Assessing the value of distributed Energy Storage systems: A case study of the University of Birmingham

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BCCES

Presentation outline

1. Introduce motivation for energy storage and the main business models under which storage can operate
2. Introduce motivation for “behind-the-meter” energy storage.
3. Describe the University of Birmingham network and provide a breakdown of the electricity bill
4. Identify areas in which storage could reduce the bill and any where it will increase it
5. Describe simulations of ES acting in the University of Birmingham network
6. Our goal is to link this work to Cryogenic Energy Storage so I will also talk a little about that

Introduction

- Energy storage is a hot topic
- There is a growing recognition that in order to transition to a sustainable operating mode, our energy system needs an increased level of ES.
- Energy storage covers a broad range of (new) technologies: PHS, batteries, LAES, PHES, flow-batteries, fuel cells etc…
- However electricity industry is skittish about using them – no track record of safety and reliability
- We need successful and viable demonstration projects
- However rewards and opportunities for ES are not yet fully understood

Several Business models for ES

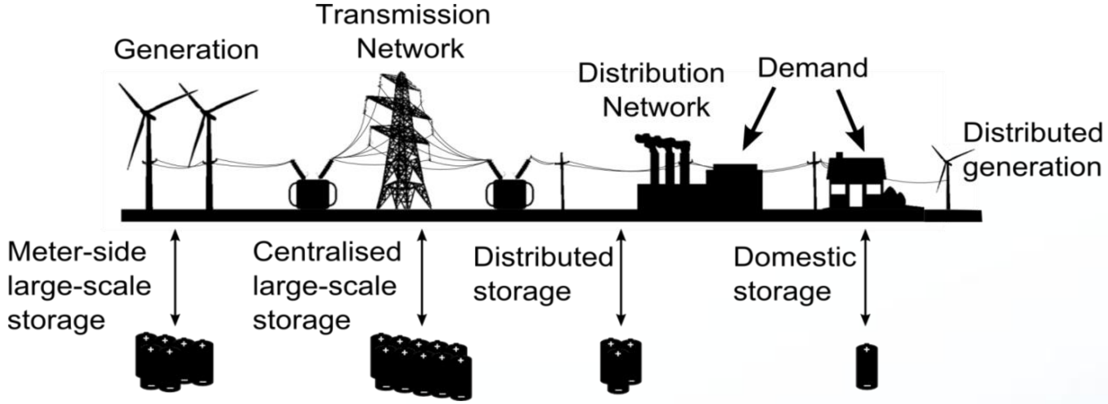
- These include:
  - Cost of service
  - Direct market participation
  - Behind the meter
- In the UK our current PHS facilities were constructed under "Cost-of-service" models, at a time when the electricity industry was a vertically integrated utility designed to provide reliable electricity at the lowest possible price
- In a deregulated Electricity Market where players are trying to maximise their profit ES is at a disadvantage when competing for a single service

Aside: Thermodynamics

- Thermodynamics states that no ES device can discharge more energy than that which was used to charge it
- Therefore it is unsurprising that it compares unfavourably to generation when treated in the same manner
- For example:
  - Coal: <$100/tonne → <1 p/kWh
  - Gas: <$5/mmBTU → <1 p/kWh
  - Electricity: average 2013 price >5 p/kWh
- Generator: Low value fuel → electricity
- Storage: electricity* → electricity*

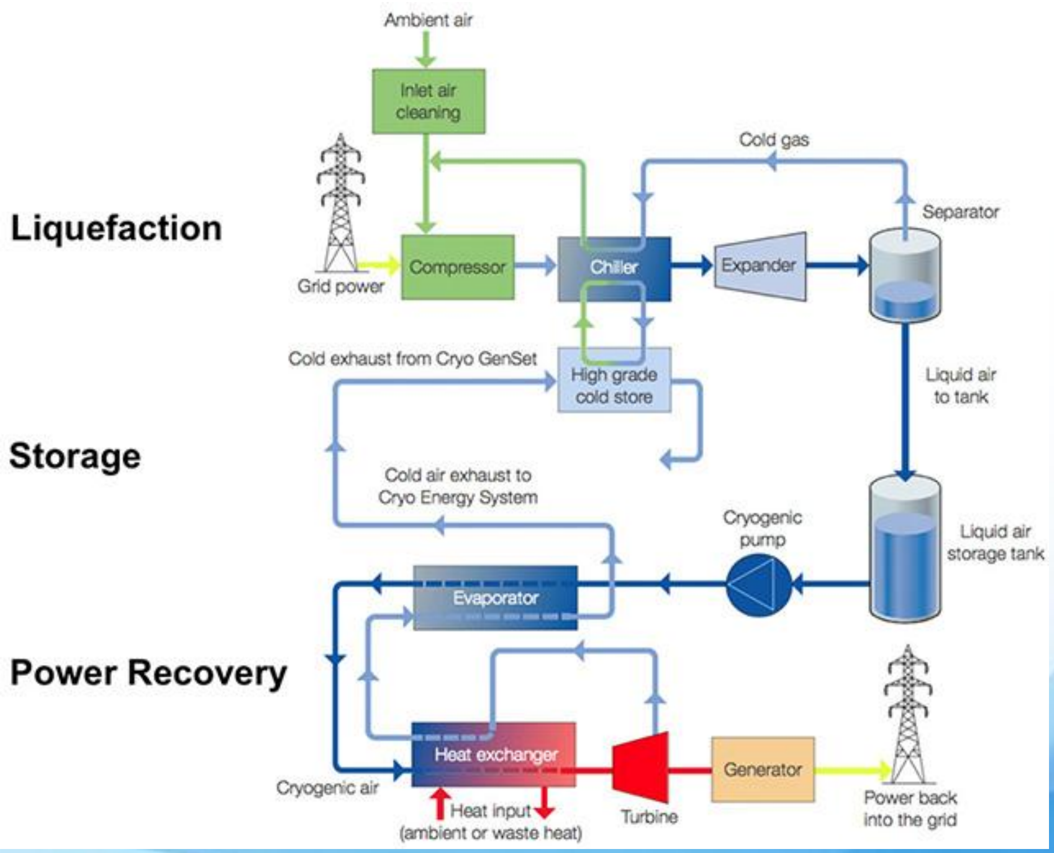
  *electricity has a variable value

Behind-the-meter Energy Storage



- Several locations where storage can be located
- potentially the most attractive to a storage developer as it provides the largest customer base to which it may be possible to sell the technology.
- Distributed storage may offer more benefits than centralised storage: the combined operation of many distributed devices could provide the same services while at the same time they would also be able to alleviate congestion on the electricity network

Cryogenic Energy Storage (CES)



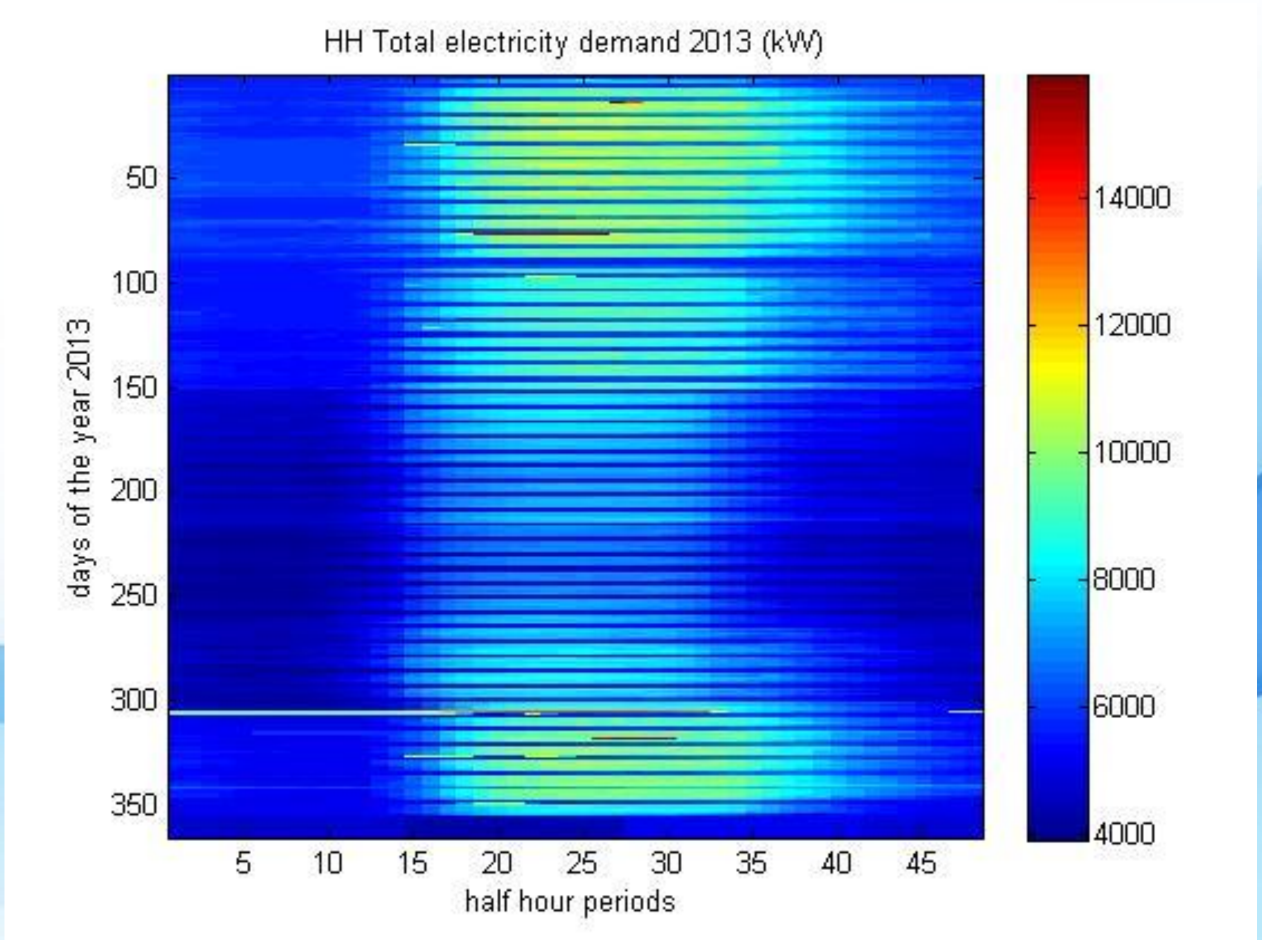
- At BCCES our particular interest is CES
- Process is as follows:
  - Off-peak electricity is used to liquefy air
  - Liquid air is stored, it has a high exergy density
  - Liquid air is vaporised by ambient heat or create superheated vapour using waste heat from industry
  - Vapour is expanded to drive a turbine and generator to get peak-electricity
- The heat generated by the process is also stored to boost the efficiency of subsequent charge/discharge cycles
- Anticipated scale: 5-50MW, hours of storage

Case study for "behind-the-meter" storage @ the University of Birmingham

- The university provides an ideal test case of a small network in which energy storage could be situated
- 132kV connection to the transmission network
- 4.5 MW CHP plant, 5 steam boilers, some diesel gensets
- Peak demand 10-14 MW
- Heat network – ability to integrate waste heat

University electricity demand

- Total Electricity demand



Electricity Charges

- Approximate breakdown of the yearly electricity bill:
  - Units used ~5.6 x 10^7 kWh = >£1500000. flat rate per month, approx. 6p/kWh
  - ROC/FIT £300000
  - Capacity charge £180000
  - BUoS charges £70000
  - Transmission Losses £15000
  - Transmission charges (via TRIADs) £83000
  - Handful of other smaller charges (standing charge, DUoS standing charge, Hydro benefit, BSC, settlement charge etc)
  - Total ~£2.2 million

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Storage Increases

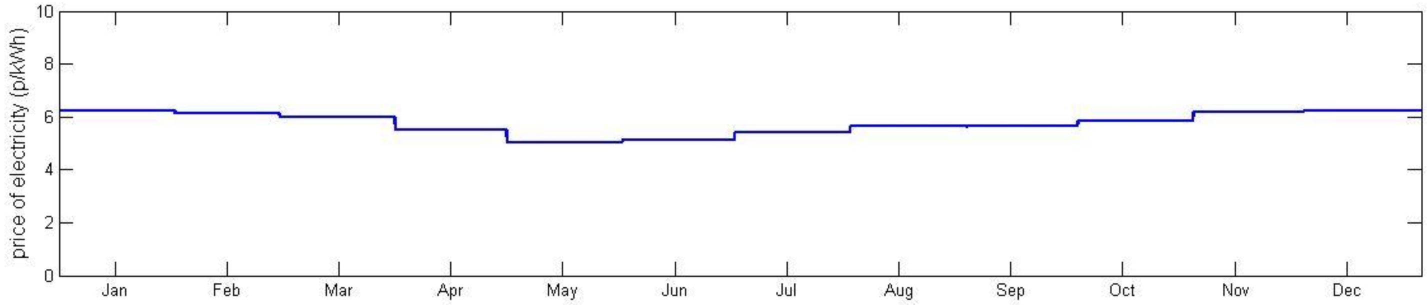
Storage Decreases

Simulating Energy Storage in the University network

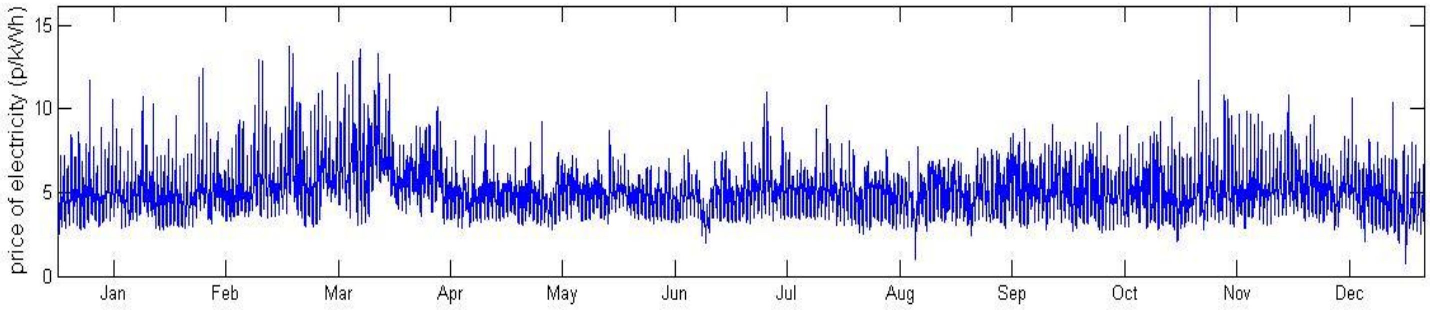
- We simulate ES adopting the following strategies in the University network
  - Maximum TRIAD avoidance: Storage only discharged at the 3 TRIAD periods
  - TRIAD-avoidance/winter-peak-time-shift: storage is discharged in peak hours (4pm – 7pm) on weekdays between Nov and Feb
  - Using spot market prices storage optimally reduces the cost of units used
  - Storage is charged in the early morning hours and discharged at peak hours
- Simulate energy storage with a power of 1MW, 75% efficient and 3 hours of storage

Actual prices vs. spot market prices

- Total electricity bill in 2013 was ~£2.19 million (actual price shown below)

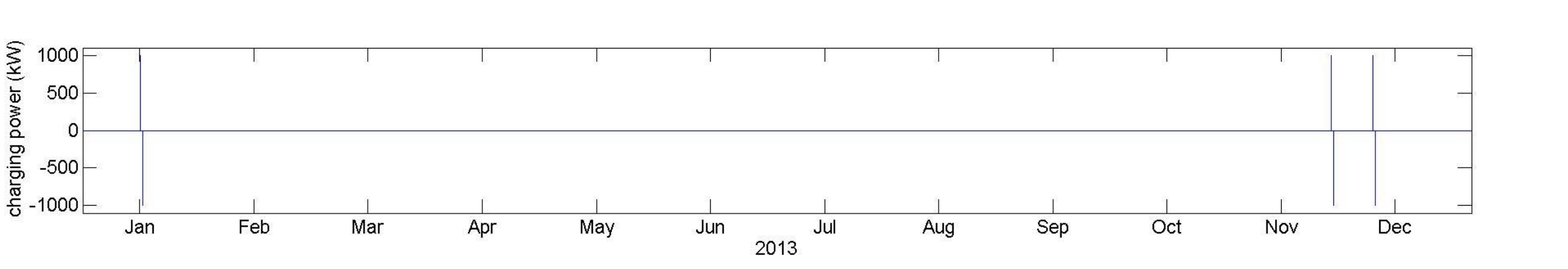


- Using spot market prices this decreases to £2.08 million

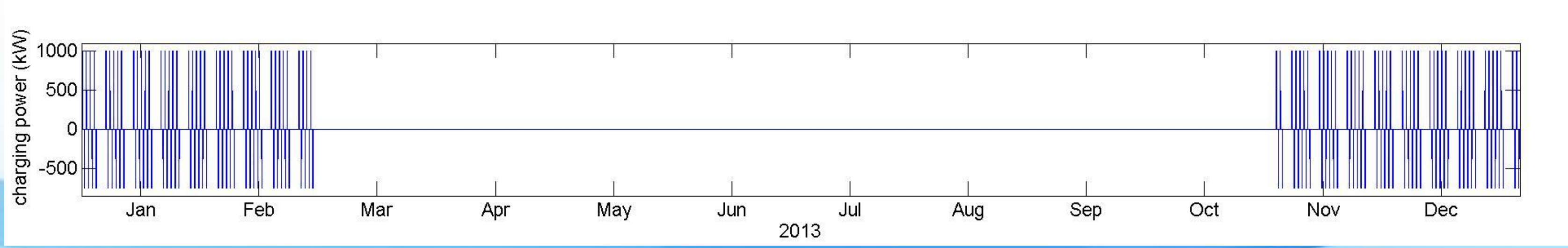


Simulated ES strategies

- Max TRIAD avoidance



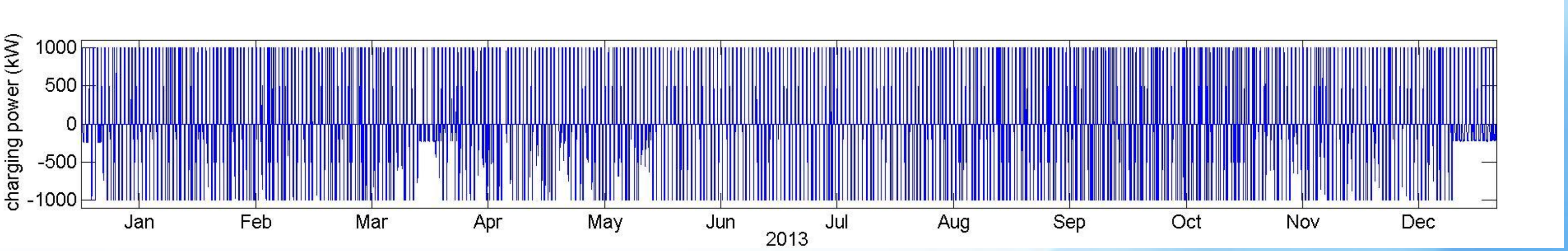
  - Decreases TRIAD charge by ~£27000
  - Increases rest of bill by £40
- TRIAD-avoidance/winter-peak-time-shifting



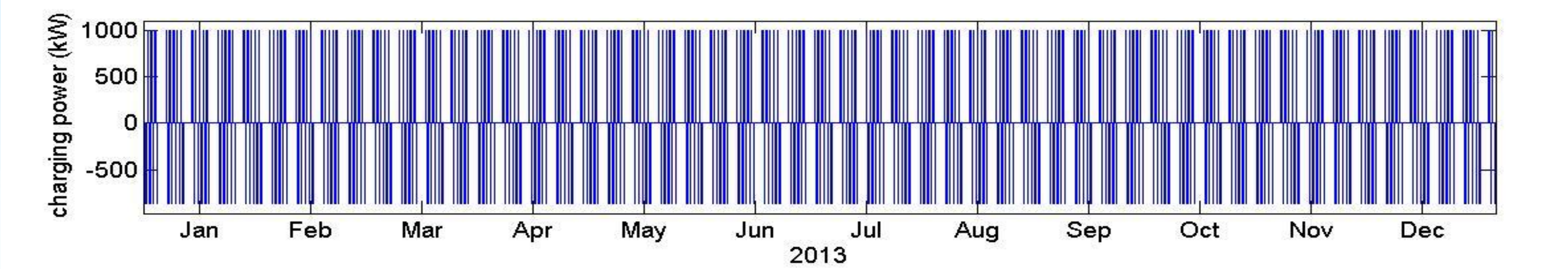
  - Decreases TRIAD charge by ~£24000
  - Increases rest of bill by ~£6000

Simulated ES strategies (continued)

- Time shifting using spot market prices
  - Reduces the TRIAD charge by £27000
  - Reduces rest of bill by £17000



- peak demand time-shifting (charging 2.30-5.30 am, discharging 4-7pm)
  - Reduces TRIAD charge £24000
  - Reduces rest of bill by £6400



Using Energy Storage to reduce capacity charge

- Energy storage could also be used to decrease the site's required capacity, currently 2 x 7500 kVA.
- To decrease the maximum demand for the year 2013 would require 5 hours of storage with 1MW power.
- This would potentially add a saving of £24000 per year
- For 2009 is compatible with TRIAD avoidance and time-shifting (with a small reduction in saving)

Effect of storage efficiency and capacity

- The efficiency of the device has a very small effect on the ability to produce revenue from TRIAD avoidance – cost of triad £27/kW, or 5400p/kWh (normally around 6p/kWh)
- However it has a very large effect for time-shifting revenue
- Capacity has no effect on the ability to reduce TRIAD demand unless it falls below that required to produce output for the peak period
- Increased storage capacity yields a small increase in the revenue from time-shifting however the returns are diminishing.

Initial conclusions

- Energy storage can reduce the electricity bill for large consumers, however it is seems likely that savings will not yet cover investment costs
- We find that savings of around £50k/year for a MW of storage may be possible for the University of Birmingham
- Time-shifting requires a variable price: with spot market prices the saving is less than the TRIAD avoidance cost

Further Work

- Investigate the potential to use waste heat, especially with CES
- Develop an optimal dispatch for energy storage and thermal generation
- Investigate future price scenarios

Thanks for listening!

The optimisation models used here can be downloaded from www.energystoragesense.com

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