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Who Does What and With Which and to Whom? The Bewildering World of Energy Storage

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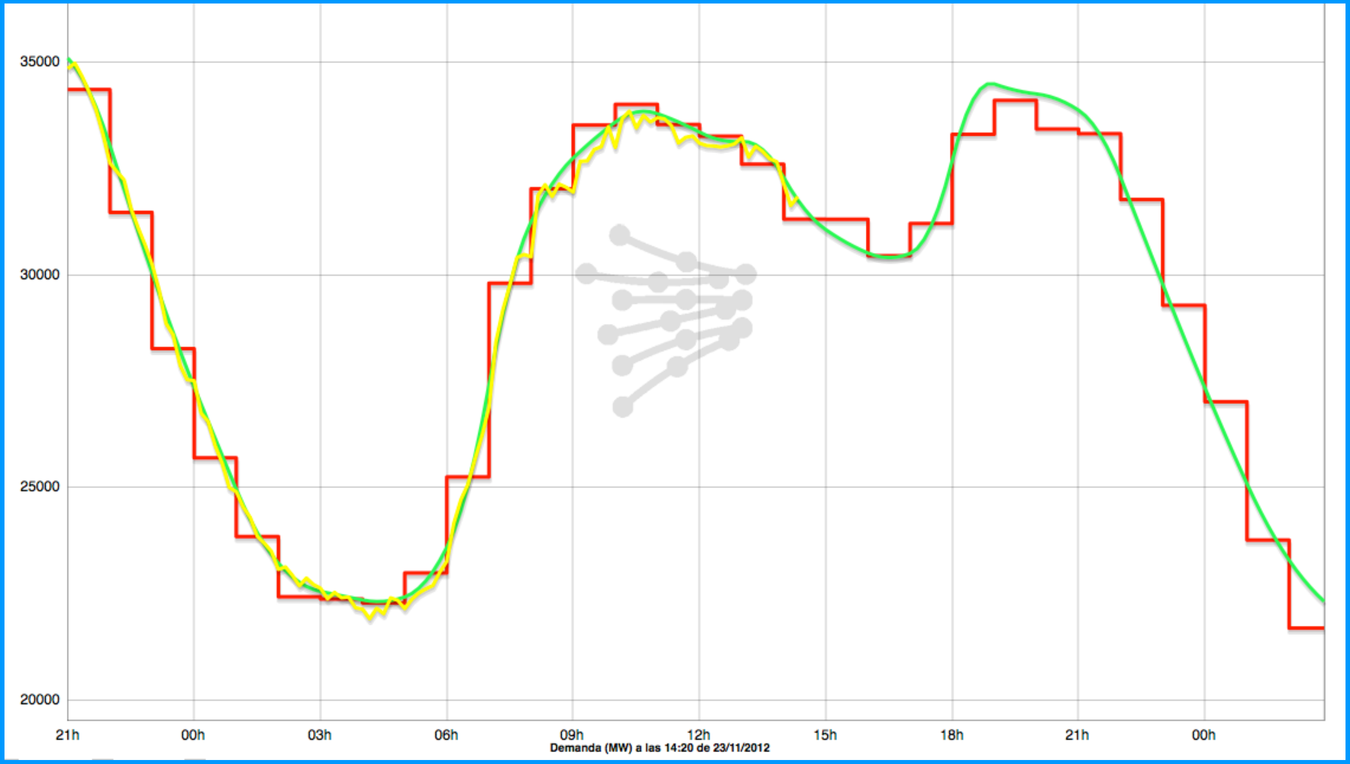
- How are electrical grids balanced?
  - The Spanish electrical grid
- Balancing future grids
  - The Role of Energy Storage
- The Sheffield "Big Battery" project

Grid Balancing in Spain

Typical demand curve in Spain (www.ree.es)

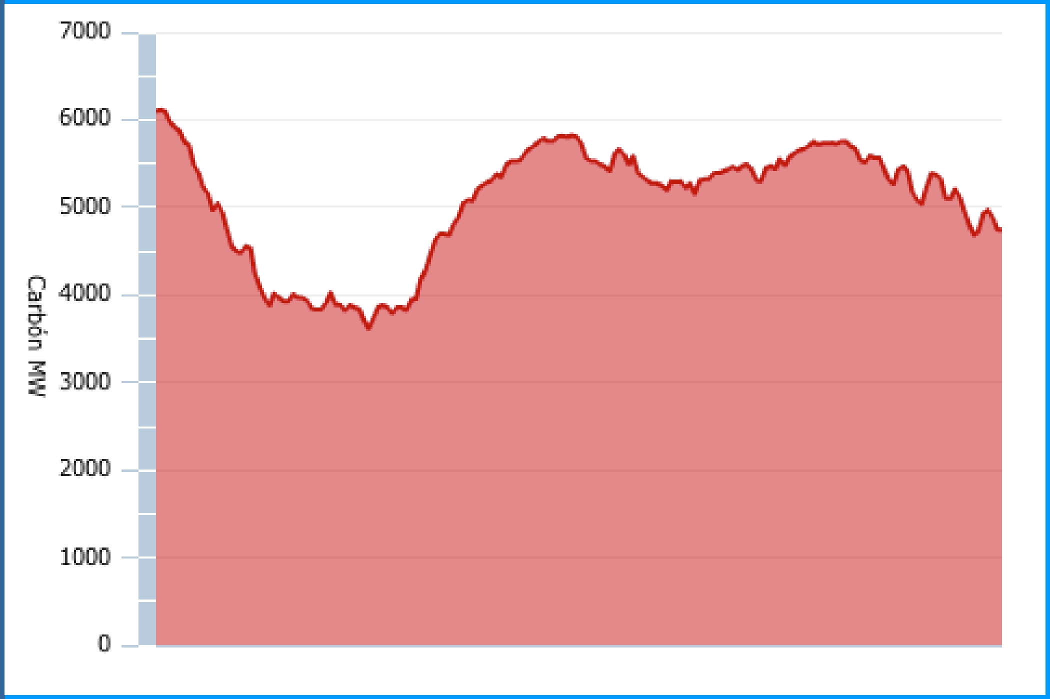


How Does Spain satisfy electrical demand?

- A portfolio of generating facilities to:
  - Provide economic energy
  - Meet demand
  - Reduce carbon emissions
- Accurate prediction is necessary

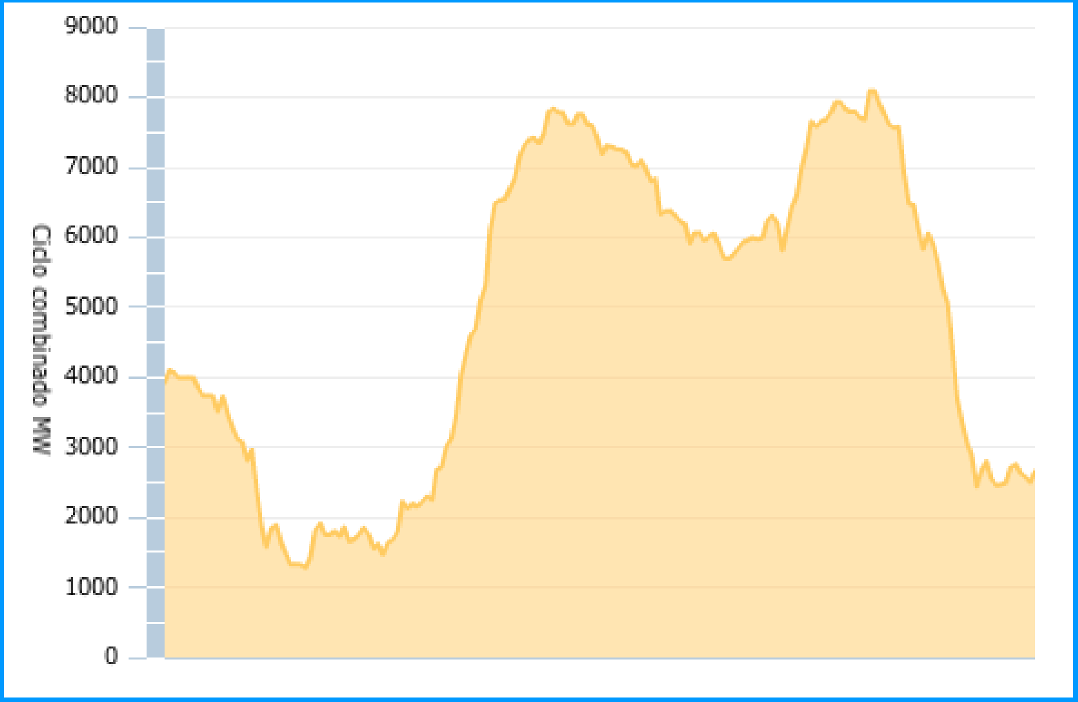
Pulverised Coal Combustion

- 6th February 2012, follows demand to some extent
  - High carbon emissions



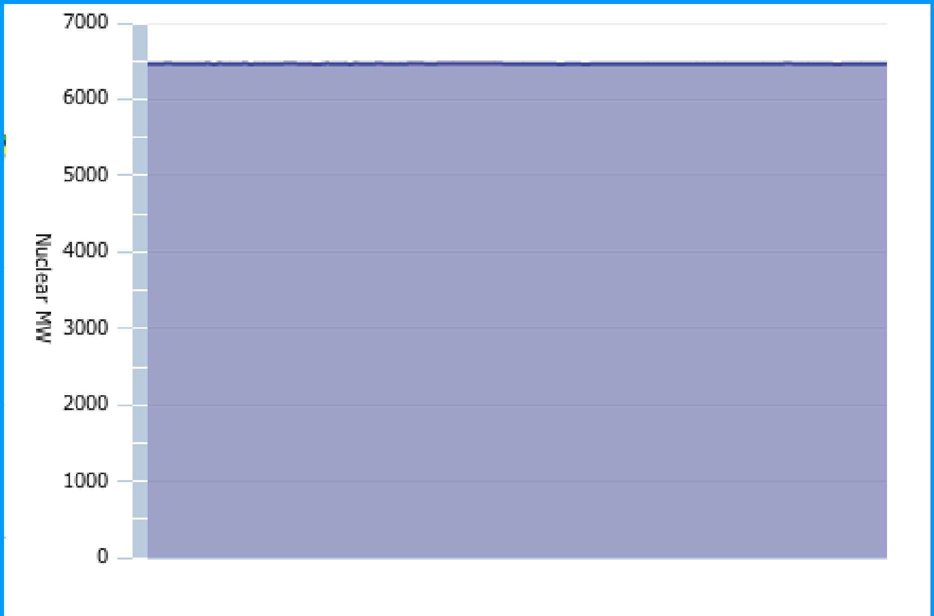
Combined Cycle Gas Turbine Output

- 6th February 2012 – can be matched to follow demand very closely
  - Lower carbon emissions



Nuclear Energy variation

- Flat output, does not follow electrical demand
  - Very low carbon
  - Base load



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Wind energy variation

- Output on 6 February 2012 (30% of total energy demand)
- Does not follow electricity demand curve

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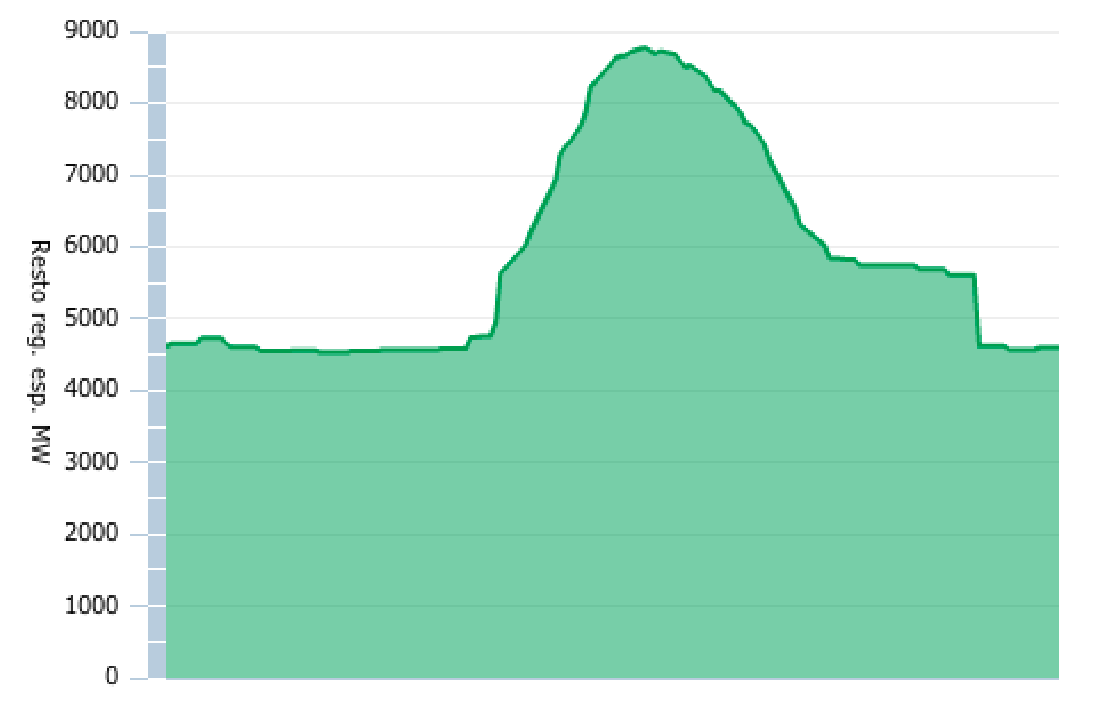
Other renewable (solar, biogas, waste etc)

- 6th February 2012
- Renewable, very low carbon emissions



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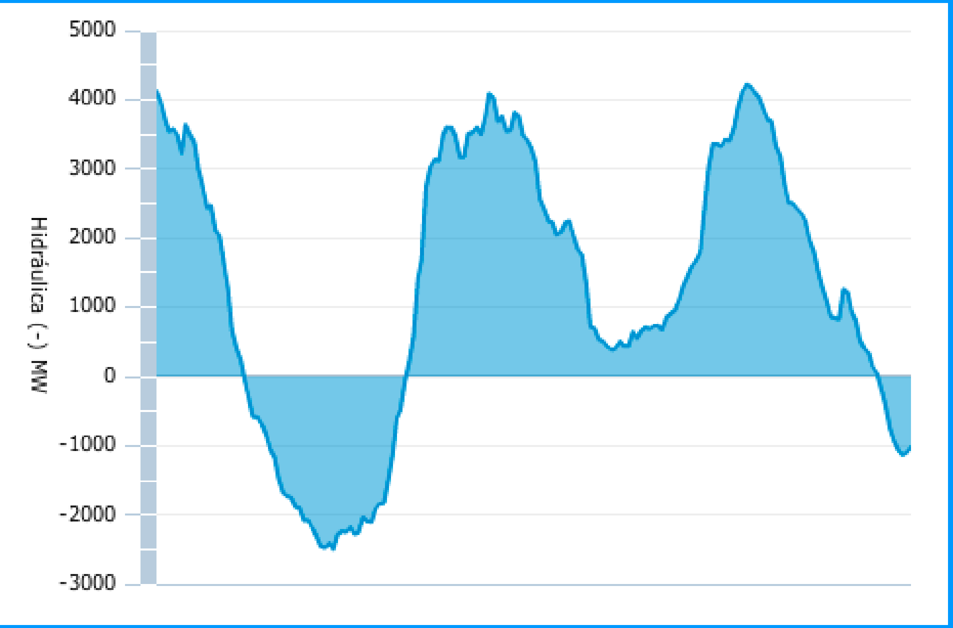
Hydro Output

- 6th February 2012
- A classic example of how energy storage can balance grids



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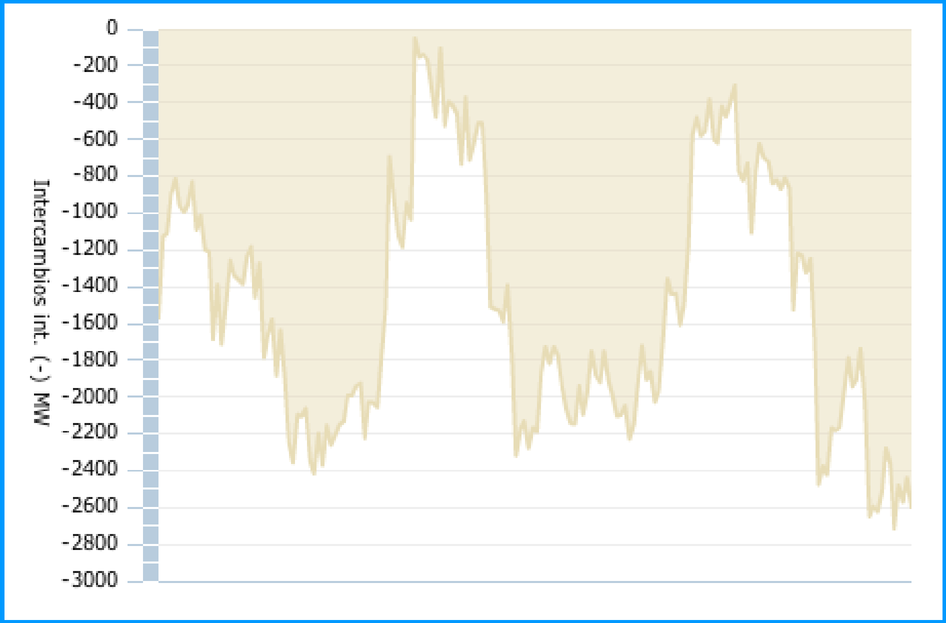
Interconnector with France

- 6th February 2012 – energy imported from France
- Spain constructing additional interconnector



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Balancing Future Electrical Grids

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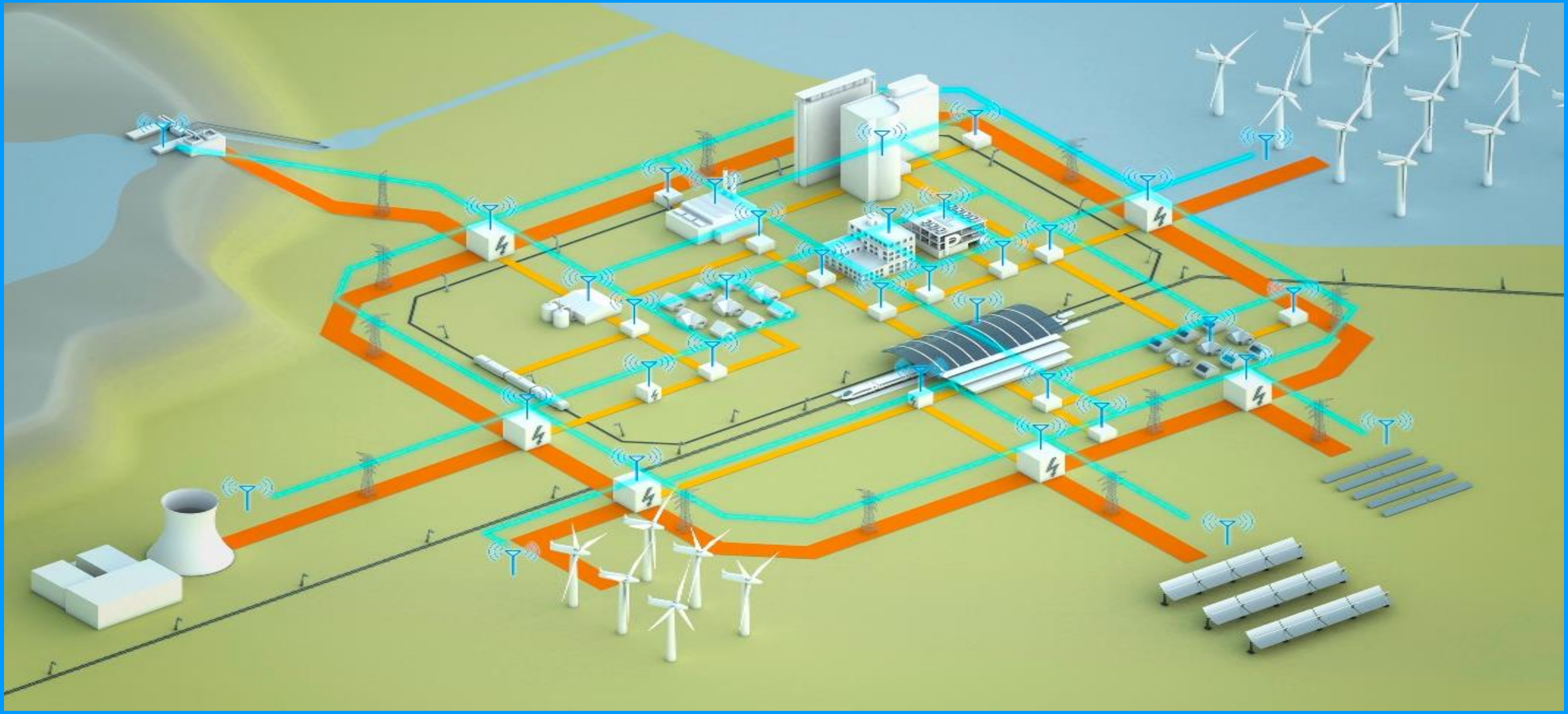
Siemens vision of smart grid



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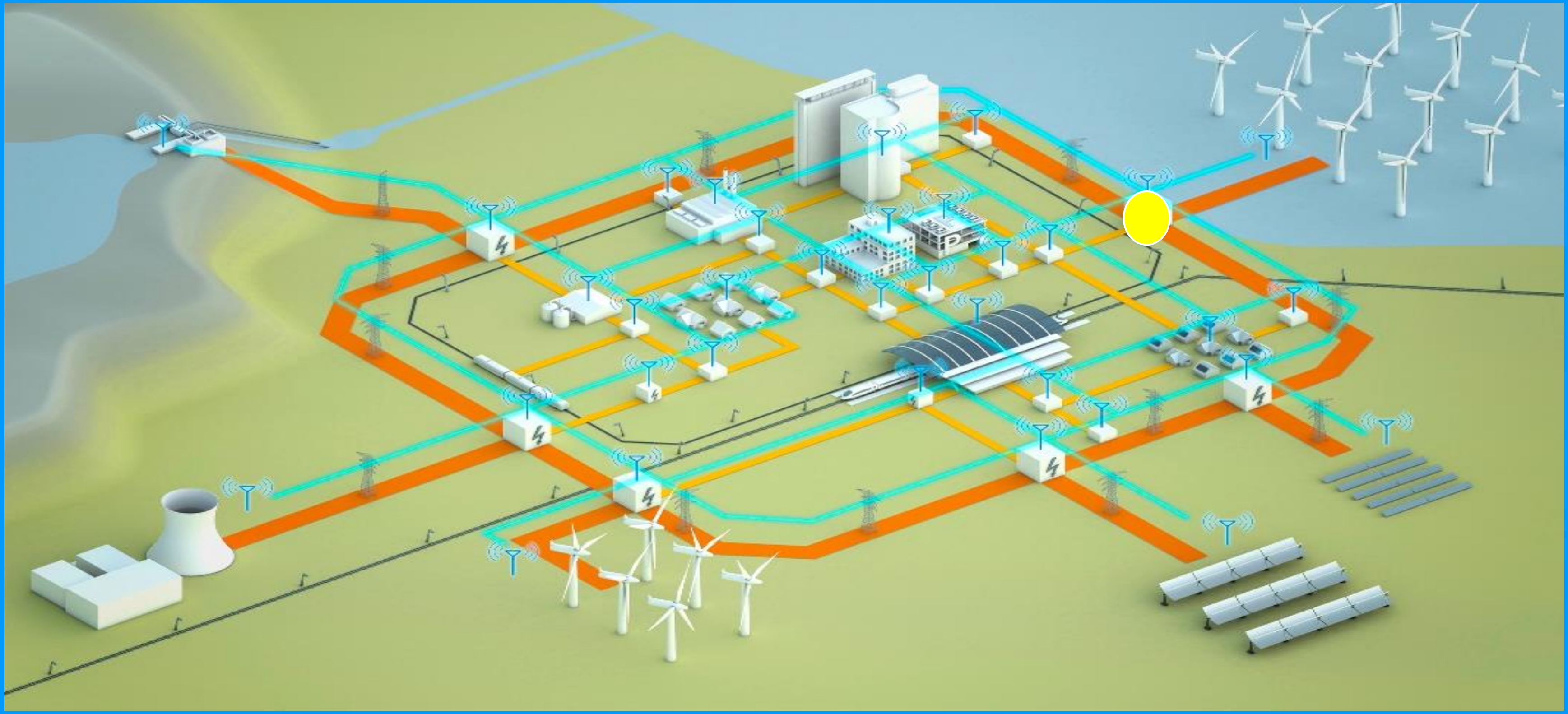
Wrong! Where is energy storage?



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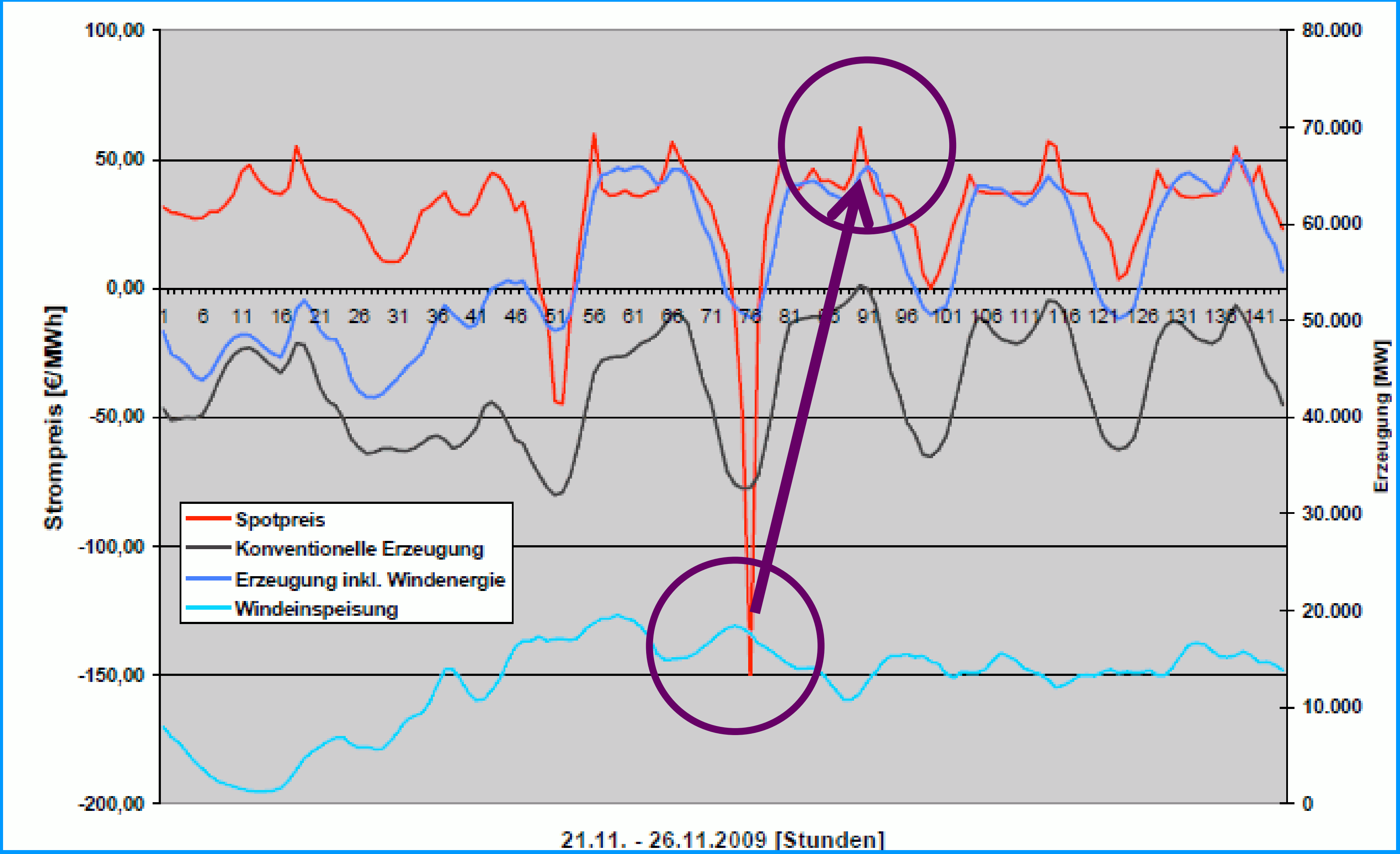
Questions:

- How much storage?
- Where located?
- Function?
- Technology?
  - Electrochemical, thermal, mechanical, chemical, magnetic?

The Role of Energy Storage

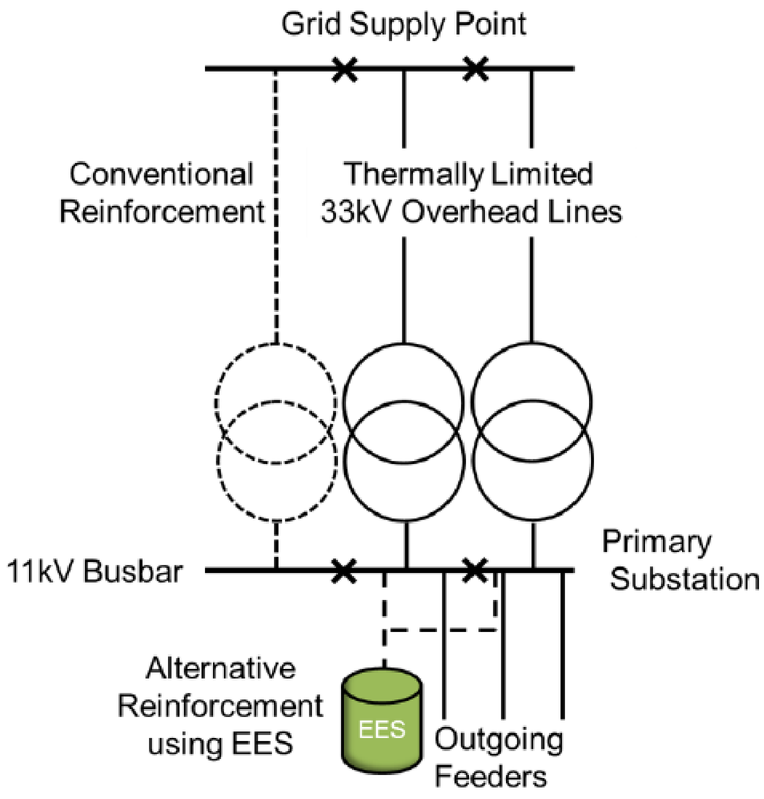
Arbitrage Possibilities (German EEX Market)



Cost reduction

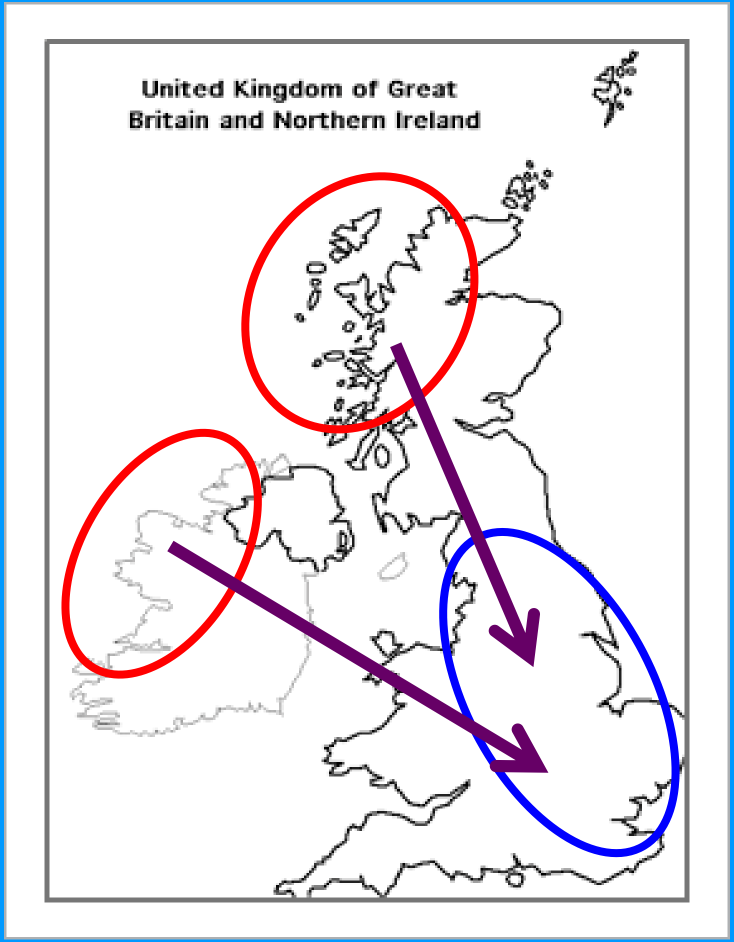
- 6 MW/7.5 MVA/10 MWh of lithium-ion storage installed in Leighton Buzzard.
- Primary substation has reached its MVA limit.
- Conventionally, another overhead line would be installed.
- Can storage solve the problem and pay its way?

http://innovation.ukpowernetworks.co.uk/ - search ‘SNS’



Transmission (high Voltage) Connected Storage (UK)

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



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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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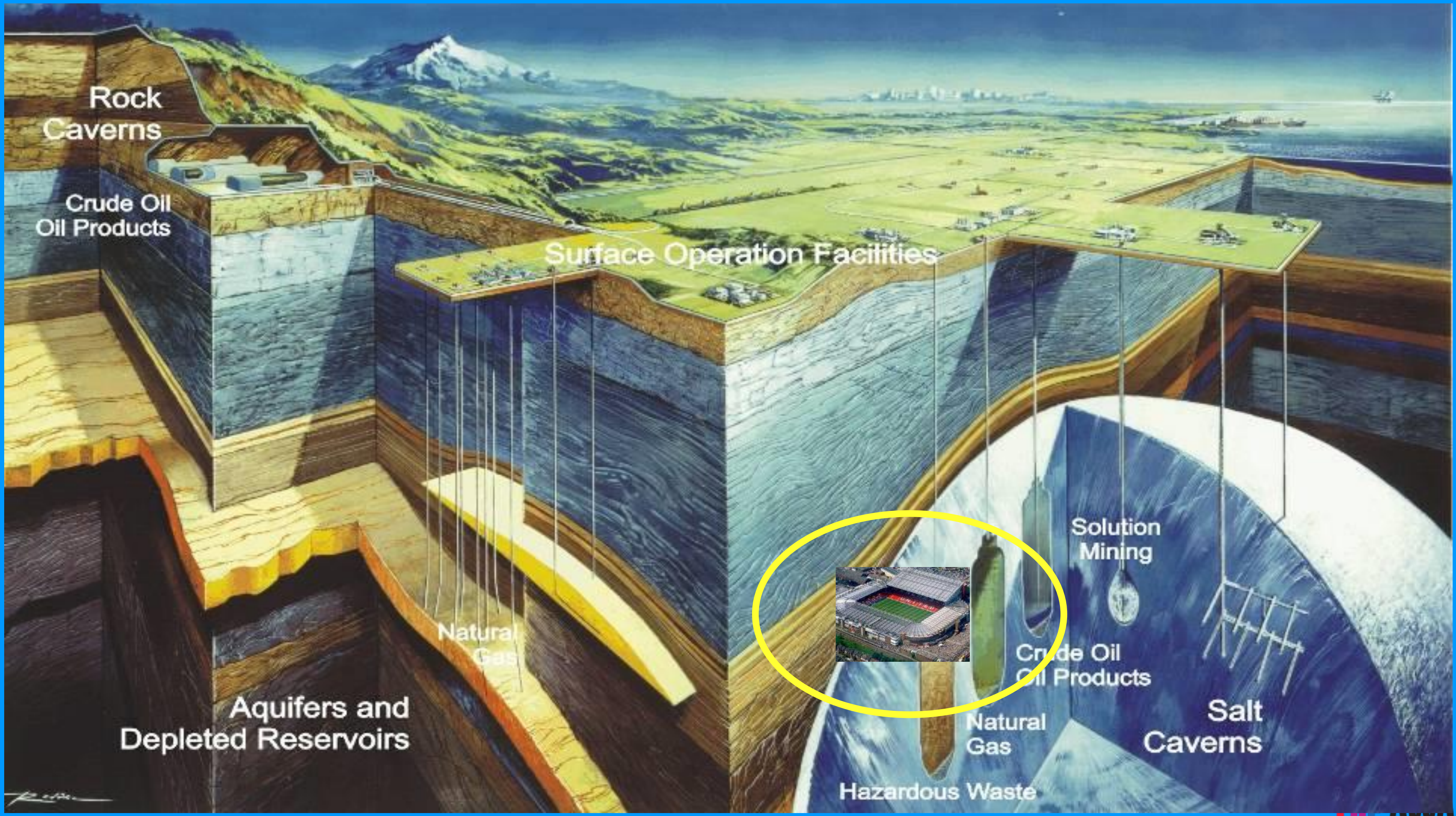
Strategic Energy Storage



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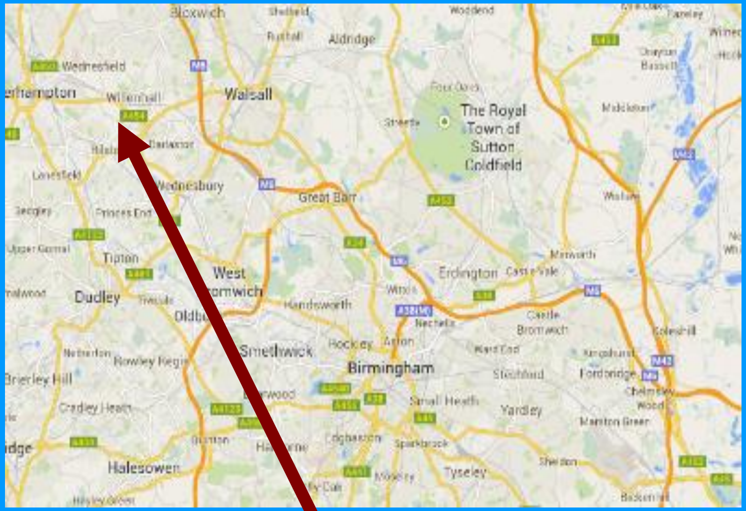
The Sheffield “Big Battery” Project

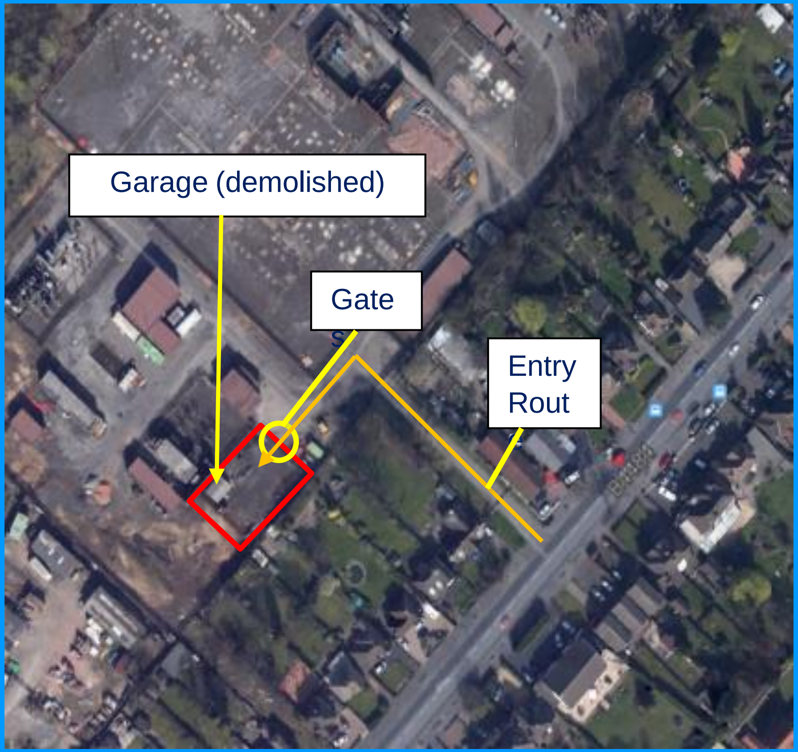
Background to Project

- Willenhall is a small town in the English midlands
- It has an 11kV transformer and some of most serious problems of voltage and frequency stability in UK
  - This is due to the presence of local industry which has a highly variable electrical demand
  - Typical fault currents are often ~1000’s A!

Willenhall Site



On the Wolverhampton /Willenhall boundary



Our Challenge:

- To construct and test an energy storage system that can stabilise the local electrical grid
- Is flexible enough to participate in other energy storage markets e.g. arbitrage
- Is safe, efficient and has a long lifetime
- We will determine the economics/business

Technology Selection:

- **Batteries** were chosen ahead of other power delivery technologies such as flywheels, supercpacitors, superconducting magnetic storage
  - Combination of **power and energy**, cost effectiveness
- LTO batteries were also quickly selected:
  - Extremely fast response time 0-2 MW <100ms
  - Safety
  - Lifetime
  - Emerging as transport battery of choice in Japan (2nd life)

TOSHIBA CELLS

Parts	Description
SCiB™ Cell 	**Nominal Voltage:** 2.3V (Range:1.5V-2.7V)
	Nominal capacity: 20Ah
	Energy density: 176Wh/L
	Dimension: 115(W)x22(D)x103(H)
	Weight: 515g
SCiB™ Module 	**Nominal Voltage:** 27.6V (Range:18V-32.4V)
	Nominal capacity: 40Ah / 1.1kWh
	Dimension: 359(W)x187(D)x124(H)
	Weight: 14kg
	SCiB™ Cell 2P12S CMU (with CAN I/F)

Design Principles

- It is important to specify and understand the **power** requirements first
- Additional energy storage can always be added afterwards
  - Frequency (FFS) and voltage are most lucrative
  - Arbitrage etc are secondary and must be as cheap as possible

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Power *before* Energy

- Project cost - £6M (€8.4M approx)
- Our design principles were:
  - Fast power delivery is essential to enter into frequency and voltage support markets
- Economics are interesting:
  - In total, 80% of costs were on balance of plant (inverters, transformers, air con, civils)
  - **The storage component cost is ~20%**
- Final battery is 2MW, 1MWh, 8,500 SCiB units, 23,000 individual cells

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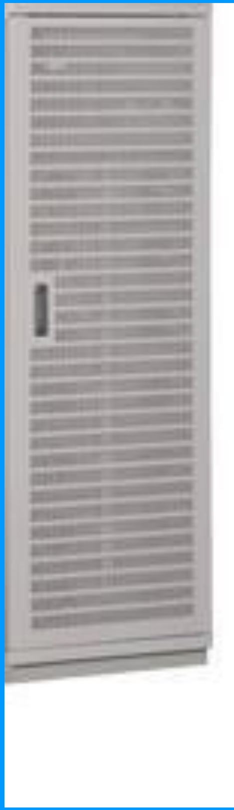
Toshiba SCiB Cell

Toshiba SCiB Module



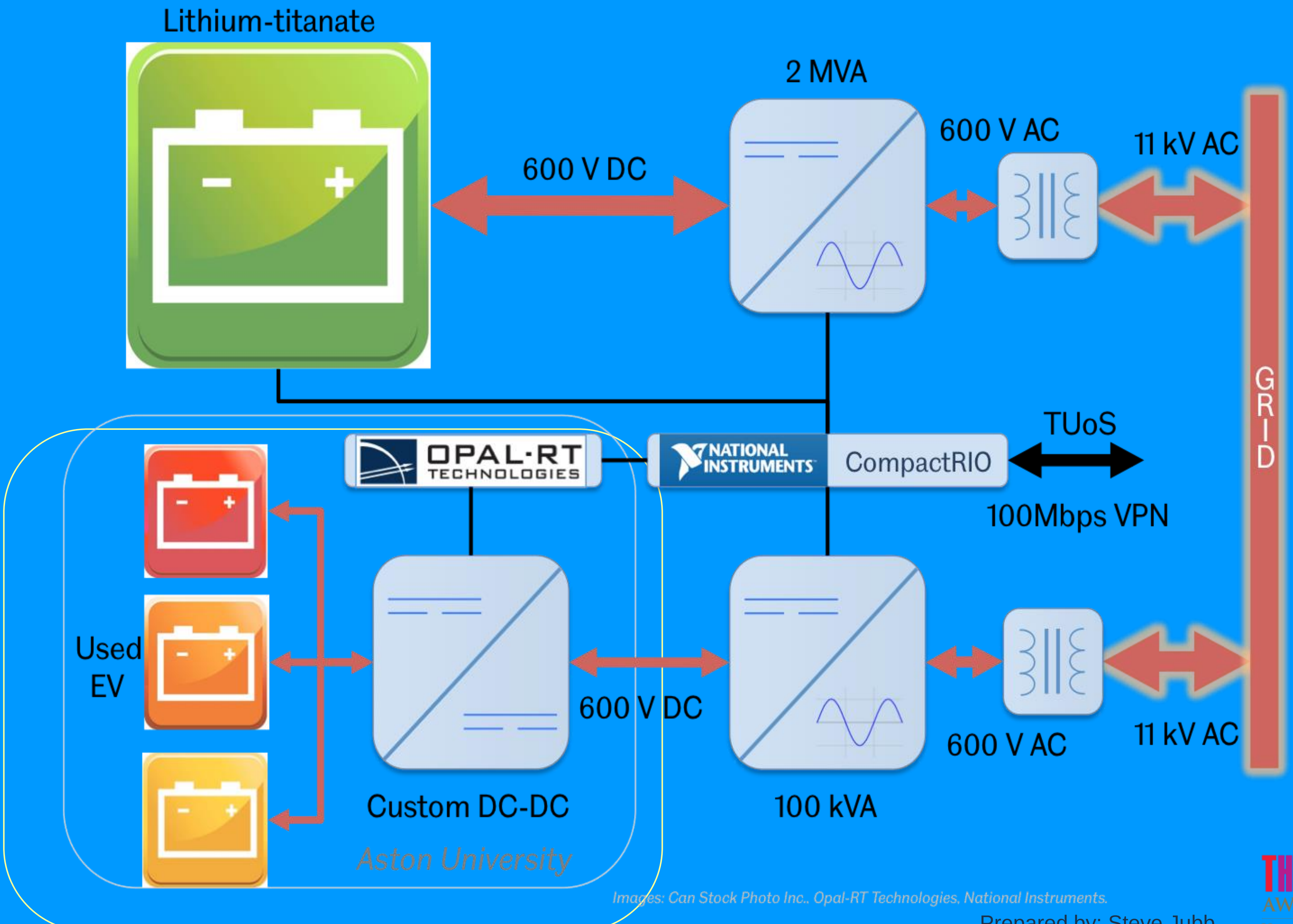
22 Modules in Rack

Cell nominal = 2.3V (1.5-2.7V)
Cell capacity = 20Ah
String = 12 x cells in series (27.6Vn @ 20Ah)
Module = 2 x strings in parallel (27.6Vn @ 40Ah)
Rack = 22 x modules in series (607.2Vn @ 40Ah)
Battery = 40 racks in parallel (607.2Vn @ 1600Ah)
Battery capacity = 972kWh
Each rack is software limited to 55kW (2.26C)
Battery max power @ 2.26C = 2.2MW

>20,000 Cells

TUoS Bttery

Grid-connected Storage Research Platform



Prepared by: Steve Jubb,

Battery monitoring

- Monitor heat dissipation.
- Each cell individually remotely monitored
- 100 Mbps Vodafone Ethernet Wireline £18,000/year
- A-end: University of Sheffield, B-end: Willenhall WPD primary substation; inc. access circuits and 100 Mbps Ethernet Virtual Circuit

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The facility

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Contact details: Dave Stone d.a.stone@sheffield.ac.uk

2MW ABB Inverter

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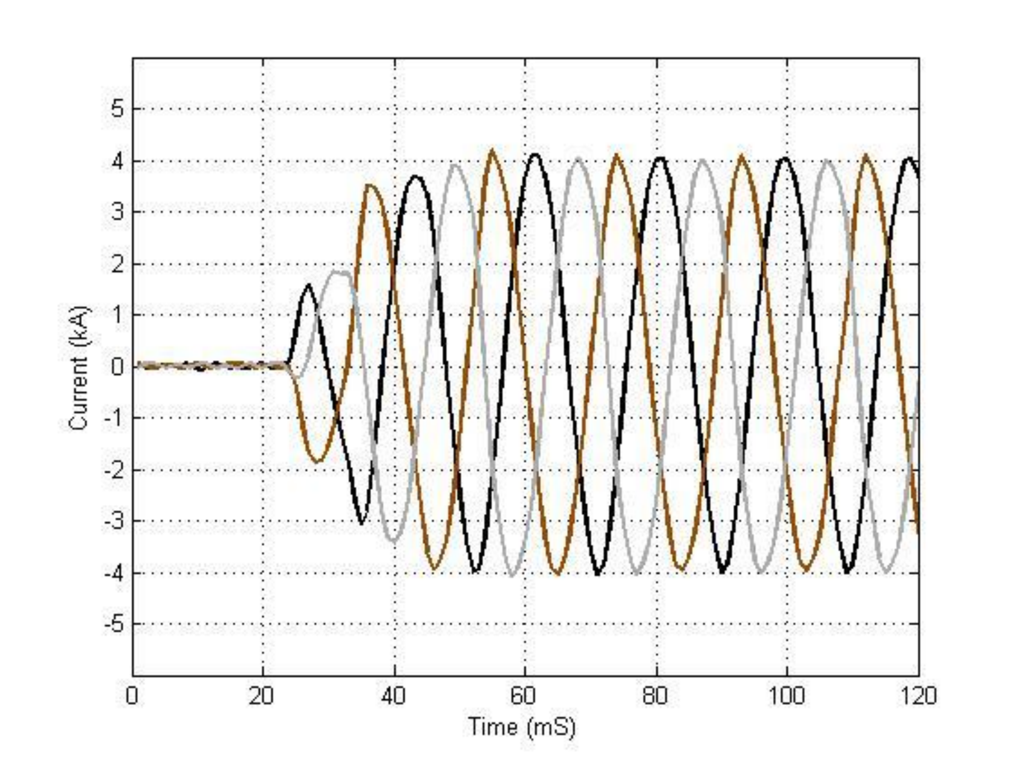
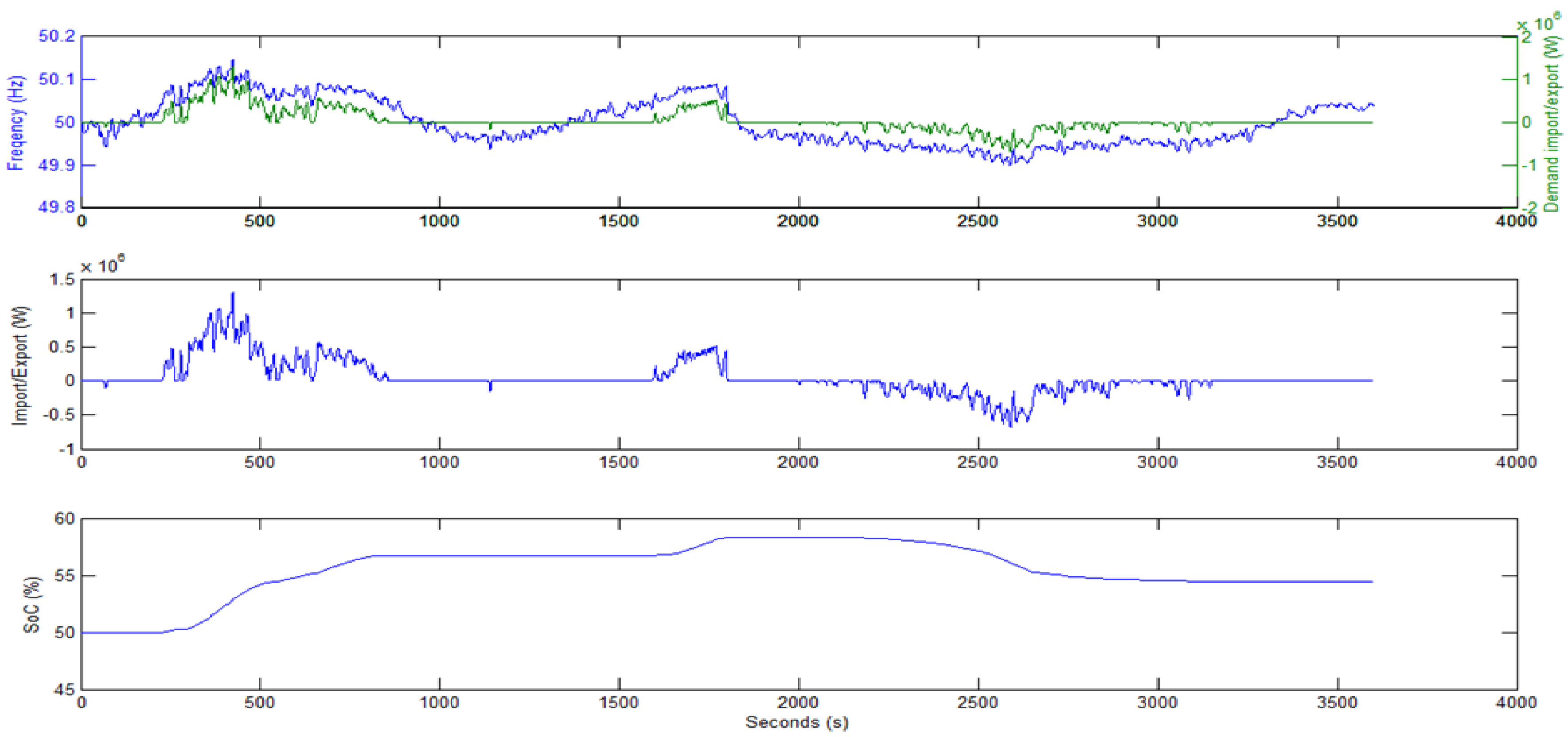
2MW step response

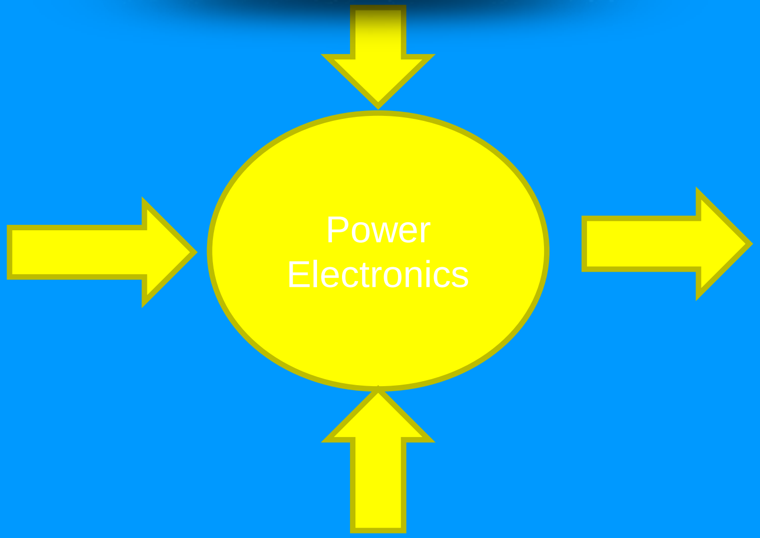


Optimizing for enhanced frequency response



Research Areas

Energy Storage Systems (ESS)
New and second life batteries



Hybrid Systems to Grid (HS2G)

Vehicle to Grid (V2G)
Battery first life

2011

Research

- Battery aging e.g. STOR
  - Already we are noting that during balancing some cells need more attention than others
  - Examine using non-invasive techniques, EIS, x-ray tomography + post mortem reasons for accelerated aging

Inverter and Second Life Facility

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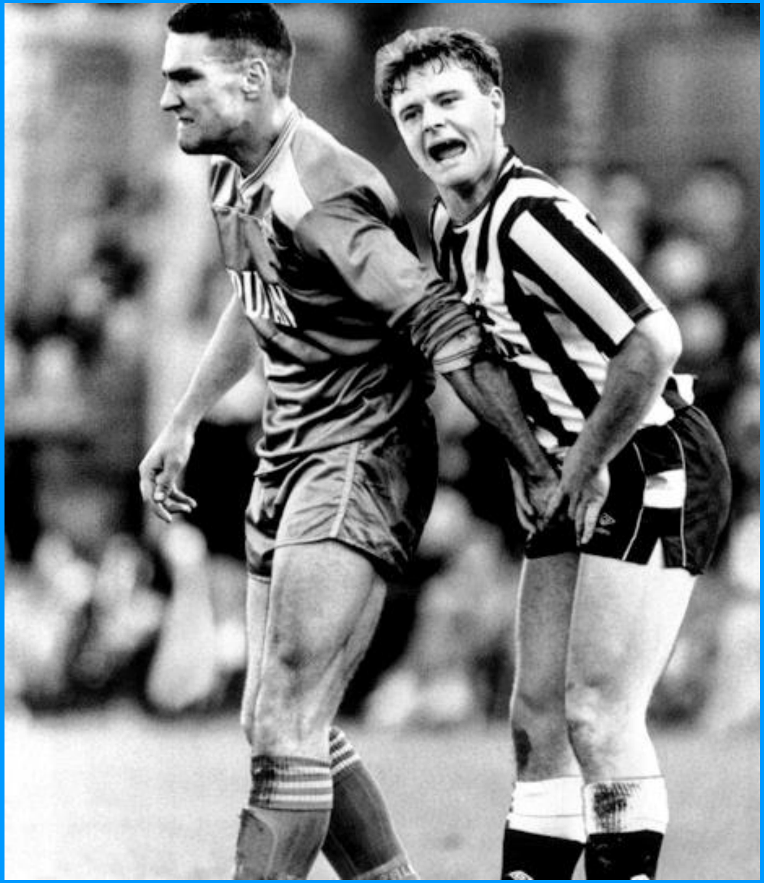
Thanks:

Easy questions please!



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