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Evaluating the Economics, Social Benefits and Technology Needs of Energy Storage

Peter Hall
Chemical and Biological Engineering
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Sheffield Energy Storage

- Focus on electrochemical materials, safety and engineering
  - ~200 channels of EIS/charge-discharge
  - Electrochemical AFM/SEM
  - Accelerating rate calorimeter
  - Manufacture of 1 Ah pouch cells under inert atmosphere
  - High current EIS (80 A)

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Sheffield energy storage

- Major facilities:
  - 375 kWh/2MW grid connected Li titanate battery
  - 225 kW V29 wind turbine connected to 30 kW fuel cell array with hydrogen/battery fuelling station
  - Host of UK Centre for Doctoral Training in energy storage

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Peter Hall Group Research

- Materials for:
  - Li air batteries
  - Materials for supercapacitors
  - Materials for NiFe cells
  - Direct formic acid fuel cells
- Interface between technology and economics

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Contents

- How are electrical grids balanced?
- Future electrical grids
- The applications of energy storage
- Economic fundamentals
- A Regulatory Framework
  - Some research questions

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Current Energy Storage

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Drax Power Station (UK)

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Rough Gas Storage (UK)

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Combined Cycle Gas Turbine Output

- 6th February 2012 – follows demand very closely
  - Lower carbon emissions

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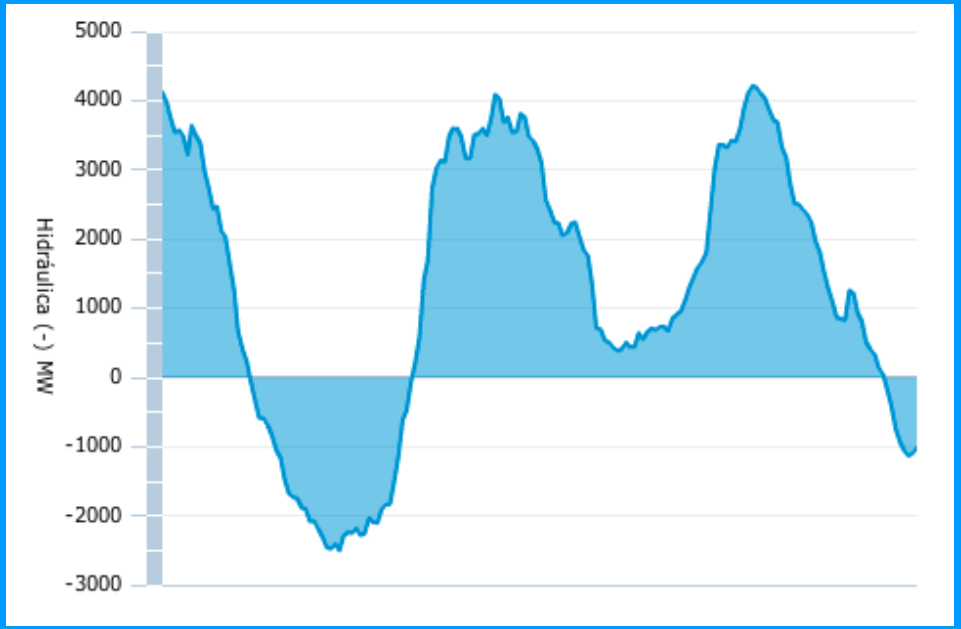
Hydro Output in Spain

- 6th February 2012
- Peter's Birthday!!



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Balancing Future Electrical Grids

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Future challenges:

- Increased electrification
  - Electrified transport
  - Electrified heating
- Greater penetration of renewable energy
- Greater nuclear

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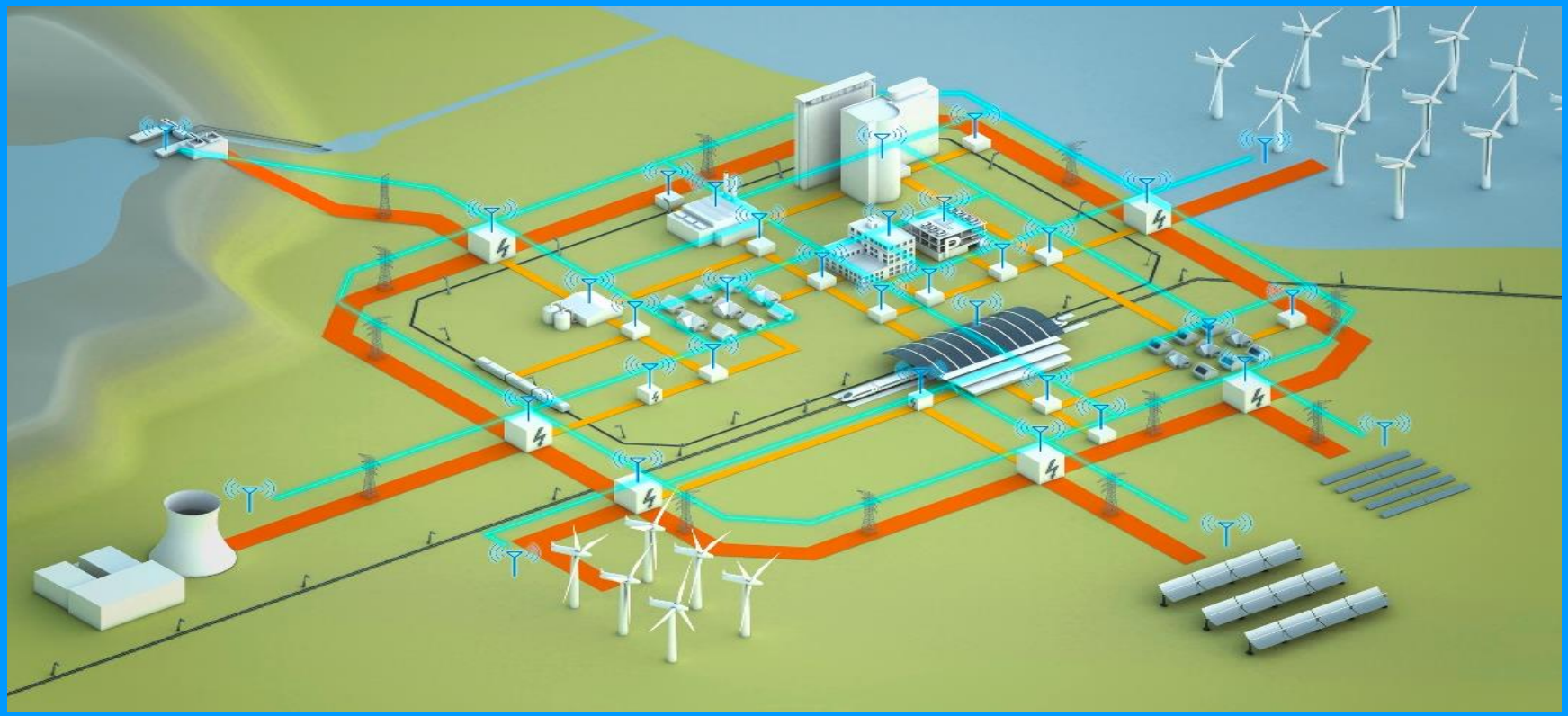
Siemens vision of smart grid



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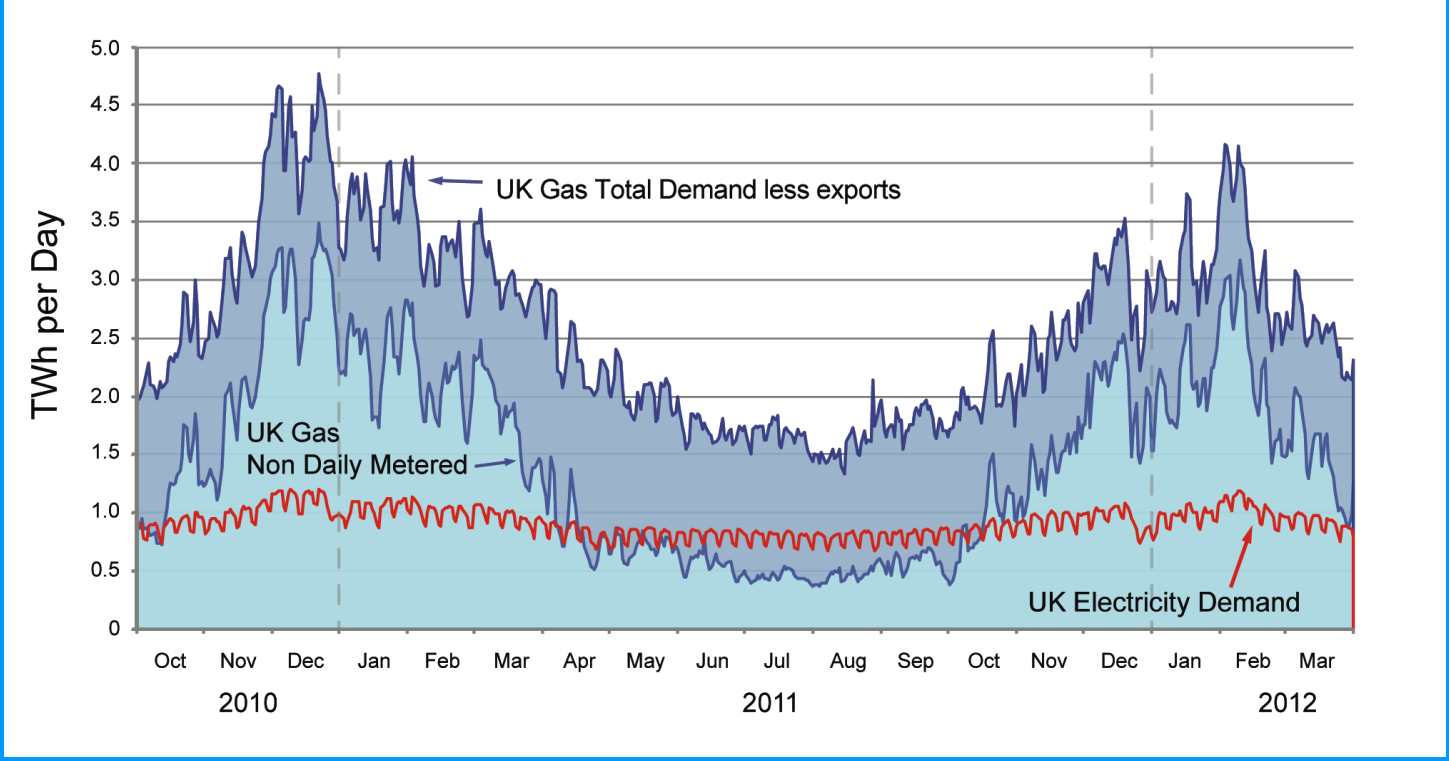
Electrification of heat (UK):



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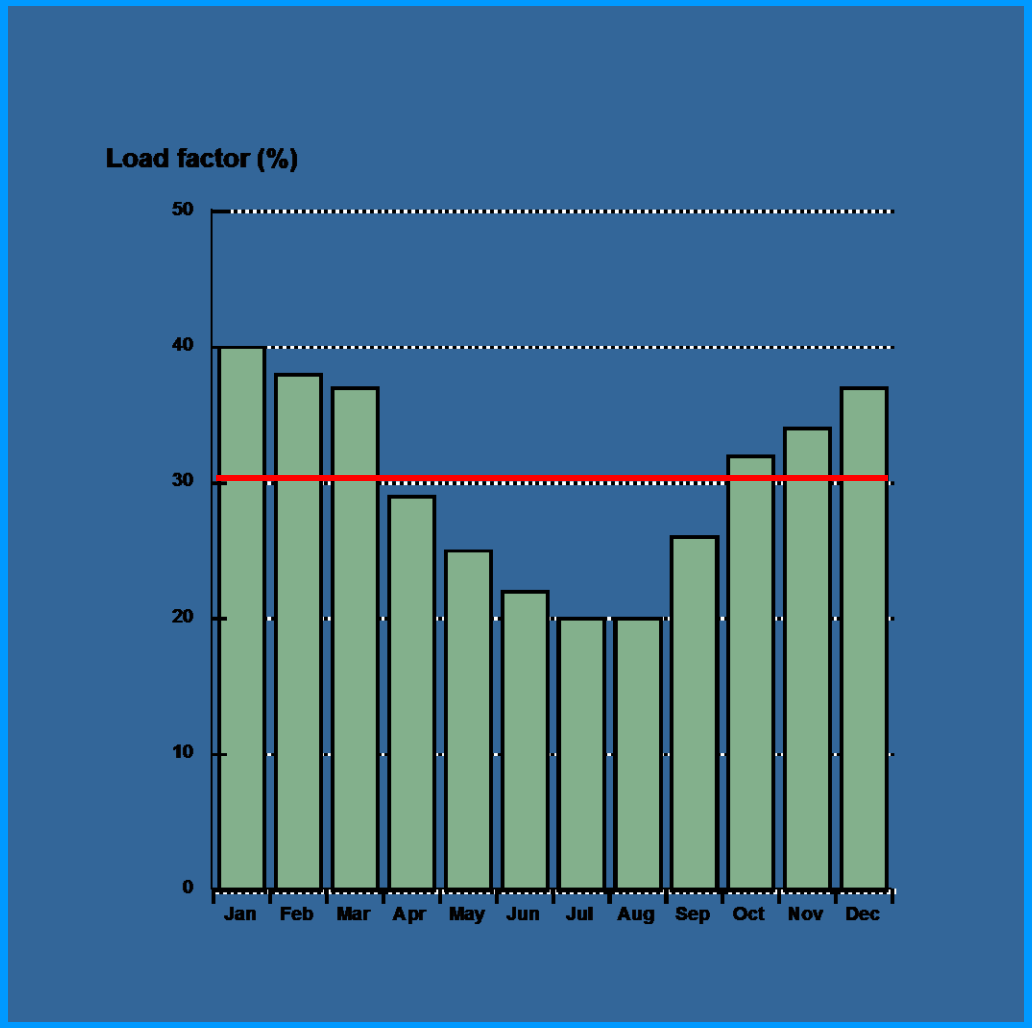
Seasonal availability of UK wind (Sinden, En Pol 2007)



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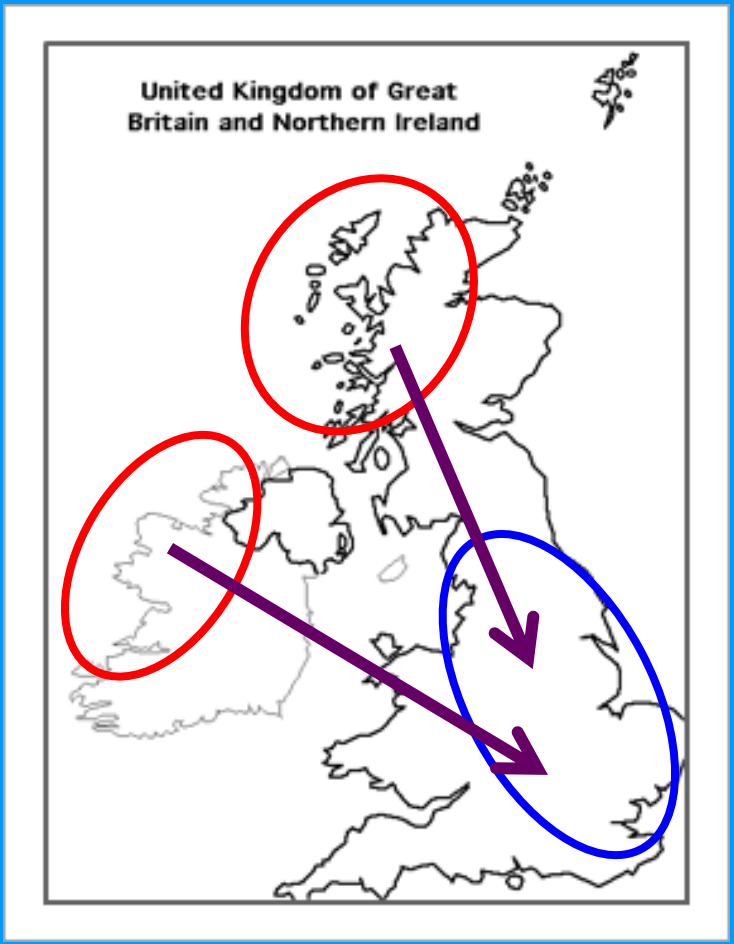
Transmission (high Voltage) Connected Storage (UK)

- Storage can be used to reduce/eliminate costs of new or bigger transmission lines



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Three Technologies:

- **Interconnection**
  - Physically move energy from one location to another
- **Demand side management**
  - Incentivise users (domestic & industry) to use energy at suitable times
- **Energy storage**
  - Shift energy in time

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Basic Economics and Energy Storage

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Using Electrical Markets

- Most electricity is sold by direct contract
  - Fraction is sold on a “spot” market” with variable price allows new generators to supply energy at a higher price, e.g. Diesel generation
- Cost deferment
  - Use storage to eliminate or defer future costs

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Determining the Value of Energy Storage

Value = Income – Cost

- Can either
  - Reduce costs (cheaper = unsafe?)
  - Increase income
  - .....or both
- What is income from energy storage?

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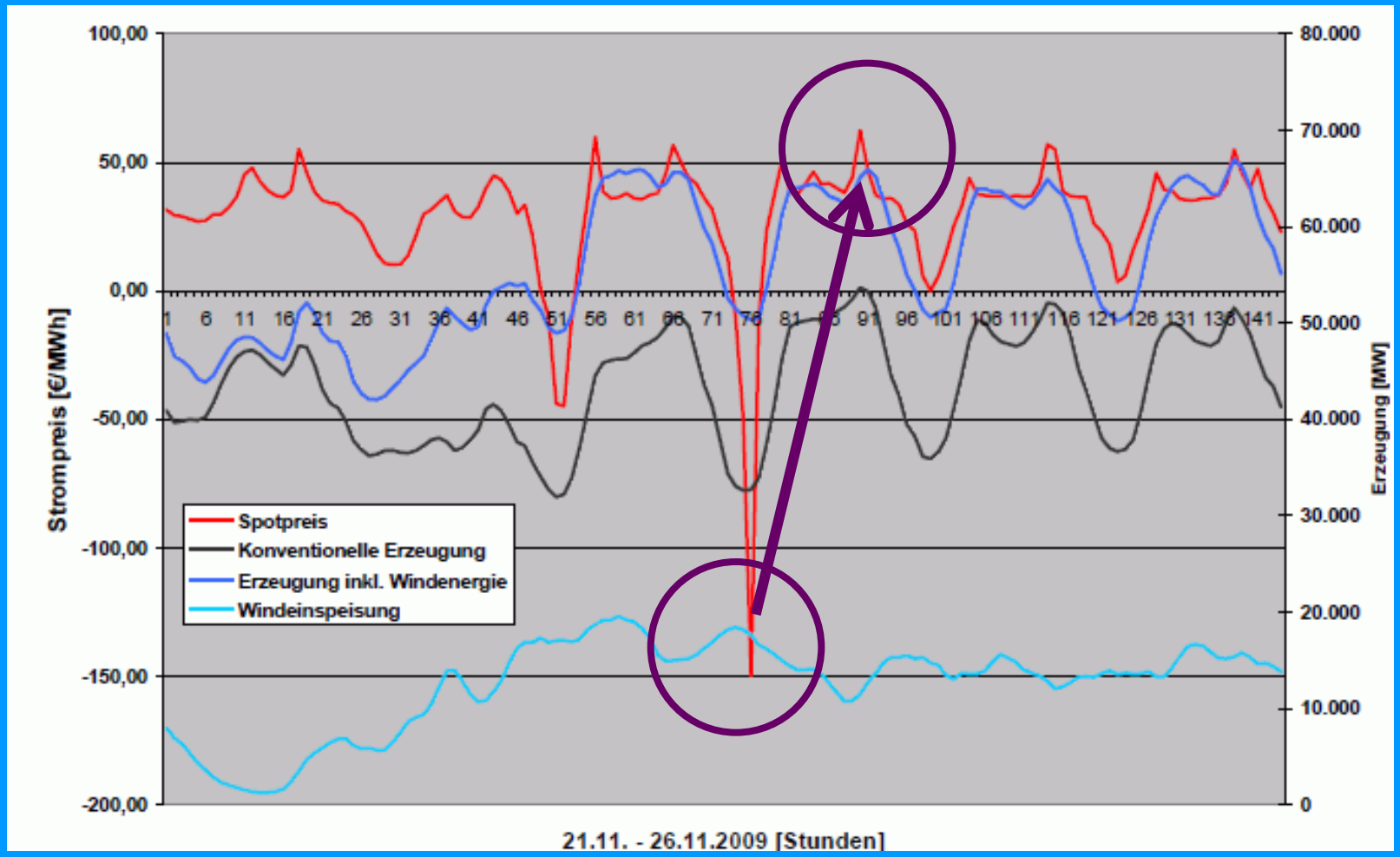
Arbitrage Possibilities (German EEX Market)



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Time shifting Model

- These features are incorporated into a time shifting model for an electrical arbitrage market model (Barbour et al EES, 2012)
  - Allows maximum theoretical income
  - Can be used to compare revenues from different technologies

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Storage Classification

- Technical:
  - Size (KWh)
  - Power (KW)
  - Input efficiency
  - Output efficiency
  - Self-discharge

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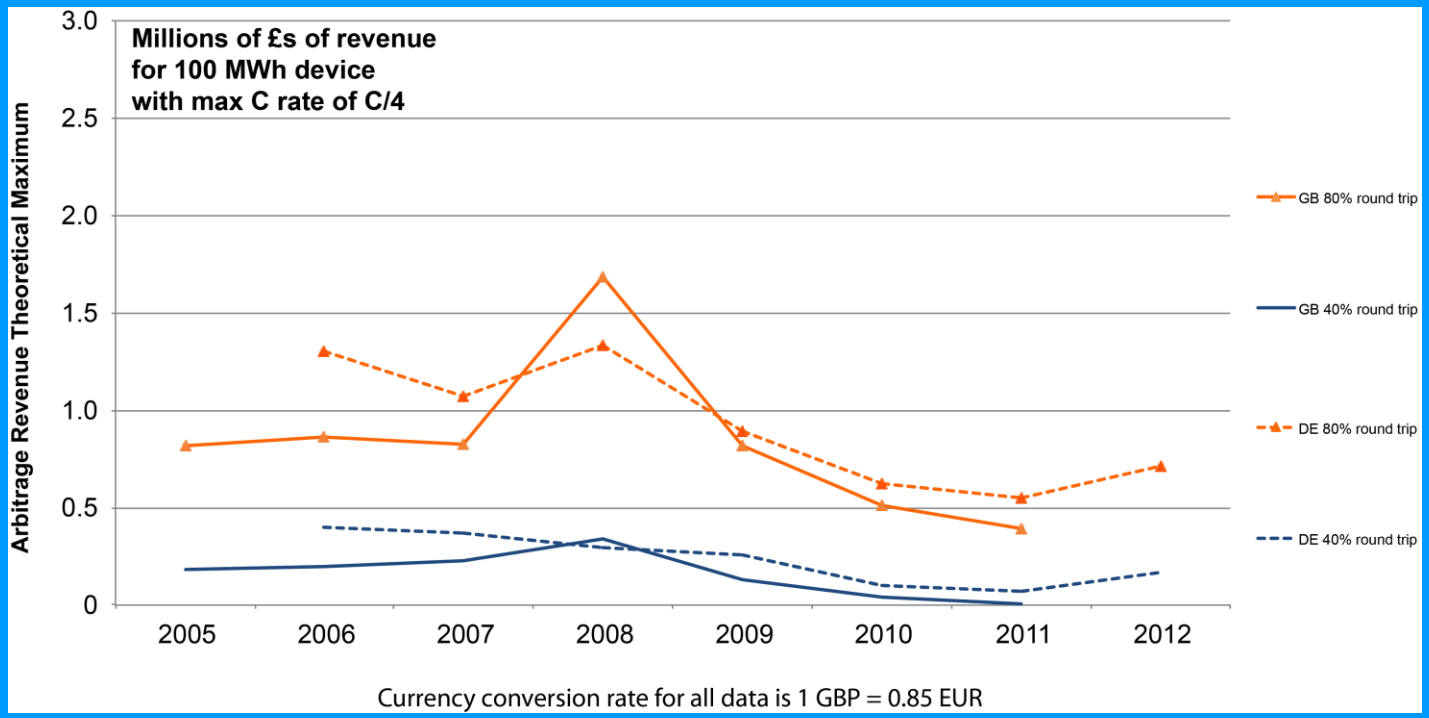
German and UK Spot Market Incomes (40% and 80% RTE)



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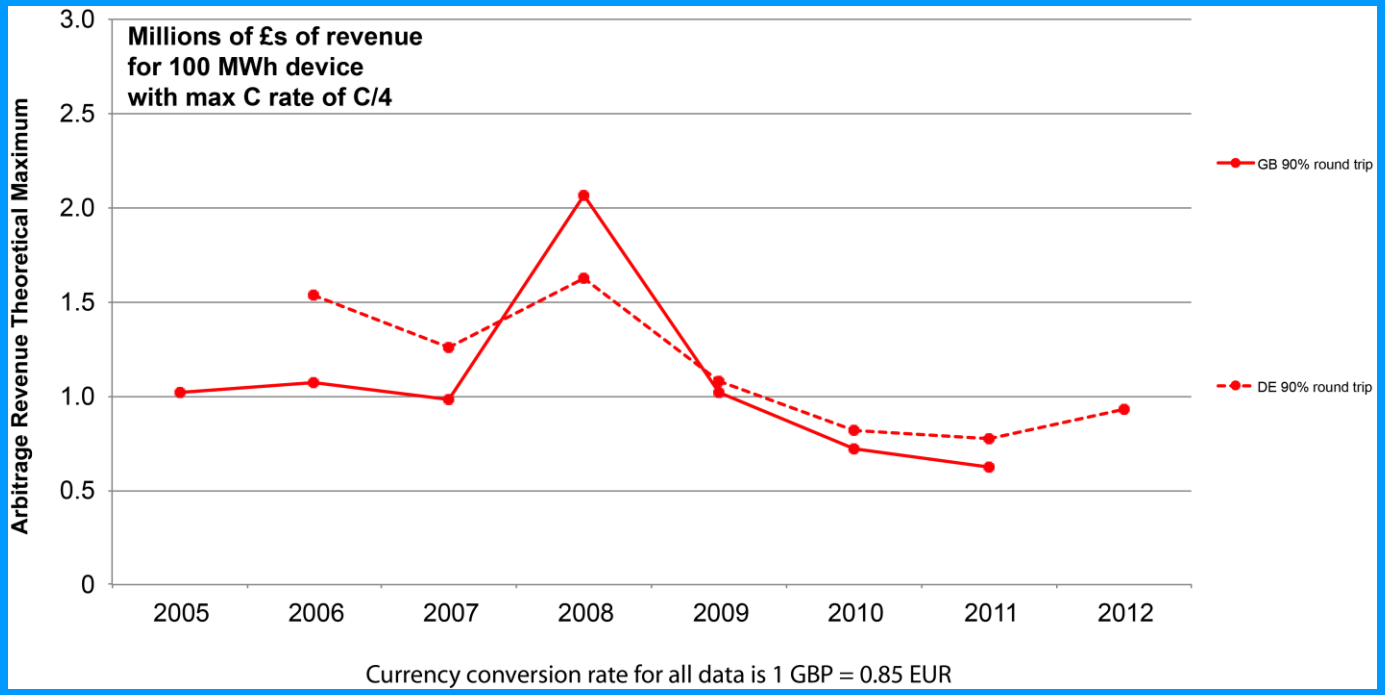
German and UK Spot Market Incomes (Li-ion C/4)



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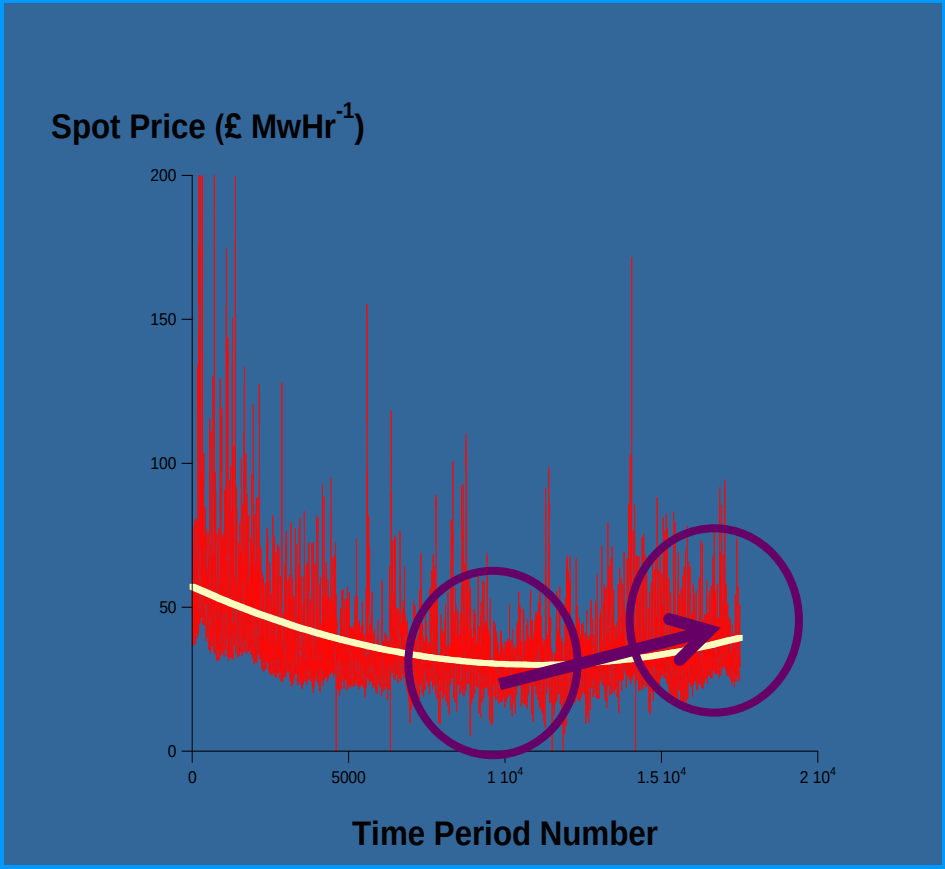
Long-Term (UK Elonex Market)



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Distribution (low Voltage) Energy Storage

- Increasing electrification (heat and transport) will mean higher currents sent through local cables
- Energy storage can smooth these flows
- Not enough money in EU to rewire the entire distribution system

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Domestic Energy Storage

- Storing energy from micro generation
- Exploit difference in export tariff:
  - 4.2p export vs ~13.1p (domestic, inc VAT)
  - 3.75p export vs 9p (exc VAT)
- However, some losses in round trip efficiency

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Energy Storage Applications

- **Short-term (days ~GW hr)**
  - Price fluctuations
  - Auxiliary services
- **Long-term (inter-seasonal ~TW hr)**
  - Security of supply
- **Transport**
  - Replacement of petroleum products
- **Investment deferment/avoidance**

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How should energy storage be implemented?

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Market solutions

- Correct amount of energy storage:
  - Too little – grid instability
  - Too much – no market incentive
  - Strict regulation framework necessary
  - Licensing
- Market will decide technology

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Non Market Solutions

- Should governments help promote energy storage?
  - Recognise social benefits of energy storage
  - Increase security of supply
  - Independence from foreign fossil fuels
  - New job creation
- Mechanisms for support?

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Which technology?

- Electrochemical - Batteries
- Electron – Supercapacitors, SMES
- Mechanical –Flywheel, pumped hydro
- Chemical – Hydrogen, Methanol
- Thermal (cool and hot)

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Storage Classification

- Other considerations
  - Capital costs
  - Asset lifetime
  - Safety
  - Site availability (geography)
  - Location

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La vida es sueño.....

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Strategic Oil Stocks in Europe

- Directive 2006/67/EU:
  - “Member States are required to build up and constantly maintain minimum stocks of petroleum products equal to at least 90 days of the average daily internal consumption during the previous calendar year.”

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2006/67/EU

- “Specific stocks shall be composed of one or several of the following products:
  - Ethane; LPG; motor gasoline; aviation gasoline; gasoline-type jet fuel (naphtha-type jet fuel or JP4); kerosene-type jet fuel; other kerosene; gas/diesel oil (distillate fuel oil); fuel oil bitumen; paraffin waxes; petroleum coke.”

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Strategic Electricity Storage?

- Directive 2015/1/EU

  "Member States are required to build up and constantly maintain minimum stocks of non-carbon produced electricity equal to at least 90 days of the average daily internal consumption during the previous calendar year."

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2015/1/EC

- Specific stocks shall be composed of one or several of the following products:
  - Short-term technologies for power delivery
  - Storage technologies at the domestic level
  - Technologies for diurnal energy storage
  - Technologies for seasonal energy storage

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Easy questions please!