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Grid Connected Energy Storage for Residential, Commercial & Industrial Use - An Australian Perspective

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- Electricity supply system must be sized to cope with maximum demand, which may only represent a few hours/year

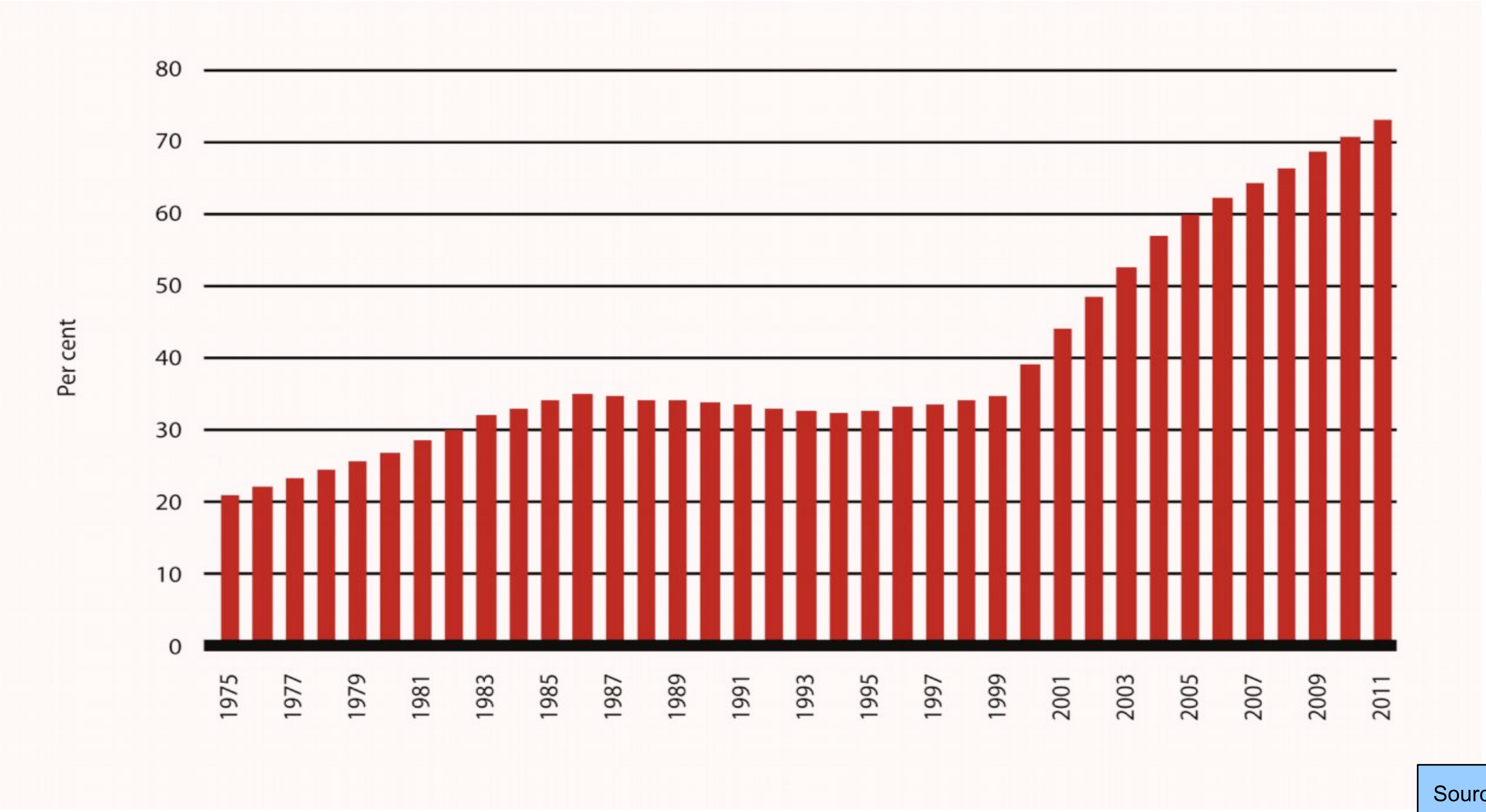
In Australia, peak demand is very costly

About 15 per cent of the national electricity network caters for peak periods. $11 billion worth of infrastructure is only being used for 100 hours – or four days - a year[6].

Source: Ausgrid, Supply and demand: our five year network plan, 2011-2012 update, p. 10

What's driving growth in peak demand?

FIGURE 1: **AUSTRALIAN HOMES WITH AN AIR-CONDITIONER OR EVAPORATIVE COOLER, 1974-75 TO 2010-11**



Source: ENA

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  -$100 to $12,500 /MWh
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- Storage can link variable generation with variable load

Why store (electrical) energy?

Transmission grids provide energy ***where*** it is needed

Energy storage provides energy ***when*** it is needed

Dr Imre Gyuk – Program Manager, Energy Storage, US Dept of Energy

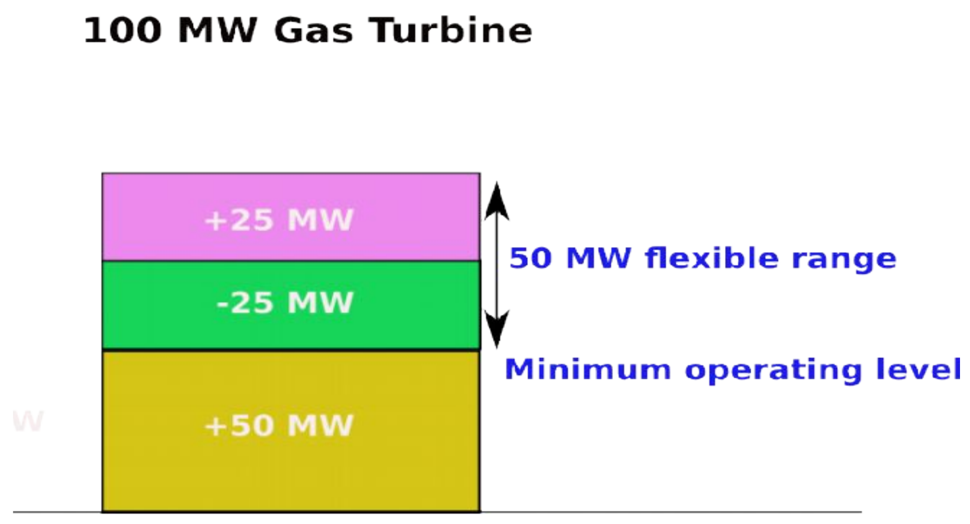
Valuing energy storage

- Energy (minutes & hours)
  - ***Diurnal load shifting***
  - ***Renewables integration***
  - ***Peak shaving***
  - Slow frequency response (FCAS)
  - Spinning reserve
- Power (milliseconds & seconds)
  - Power quality
  - ***Frequency control***
  - Fast FCAS

Ancillary services to maintain grid stability

- Supply must meet demand
  - If wind/solar power output goes up, other generators must compensate
  - This occurs at the second, minute and longer timescales
- Even without intermittent generation, “ancillary services” are needed to balance load
  - 6 second raise/lower
  - 60 second raise lower
  - Delayed raise/lower (5 minute)
- Increased intermittency requires more regulation

Battery or Gas Turbine for Ancillary Services



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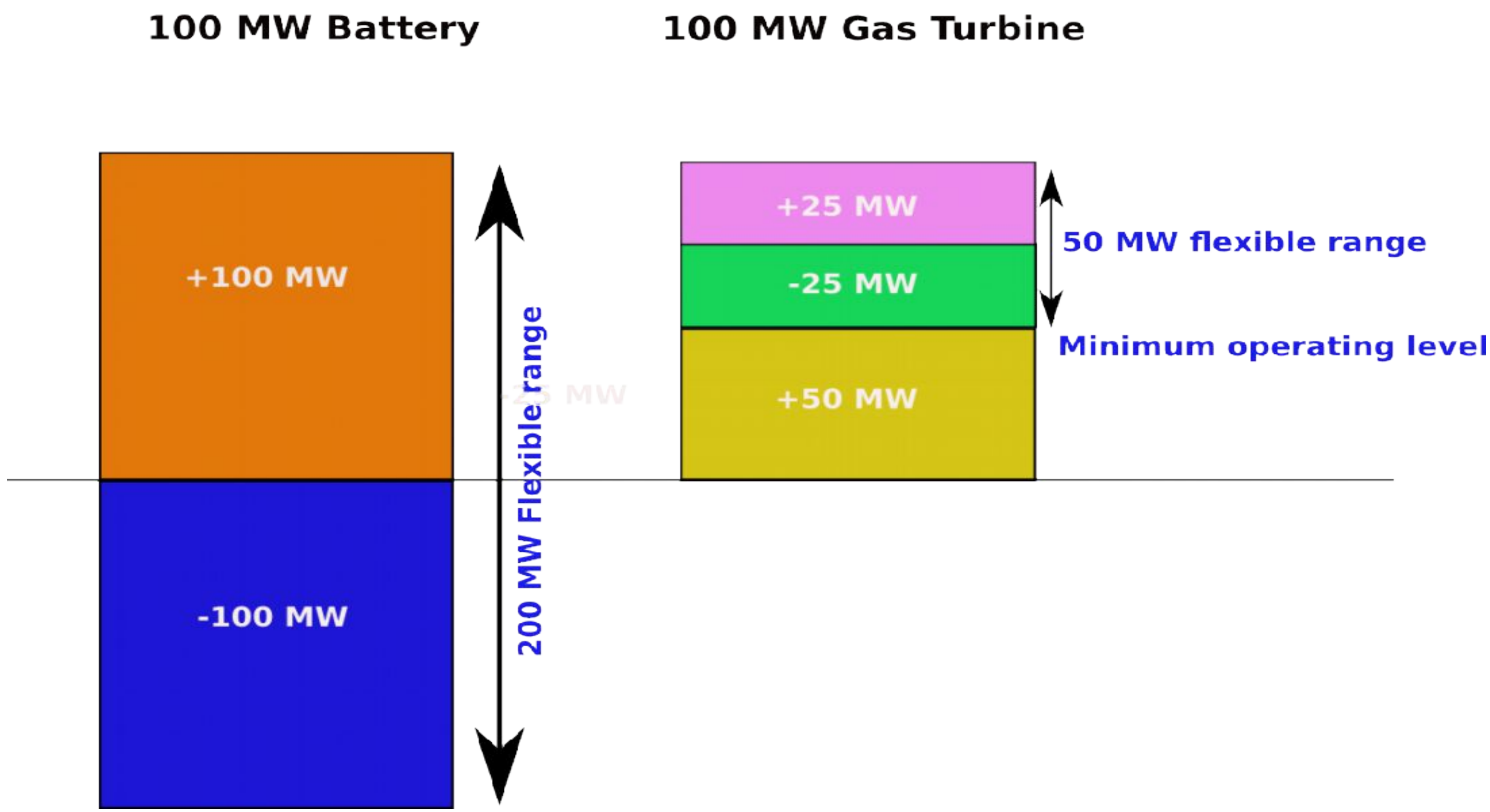


Storage costs – two main aspects

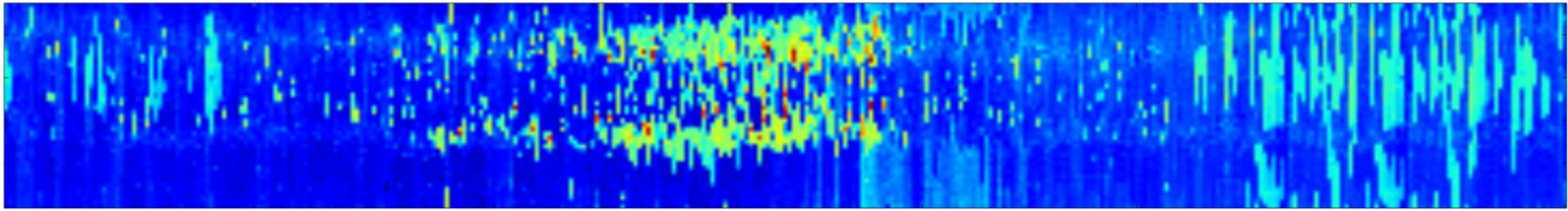
- Stored energy ['fuel tank']- $400-4000/kWh depends on chemistry
- Power delivery ['engine'] - $300-600/kW [DC/AC, plus associated systems – more silicon]
- High power, fast charge/discharge means greater cost in power converters – e.g. seconds, minutes
- High energy – hours, e.g. 2-4 hr charge/discharge means greater cost in cells/stacks
- Battery cost is not the important figure, but cost of stored energy, which is a function of ...

How much does it cost to store electricity?

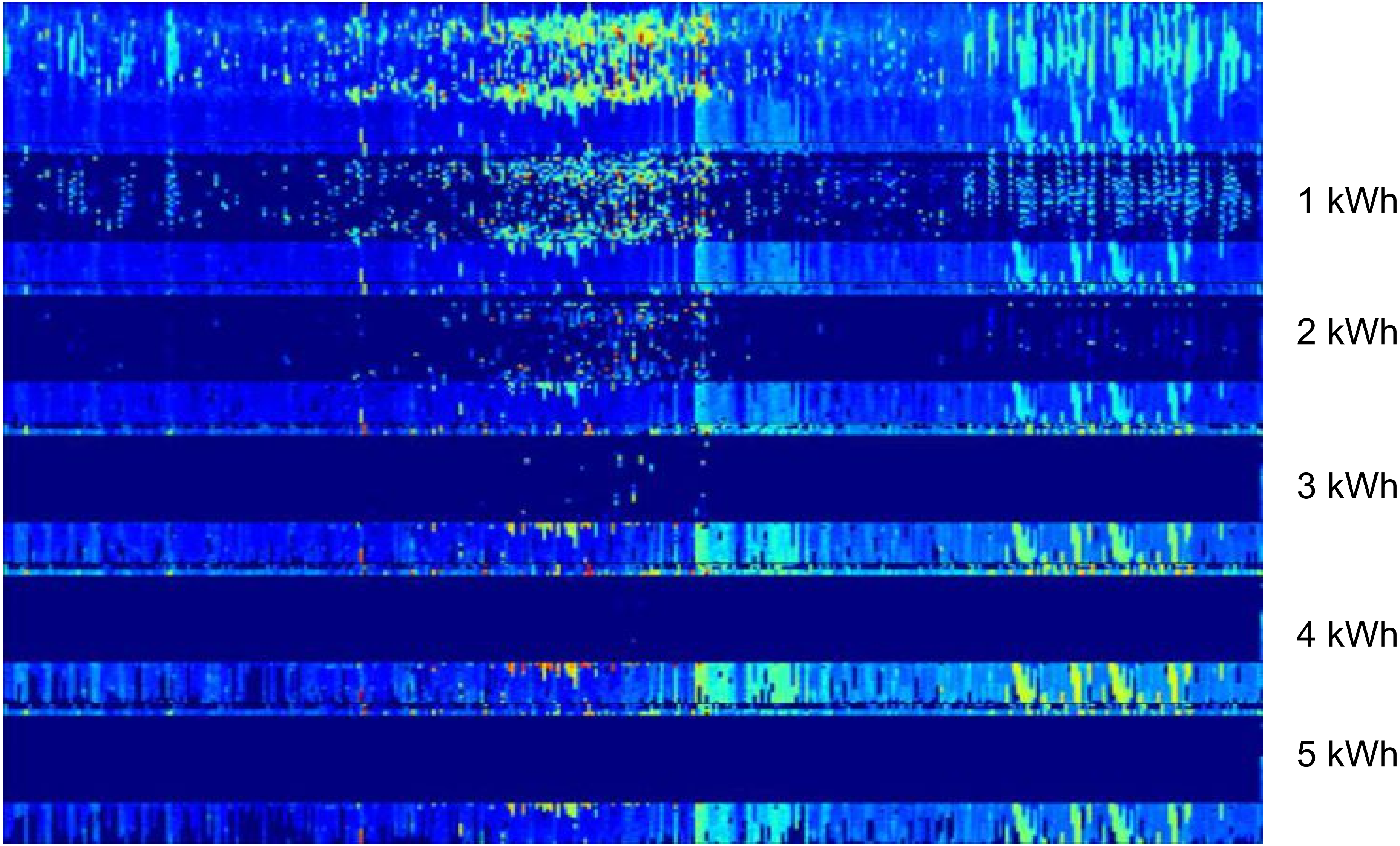
- Capital cost of storage system
    - Storage + power conditioning
- Lifetime number of cycles
- Efficiency of storage
- O&M…

$/kWh	efficiency	cycles/ day	lifetime	depth of discharge	lifetime throughput	$/kWh
1000	75%	1	10 y	100%	2737 kWh	0.36
500						0.18
500			20 y		5475 kWh	0.09

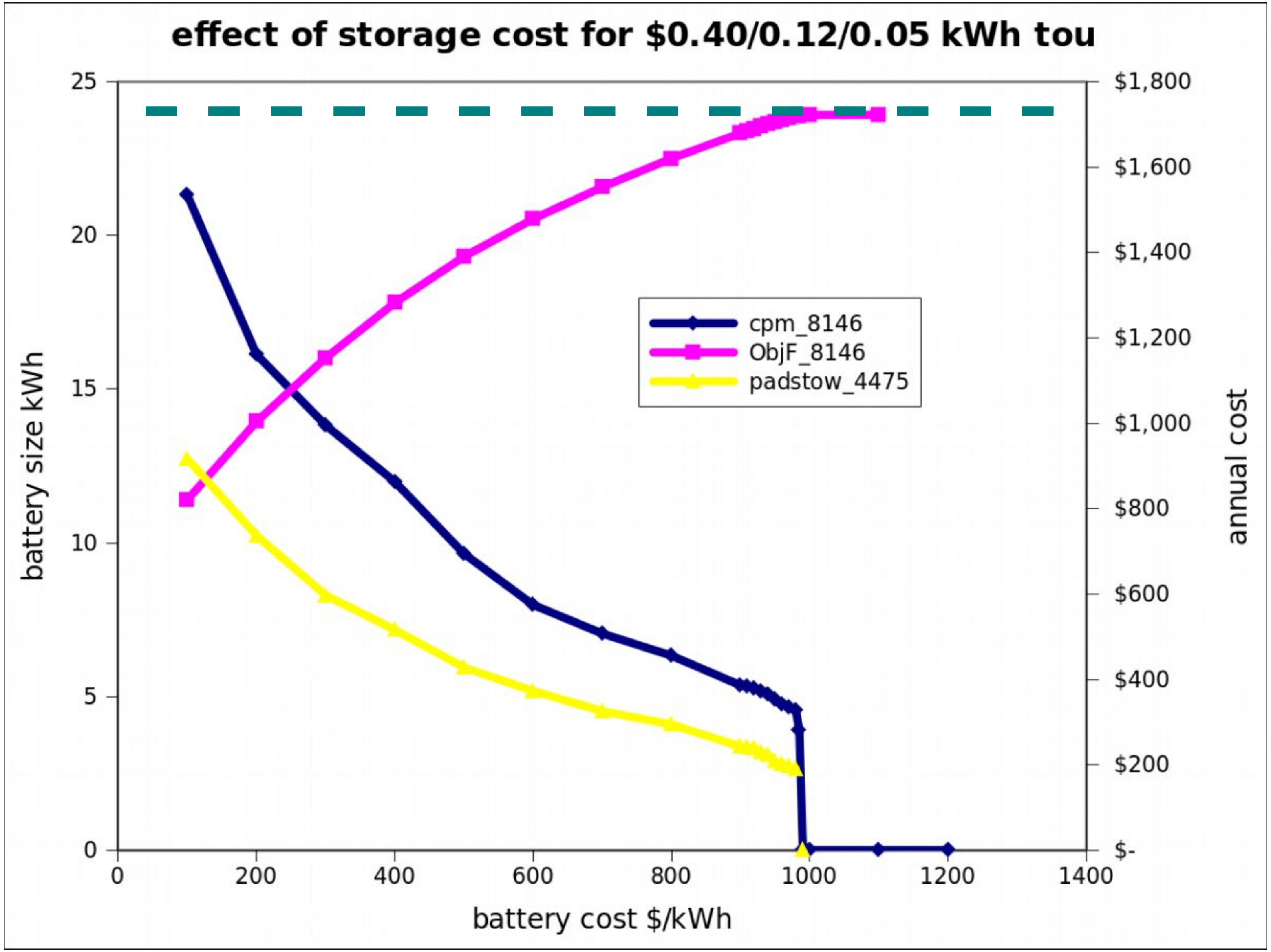
Residential demand – hb_146
1/1/2010 to 31/12/2010



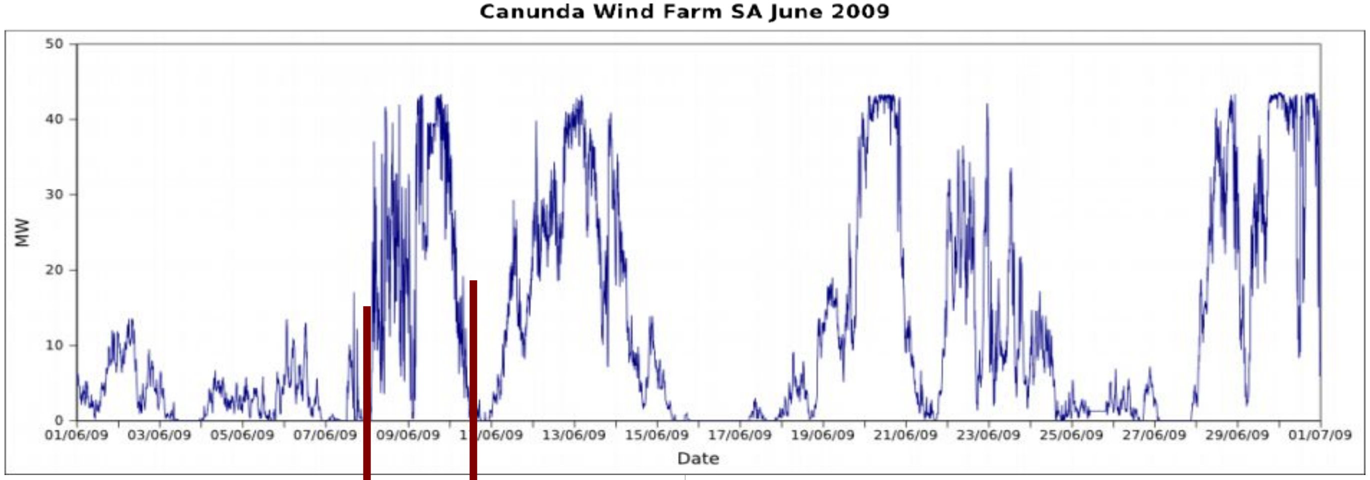
Effect of storage on peak demand

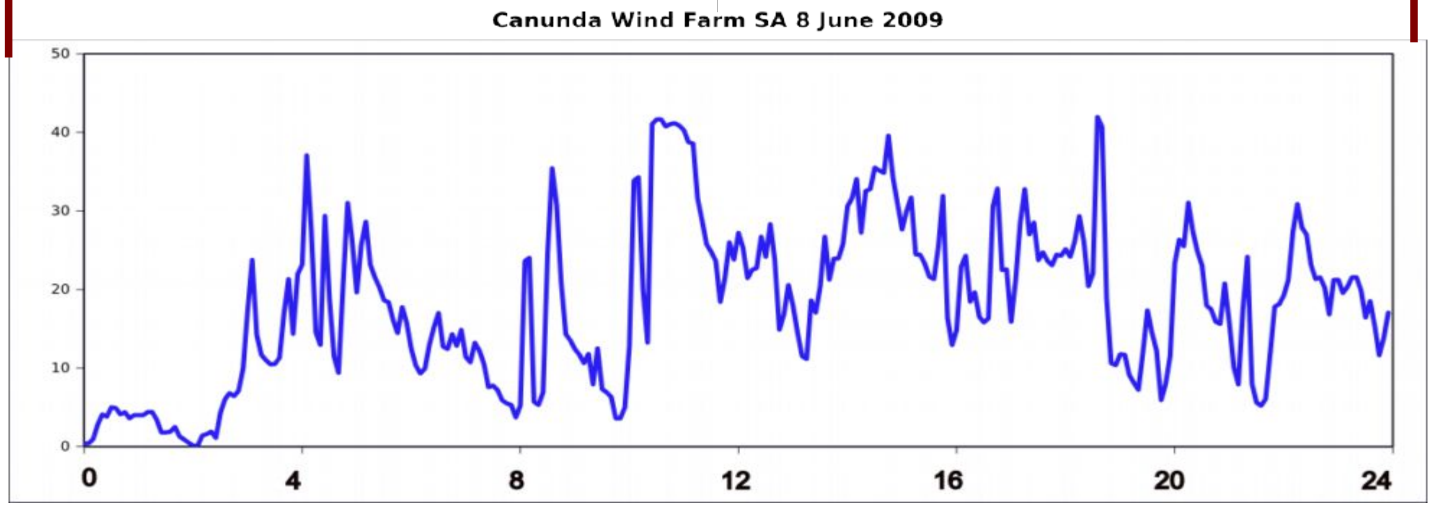


Effect of battery cost on optimum capacity



Variability in Canunda wind farm output





Why combine energy storage with wind power?

- Time shift output
- Reduce ramp rates
- Reduce losses (mlf)
- Reduce connection costs

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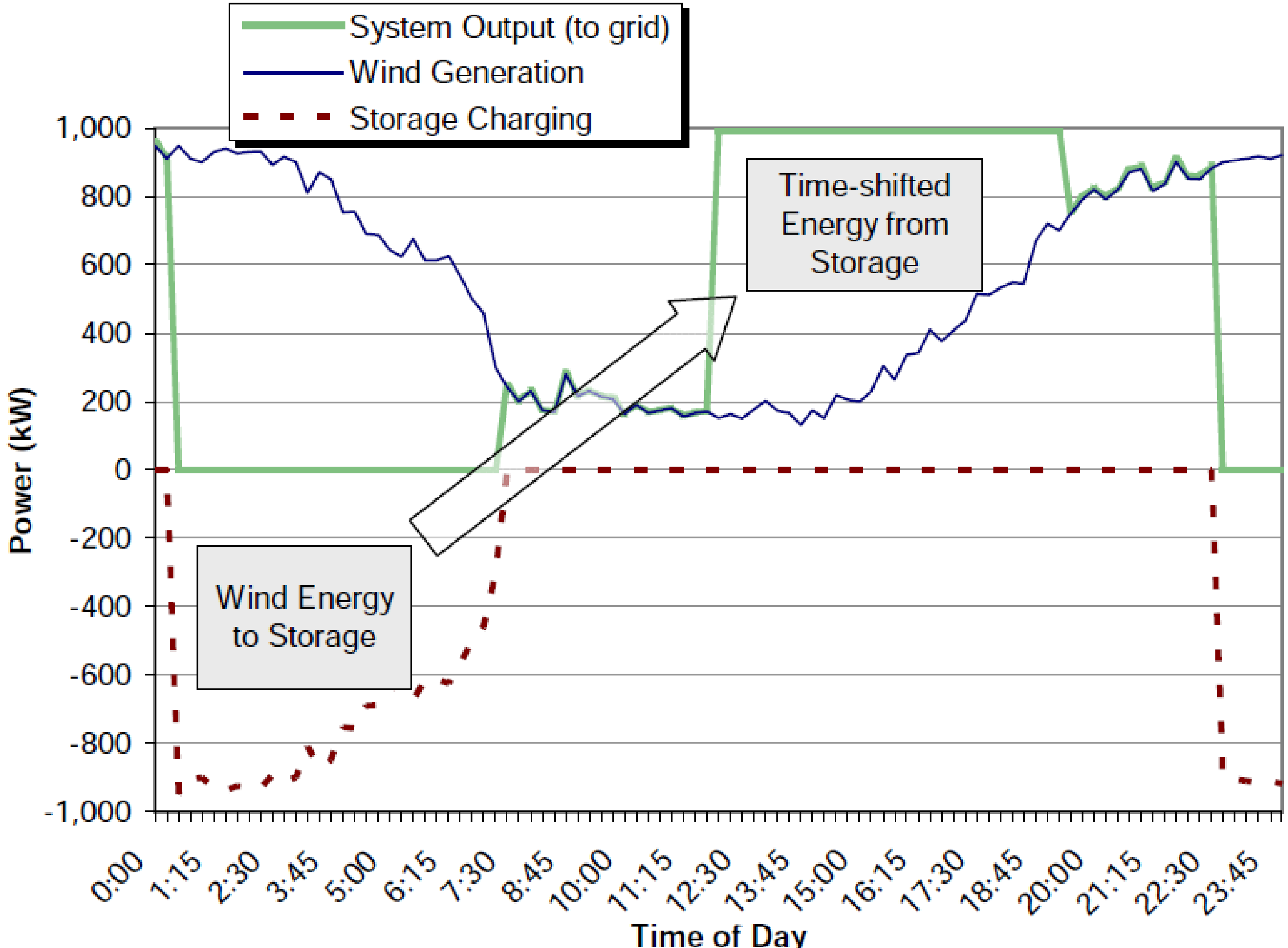
Time shift output



Source: Sandia 2010

Ramp rates

- Reduce ramp rate
  - Currently 3 MW/min or 3% max output (in Australia)
  - Considering change to 6 MW/5 min
  - Many wind farms exceed this for 2-5% of time

Losses & connections

- Reduce losses
  - Losses proportional to current^2
- Reduce connection costs
  - Cheaper to connect e.g. 65 MW high utilisation than 100 MW low utilisation

Flow batteries for wind farms?

- Electrolyte flows over non-reactive electrodes
- Energy is stored in the electrolyte
- Analogous to rechargable fuel cells – regenerative fuel cells
  - Zinc bromine
  - Vanadium
  - Polysulfide – bromine
  - Many different forms

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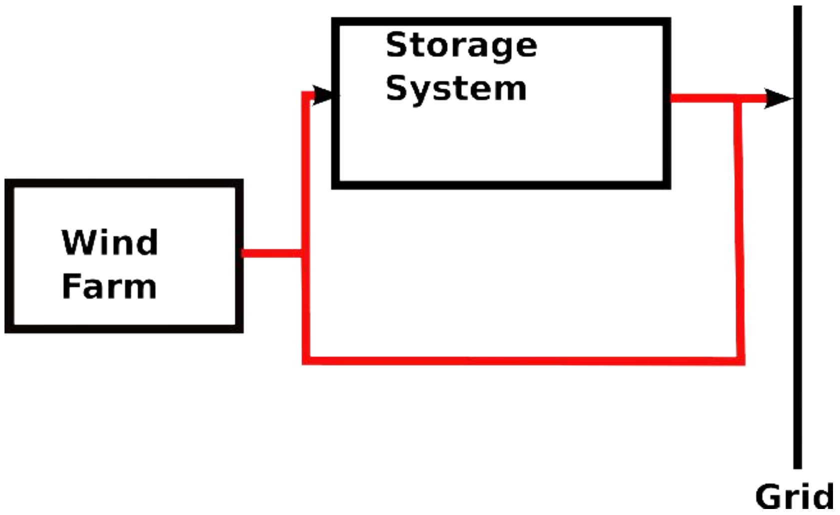
Why flow batteries?

- Total/substantial control over energy/power ratio
- Energy ~ volume of electrolyte
- Power ~ area of electrode
- Potential for low cost in some chemistries

Aim of the Study

- What size (cost) of storage to reduce ramp rates?
- What size (cost) of storage for time-shifting?



Modelling storage for wind farms

- <5 min wind farm data not widely available
  - Used 5 min data for ramp rates
  - Battery SoC, lifetime, efficiency
  - Energy (MWh) & power (kW) cost estimates
- Used Simulink
  - Time shifting used multiple linear regression to estimate forward demand [using demand as proxy for price]
    - High forward demand = discharge battery + wind output [0.9 for 30 min/24 h]
    - Medium forward demand = wind output only, neither charge/discharge
    - Low forward demand = priority to charge storage

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Wind farm data

- 4 wind farms in SA used for ramp rate control
  - Snowtown 99 MW
  - Clements Gap 57 MW
  - Hallet 1 95 MW
  - Hallet 2 71 MW
- Snowtown used for time-shifting analysis
  - 10% DR, 20 y life, 30% tax rate, SLDeprec

Modelling Results – Wind Ramp Rate Mitigation

- Modelled various configurations of Li-ion, VFB & NaS
  - Objective achieved at lowest capital cost by 1 h VFB

- Key driver for capital cost is discharge duration.
  - Incorrect optimisation can more than double capital cost

- Natural smoothing effect between nearby wind farms.
  - Centralised rather than individual storage systems are a more efficient solution → >80% reduction in capital costs
  - [Centralised systems also achieve greater GHG emission reductions]

Cost to limit >6MW/5 min to <1%

Wind Farm	MW	6 MW/5 min (%)	Storage cost ('000s/MW)#
Snowtown	99	95	65
Clements Gap	57	98	34
Hallet 1	95	95	54
Hallet 2	71	97	36
Combined	322		18

Lowest cost

Time shifting

- Aim: Store energy generated during off-peak demand and discharge during peak demand to achieve greater value
  - [Snowtown received average of $17.8 /MWh cf $38.80/MWh pool price]
- Dispatch decision controlled by demand forecasting model
- Storage can increase revenue by >50%
- Optimal ESS for Snowtown is 60 MW, 4 h capacity
- -ve NPV at current costs, break-even at ~$75/kWh
- Analysis only valid for Snowtown and pool prices 2009-2011

Conclusions & observations

- Large range of storage applications from sub-second to multi-hour
- Value is there, but costs need to reduce
  - Regulatory environment needs changes
- Flow batteries well suited to wind farm output
  - 4-6 hr capacity
  - [Zinc-Br more challenging than VRB because of need for strip cycle]
- Key challenge for time-shifting economics is dispatch algorithm
  - attempt to forecast price or use standard approach(s)?
  - perfect foresight can easily double or triple revenue

Acknowledgements

- Marija Petkovic