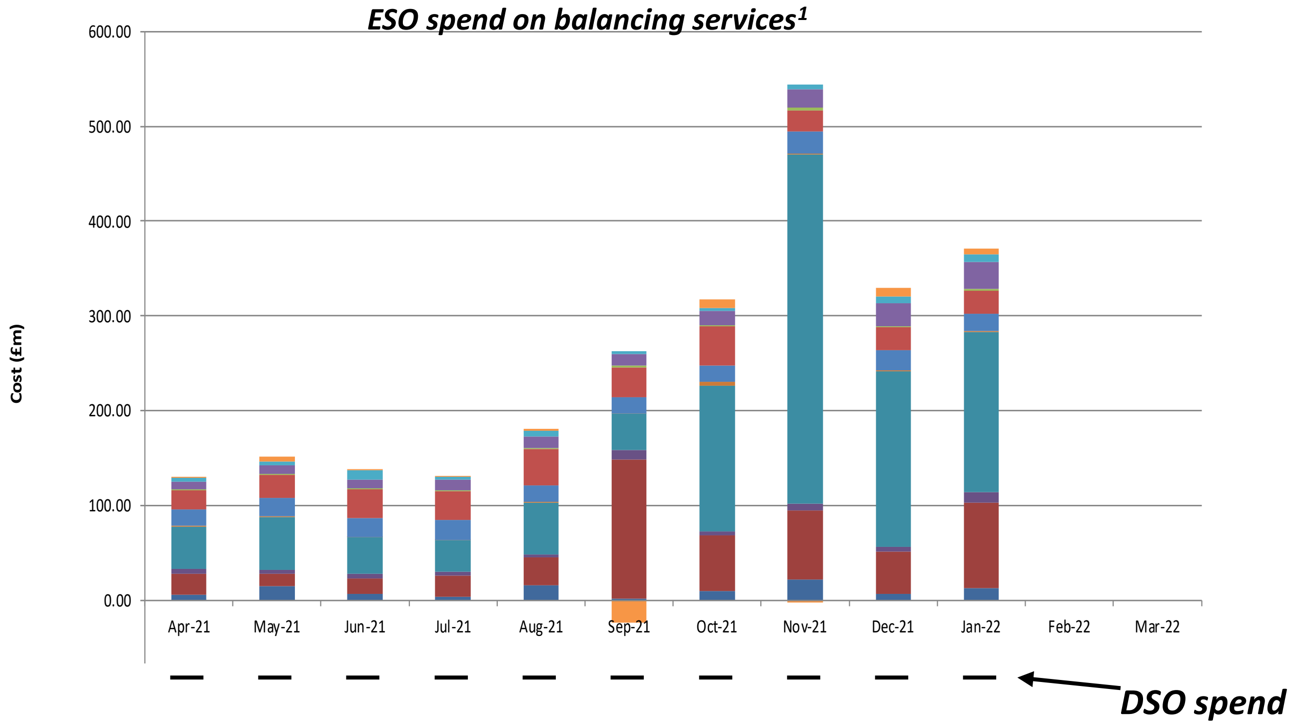
- Balancing Mechanism
  - ~£2bn p.a.
  - Half-hourly bid/offer to ESO so it can take actions to manage the system for hour-ahead period
  - No long forward commitment, so can be stacked (time multiplexed) with other activities
  - Reasonably liquid, but subject to merchant risk, & markets will top out as capacity grows
- Ancillary Services
  - ~£600-800m p.a.
  - Historically bought through periodic (annual & monthly) auctions, but moving to day-ahead
  - Some products very lucrative (e.g. Dynamic Containment in 2021), but require specialist tech
  - Many small products & shallow markets – prone to saturation and price volatility
  - Value split between availability and utilisation; stacking is possible (time multiplexed), needs careful management
- Capacity Market
  - Annual auctions
  - Prices at auction pretty volatile, most recently ~£75k/MW p.a. but average is more like £10-20
  - Storage heavily derated until has about 5 hours of duration
  - Designed to be stackable (e.g. in parallel to response services)

DSO Flex Markets

ENA data on market size (MW)

Price is highly locational. WPD pays average ~£8k/MW p.a., but it can go to ~£30k.





Trading on Wholesale Markets

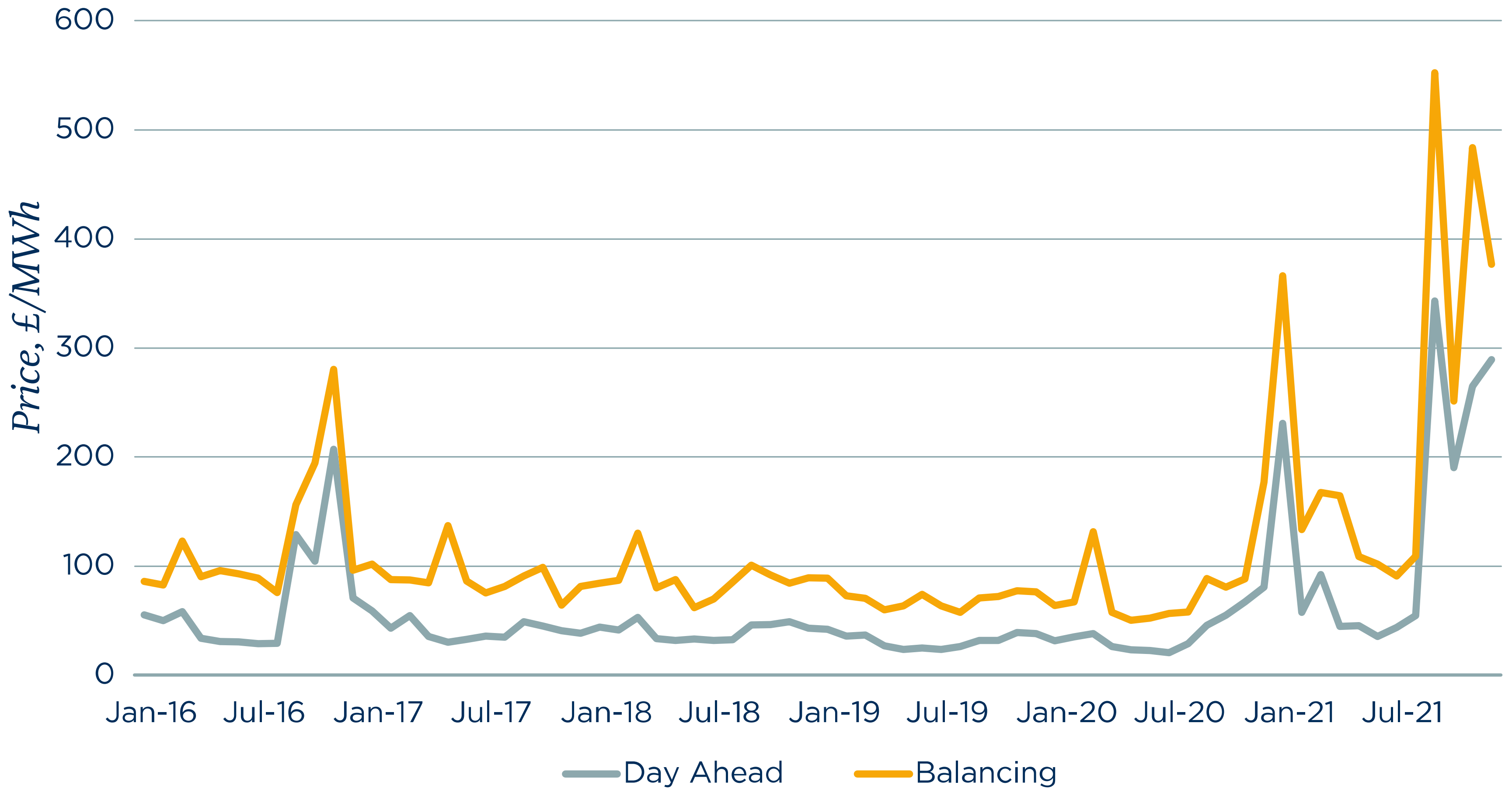
- Total market >£10bn p.a. – Far away the deepest & most liquid opportunity
  - Flex-enabled trading strategies could reduce a supplier's underlying energy costs by 10-30%
  - Again has merchant risk, but investors are getting comfortable with this

- Forward trading via bilateral contracts & PPAs
  - Main opportunity for LDES might be to enable firmer PPAs (to generators, offtakers/suppliers, or consumers)?

- Day-ahead and intraday trading
  - Allows suppliers and traders to fine-tune their position as they gain information on actual supply & demand
  - Can be attractive arbitrage opportunities for time shifting
    - Value is essentially (amount of energy) x (price spread) x (no of cycles)
    - Short duration has less energy but is now aiming for ~600cycles p.a.
    - Will LDES' larger energy capacity compensate for (a) fewer cycles p.a. & (b) lower spread due to price smearing?
  - Would locational marginal pricing create spatial arbitrage opportunities?

Trading on Wholesale Markets

Intraday price spread (monthly average)



Imbalance Market

- Accounts for parties (BRP) failing to meet their contracted positions
  - E.g. failure to generate as forecast, or to estimate actual demand accurately
- Elexon holds ~£500m credit p.a. from suppliers to cover potential costs
- Flex / storage can help BRP adjust its position to avoid costs (& maybe credit requirements?)
- Traders can also earn value by “NIV Chasing” (attractive strategy to optimisers)

Price Optimisation

- Help end customers optimise the price they pay / receive
  - Buy / sell at the optimum time
  - Avoid network charges
  - Help hedge against future price increases
  - May also be some opportunities for policy & regulatory arbitrage (e.g. complex sites)
- Exploit flexible connections (and network constraints)
  - Reduce connection costs & delays
  - Avoid curtailment
  - Network capacity trading
- Time arbitrage via ToU tariffs (domestic & SME) or wholesale pass through (larger I&C)
- Might combine with transmission rights and network capacity trading to give locational arbitrage?
- Access ESO & DSO flex market revenues

How does this translate into value for the end customer?

- Reduce energy costs
  - Time shift against Time-of-Use tariffs
  - Exploit discounted, flex-enabled tariffs (Tempus model; Octopus is active in this space now)
- Earn revenue
  - Export excess generation at peak times (against tariffs or direct to BM & wholesale markets)
  - Sell services to ESO & DSO flex markets
  - Sell network capacity to future markets?
- Enhanced products
  - Energy as a Service offers convenience, reduced weather risk, etc
  - Community and local energy can enhance customer engagement, brand, etc
- Improve equipment maintenance
  - Manage equipment usage to reduce degradation

How can heating systems help deliver this value?

- Timeshifting
  - Use thermal inertia of building fabric or thermal storage to shift demand to cheap times
- Sell to flex markets
  - Option to reduce demand at peak times (for system or network)
  - Option to increase demand when excess generation (e.g. to avoid curtailment)
  - Needs to be managed within comfort limits; thermal storage extends the amount of flex
- Building efficiency
  - Reduces demand
  - Increases thermal inertia
- Behaviour change
  - Provide incentives to adjust comfort limits
  - Potentially amplified by gamefication

What sort of technologies are involved?

Heating Tech

- Space Heating
  - Heat pumps, resistive, hybrid, networks, …
  - Necessary anyway – flex adds value to existing asset
  - High load – grid is scared of it
  - Can't export; turn down (or up) only
  - Limited flex in summer (unless have air con)
  - Complex interaction with building fabric, occupancy
  - Interoperability laggard
- Hot Water
  - Year round demand
- CHP
  - Can export, but limited greenness unless H_2
- Thermal Storage
  - Water is cheap; phase change is more expensive
  - Significantly increases flex, but still can't export

Competing / Complimentary Tech

- Batteries & other storage (e.g. CAES)
  - Extreme flexibility; can swing from import to export
  - Less driven by building physics, simpler to manage
  - No value in its own right – flex case must stack up
  - Interoperability is better, but still not great
- EVs
  - Necessary in own right – V1G adds value
  - V2G gives extreme flex, but uncommon & expensive
  - Not always plugged in
  - Lots of standards; real world interoperability is tough
- Smart appliances
  - Low load
  - Interoperability is tough

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Implications

- Design for whole building – consider fabric, storage, total load, occupancy, …
- Capture data – good, granular usage data is a constraint to most business models right now
- Provide APIs and monitor standards

How does this relate to the technologies you're working with?

What type of business models can this enable?

- Smart Appliances
  - Sell kit at premium price
  - Sell kit at discount, retaining access to trailing revenues from flex (in extremis, finance the kit)
  - Use flex to gather data to drive maintenance and servicing, hence help sell these services
- Energy Management Systems / Services
  - Fixed subscription fee
  - Share in value created (cost savings & revenue; complex counterfactual)
  - Enable discounted tariffs (requires supplier participation)
- Energy as a Service
  - Fixed fee, with risks mitigated by "fair use" policies and regular reviews
  - Sell convenience, reduced admin cost (as bundles multiple bills & contact centres into one), reduced weather risk
- Microgrids
  - Greater liquidity amplifies value of flex, e.g. through peer-to-peer and reduced need for external network
  - Complex regulatory space

Asset Financing Models

1) **Household buys asset** & receives benefit of self consumption, tariff optimisation, flex revenue. It sells the asset with house. The household can switch suppliers whenever they want. Suppliers receive standard margin on the tariffs they sell -- if ToU is more profitable / lower risk, they get the full benefit.
2) **Household leases the asset** for a monthly fee. When they sell they house, they use the proceeds to pay off any residual on the lease. Otherwise exactly as (1).
3) **Household buys an energy management service** that has the asset bundled within it. Household receives benefits as for (1) & (2), and pays the service fee. So looks very like (2), but the household benefits from any service guarantees (e.g. guaranteed savings, enhanced service levels) that come with the EMS. Transfer of contract on house sale needs thought, as does ability for customer to exit the service (how are assets recovered?).
4) Household buys energy management service that has asset bundled within it, and is tailored to work with tariffs from a **defined basket of suppliers**. House can share in energy market benefits to the extent they're built into the tailored tariffs (c.f. (1)-(3) where the supplier reaps the full benefit), but are restricted to switch within the basket of suppliers if they want to retain this benefit. Energy mgt service provider negotiates with the basket of suppliers to keep tariffs attractive.
5) **Household signs up to a discounted tariff** in association with an energy management service provided by the supplier (or its close partner). No monthly fee, as that's built into the tariff. This makes a cleaner bundle for the household to buy (all-in-one energy bundle), but creates problems w.r.t. asset ownership in event of switching -- maybe exit fee or switch to asset leasing?
6) **Household buys energy as a service**, either as a separate service or as part of their monthly rent. Service provider takes more risk c.f. (5), but this is mitigated by (a) higher margins, (b) fair use policies, regular service reviews, etc. No longer constrained by switching issues, as are buying a service not commodity energy, but will be subject to consumer protections as the regulatory model develops & need to deal with end of contract issues as per (5).

Tariff Discounting Models

1) **Supplier discounts kWh** upfront, based on forecast flexibility within the asset, and takes risk if forecasts are wrong

2) Supplier caps risk through **tiered discounts** (e.g. progressive tariff with higher discount for first few kWh, tapering off to zero as volume grows. Can also provide volume discounts where the discount grows with volume...)

3) Supplier offers a **standard tariff, but with a rebate (in arrears)** based on actual saving achieved. This eliminates much of their risk, but it creates uncertainty for the household (what benefit wil they actually get?), making it harder to sell. Also need to manage complex counterfactuals.

4) As per model 3, but mitigate the uncertainties by putting a **cap and floor onto the rebate**. (Cap reduces supplier downside; floor reduces household uncertainty. In extremis, can offer a fixed rebate, based on forecast savings.) Also scope to pay some of the rebate (e.g. the floor) up front, making it more attractive to household. (If pay more than floor, can be issues with recovering savings that don't materialise.)

5) **Blended** discount + rebate

6) **Energy as a a Service** -- charge service fee rather than tariff. Supplier then takes volume as well as price risk, but can mitigate with fair use policies, regular reviews, higher margins. Household receives convenience and certainty in return for these margins.

How could this complement your business model?

Do you have other business models you’re considering?

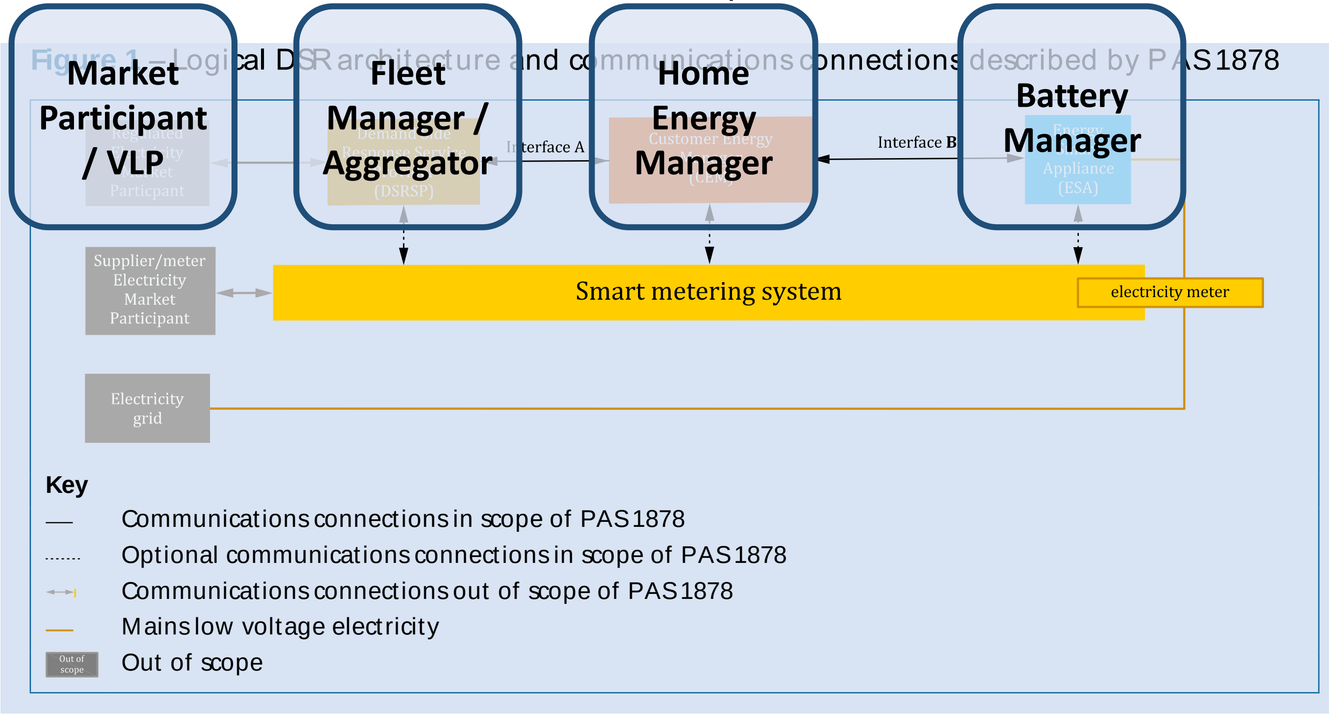
What do the supply chains look like?

- Flex has its own tech stack and supply chain – need to integrate multiple non-standard assets and then take them to fragmented markets (ESO, DSO, supplier/trader).
- Need to integrate this into supply chain for building services & etc, which means navigating the various decision makers and influencers.
- Further complicated by landlord / tenant issues (which can split the value pool, making it uneconomic for anyone to invest).

Flex value chain needs interoperability – BEIS PAS1878 ????

BEIS recently sponsored development of the PAS1878 standard for interoperability of smart appliances. I suggest we use this standard to inform our discussions as (a) it's as good as anything else out there, and (b) this project is at least partly publicly funded, so I assume we will want to follow the policy direction set by BEIS. That doesn't necessarily mean that PAS1878 is ideal, nor that it will automatically be a requirement for the batteries and service providers that will ultimately be procured. It just means that it's a fair enough framework within which to frame our discussion of requirements.

The model looks like:



For our context, this broadly recognises 4 parties:

1) Battery manager
2) Home energy manager
3) Fleet energy manager / aggregator
4) Market participant / VLP

(Aligning CEM & HEM isn't strictly the way the PAS describes things, but it's close enough for this discussion. In practice, CEM might often be built into/alongside the smart appliance, with HEM being another layer in the architecture that the PAS didn't really cover. Distinguishing Home from Fleet management is useful for considering some elements of flex portfolio management.)

Roles of the 4 parties in these flows

Battery Manager

- Discover, connect to & register with HEM. Pass it relevant information about battery capabilities & user preferences.
- Provide ongoing data on power flows in/out, state of charge, etc
- Respond to control signals, e.g. to charge / discharge, go to frequency sensitive mode

Home Energy Mgr

- Check battery performance, register it & pass details to fleet manager
- Monitor energy flows in home
- Manage local devices to meet comfort settings & optimise self consumption
- Predict energy usage and availability of flex over next N hours
- Pass forecasts to fleet manager
- Receive control signals from fleet manager and pass these through to appliances
- Provide visualisations to household; accept user input to set controls & preferences
- Gather meter & submeter data and make it available to relevant parties

Fleet Manager

- Register battery into its fleet, pass details to market manager
- Aggregate view of forward flex availability & adjust it as necessary for reliability, etc
- Pass flex availability to market manager
- Accept dispatch signals from market manager and pass them through to homes
- Accept meter data from HEM, aggregate as necessary, pass to market manager
- Accept settlement data from market mgr, apportion across fleet, pass to payment system

Market Manager

- Qualify & register battery with flex buyer as necessary
- Accept forecasts from fleet manager & validate & adjust as necessary
- Identify best market(s) for flex and bid into them
- Accept dispatch signals from market and pass them through to fleet manager
- Accept meter data from fleet, check, calculate baselines & service delivery, etc, and pass to flex buyer
- Accept settlement data from flex buyer, check accuracy, extract cut, trigger payment to fleet and pass data to fleet manager

Model 1: Smart Battery Cloud + VLP

Battery Manufacturer | Aggregator / UX | VLP

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Model 2: Aggregator manages fleet

Battery Manufacturer | **Aggregator / UX** | **VLP**

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Model 3: VLP manages fleet

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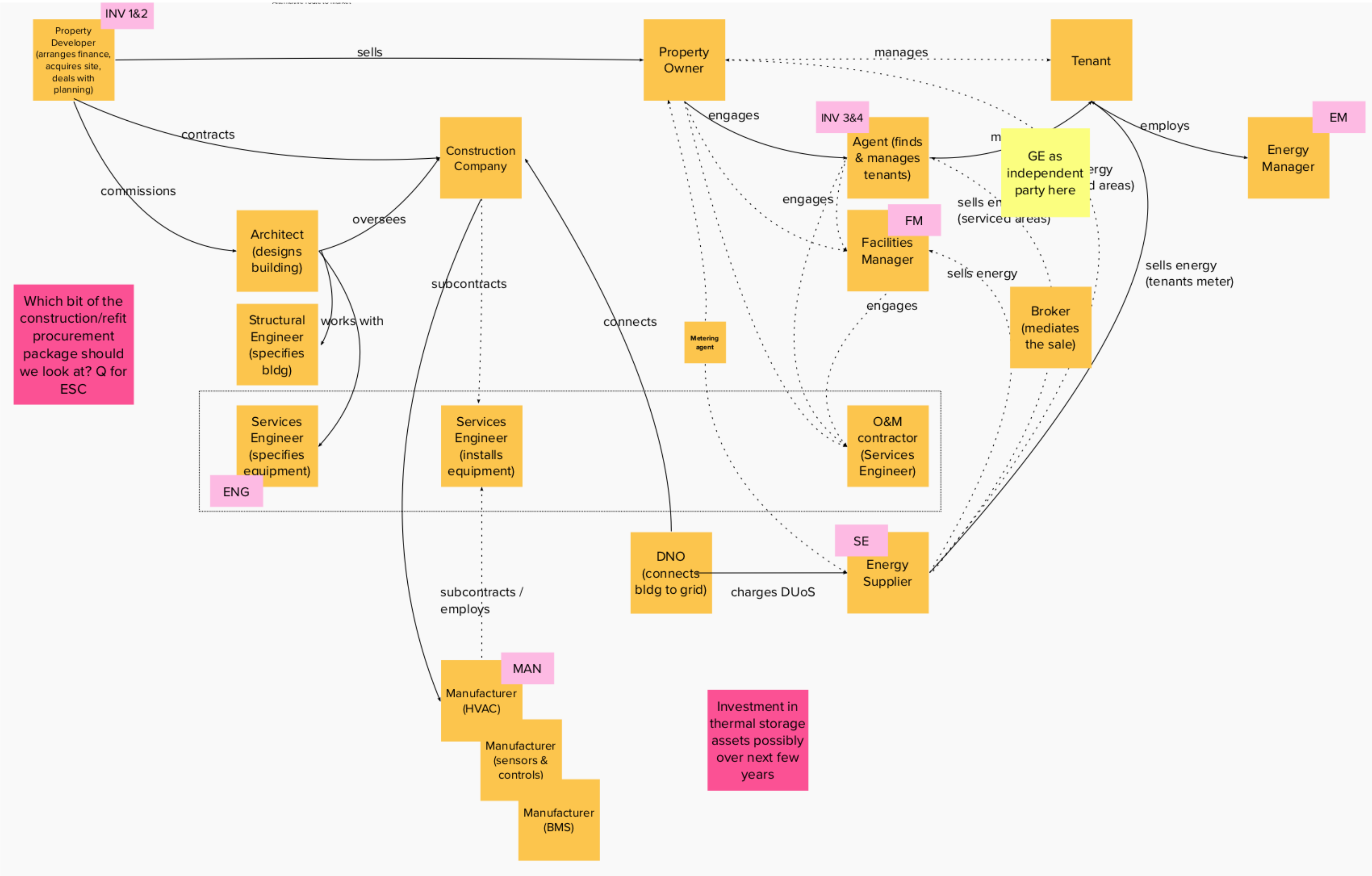
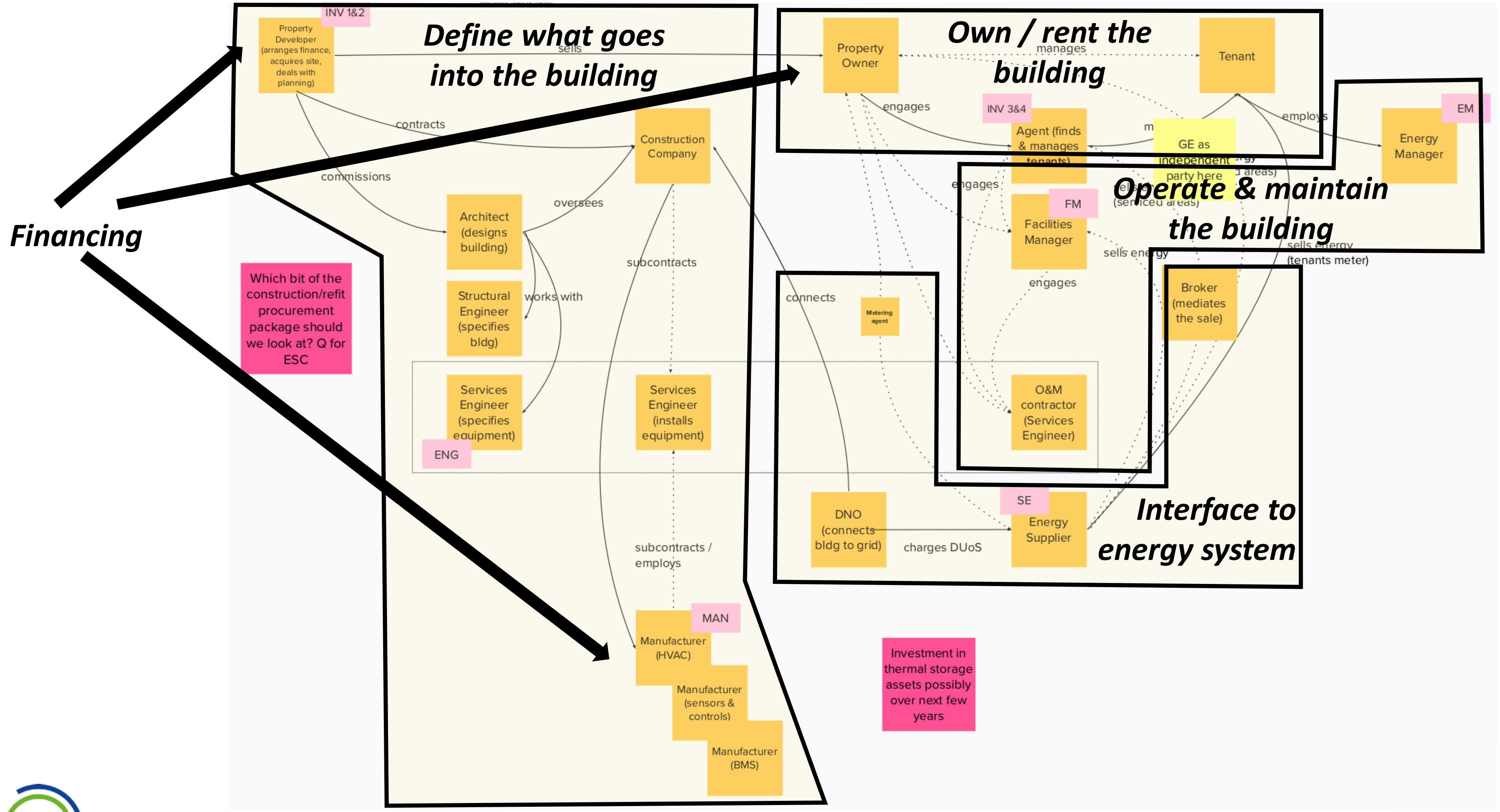
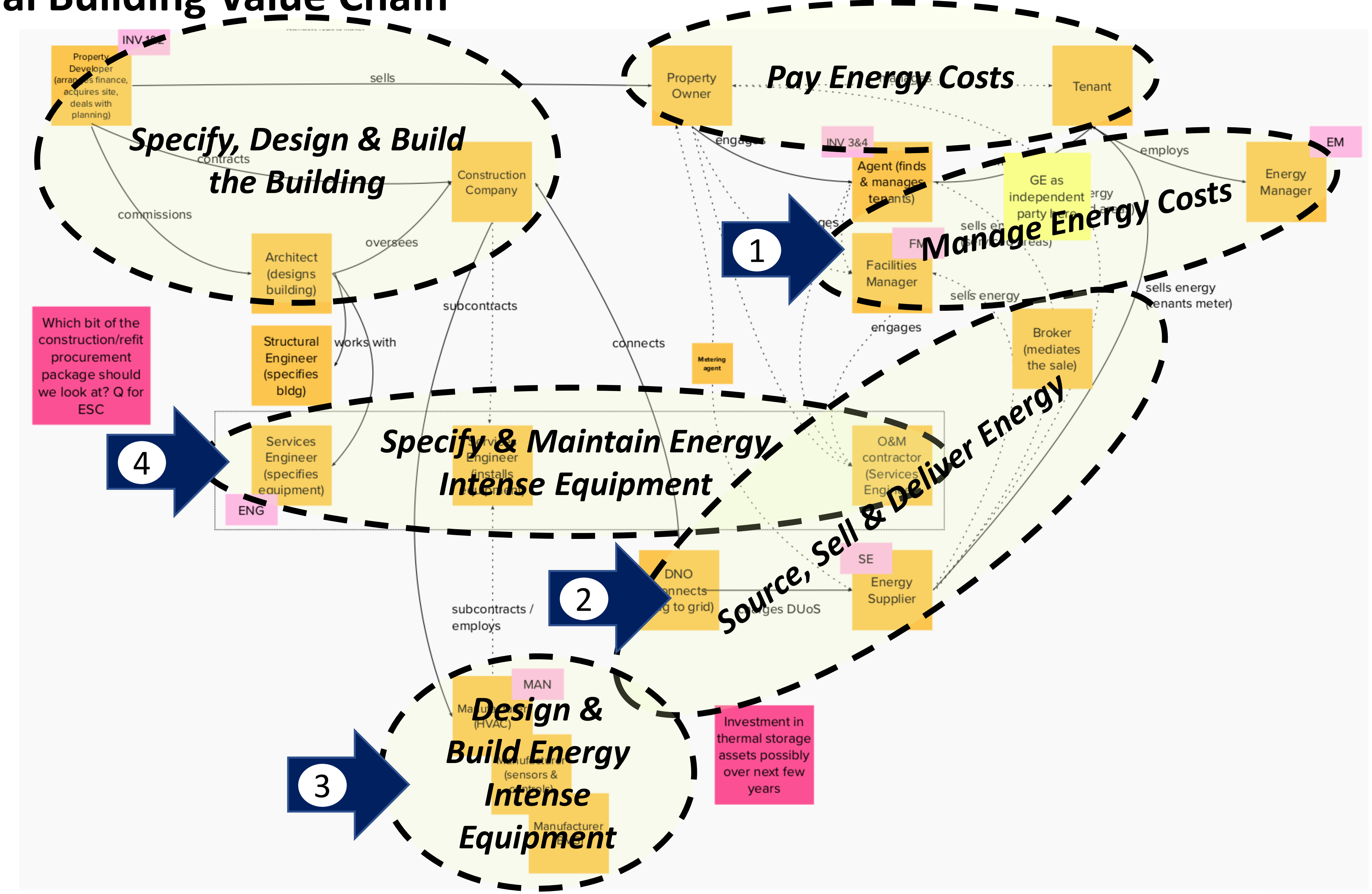
Commercial Building Value Chain



Commercial Building Value Chain



Commercial Building Value Chain



Climate-KIC
Climate-KIC is supported by the EIT, a body of the European Union

CATAPULT Energy Systems

Domestic supply chains may be slightly simpler

- Owner / Occupier can be simple
  - “Single” decision maker (no energy manager, facilities manager, etc)
  - All benefits accrue to the household
  - Often lack capital to invest
- Landlord / Tenant can mean splitting the value streams
  - Energy cost savings go to the household
  - Building value enhancement goes to the landlord
  - Revenue tends to go to whoever has capital to invest, generally the landlord
  - Can combine the value streams through energy-as-a-service and rental+bills models, but these can entail taking more risk
- Social landlords can be complex
  - Nominally a large block of homes with a single decision-making entity
  - Can be risk averse and have long decision cycles

What partners might you want to work with?

Questions?

Thank you

Scottish Enterprise

Scottish Enterprise

Green Heat Accelerator

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