THE UNIVERSITY OF QUEENSLAND AUSTRALIA

The business case for battery energy storage

Andrew Wilson

Manager – Energy & Sustainability

Property & Facilities Division | University of Queensland

Presentation Outline

1. Introduction & Background
2. Gatton Solar Farm
3. Gatton Battery Energy Storage System
4. Modes of Operation
5. Electricity spot market participation
6. FCAS market participation
7. The theoretical business case
8. Learnings
9. The future: Heron Island
10. Rethinking what a battery can be

About UQ

- Queensland's oldest and largest university – founded in 1910
- Over 51,000 students and around 6,700 FTE staff
- 12,000+ of these students from 140+ countries
- Ranked in top 100 universities in the world
- Operating budget of $1.76 billion (2016)
- Main campuses at St Lucia (urban), Gatton (rural) & Herston (urban)

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

UQ's impact

- 550+ buildings across 25 sites - GFA of ~790,000m^2
- Many highly energy intensive spaces such as PC2 labs
- Total electricity usage in 2016 was ~145 million kWh
- Equivalent to 27,000 average QLD homes
- St Lucia campus peak demand = ~22 megawatts
- Gross electricity spend of $22+ million per annum
- Energy usage represents 98% of 120,000 t CO_2-e pa. footprint

About the Gatton campus

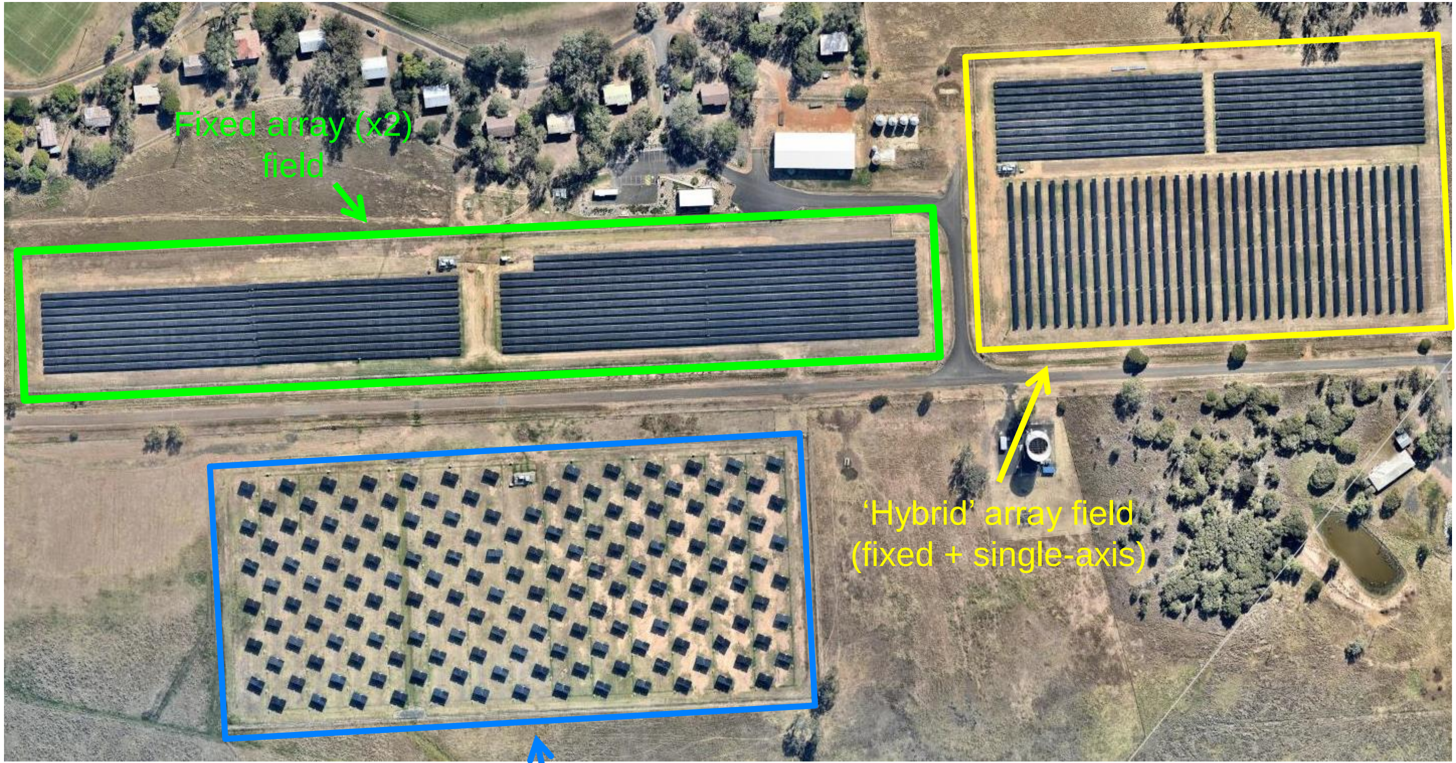
- Rural campus 1 hour west of Brisbane, covering over 1,000 hectares
- 1,700 students – main areas of focus are agriculture, plant science, and vet science
- Site also includes piggery, dairy, nursery, halls of residence
- Mix of building types and ages – WW2 history
- Previous electricity usage of ~ 16 million kWh per annum

The Gatton solar farm

Gatton solar farm - key figures

- 37,320 *First Solar FS-395-PLUS* 95W modules
- Thin film *cadmium telluride* technology – smaller footprint than traditional modules (120cm x 60cm vs. ~200cm x 100cm)
- Total capacity = 3.545 MW_{dc} / 3.275 MW_{ac}
- Three tracking systems – fixed, single-axis & dual-axis
- Same module used throughout to enable comparison studies
- 5x SMA central inverters – 720 kW each (capped at 630 kW)

Gatton solar farm - layout



Gatton solar farm - trackers



Gatton solar farm - benefits

- Annual generation = ~6.5 million kWh
- Equivalent to ~1,200 average Queensland homes
- Saving ~6,000 tonnes CO_2-e per annum
- Net campus grid usage reduced by ~40% compared to pre-solar
- Export portion for the year = ~10% (net metered)
- Forecast value of avoided energy costs in 2017 = ~$800,000 from kWh savings+ demand reduction (does not include LGC value)

Gatton BESS - overview

- Gatton solar flagships project included scope for installation of BESS to be integrated with solar farm
- Lithium polymer technology chosen – Kokam batteries assembled by local provider MPower
- 2x 380 kWh battery banks = 760 kWh total
- 2x 300 kW inverters = capped charge/disharge rate of 600kW
- Does not connect direct to solar output: solar energy converted to AC when sent to campus grid, BESS converts back to DC to store in cells, then coverts back to AC when discharged
- Several initial modes of operation designed by researchers
- Two new modes added since commissioning for commercial purposes (spot market & FCAS) led by P&F

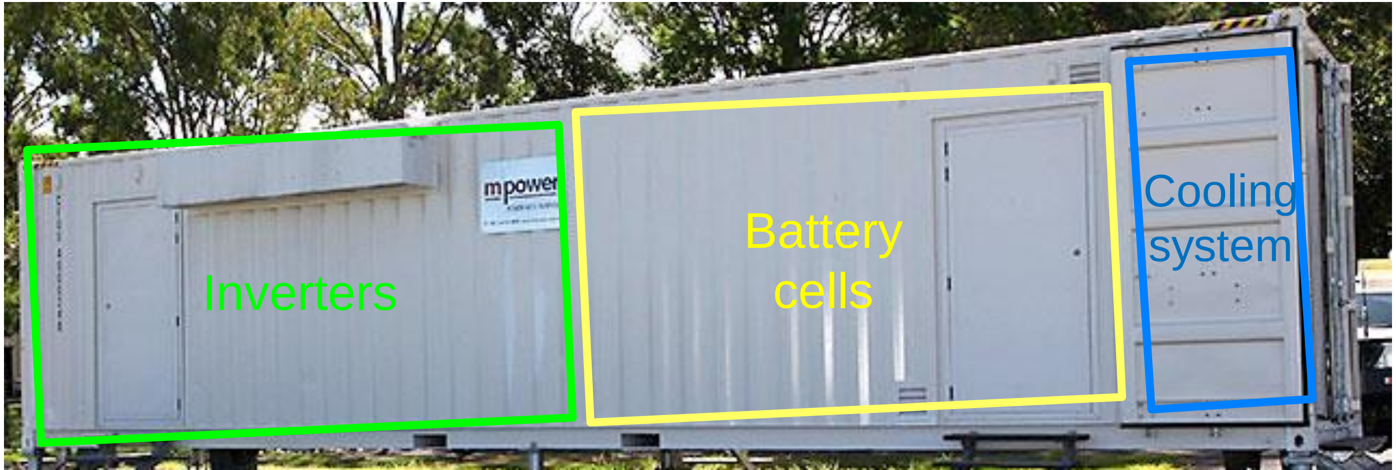
Gatton BESS - overview

55x Tesla Powerwall (v2) units

Gatton BESS - overview

The University of Queensland
AUSTRALIA

Gatton Battery Energy Storage System



Gatton BESS operating modes

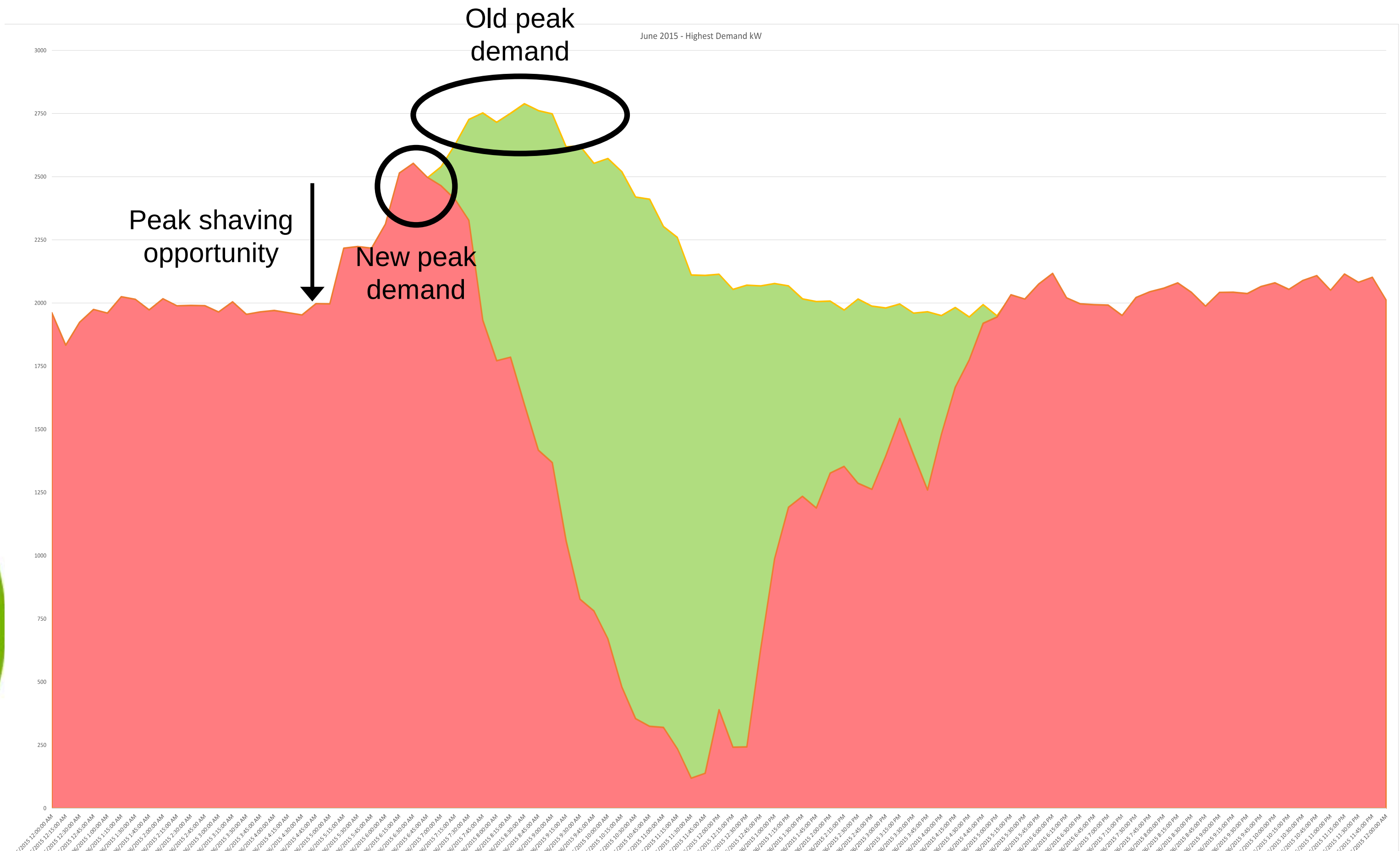
Discharge

1. Solar smoothing – fill dips in generation to match campus load
2. Peak shaving – limit maximum monthly demand (kVA charges)
3. Peak swap – discharge to reduce grid kWh in peak periods

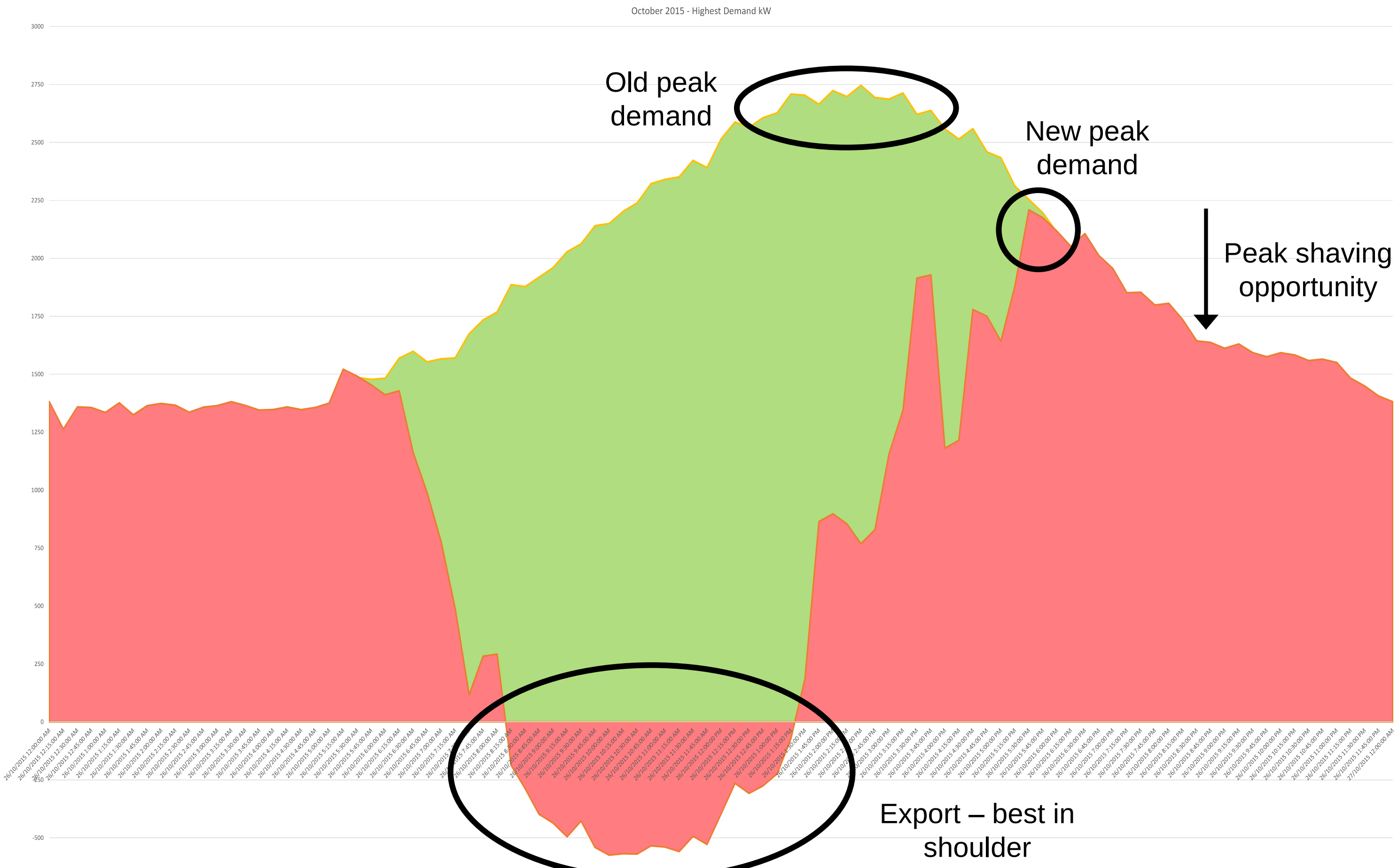
Charge

1. Limit export – send surplus solar to battery instead of grid
2. Solar charge – recharge if any amount of solar available
3. Off-peak charge – recharge overnight (*outdated concept*)
4. Trickle charge – recharge slowly to reach minimum level

Demand curve - June

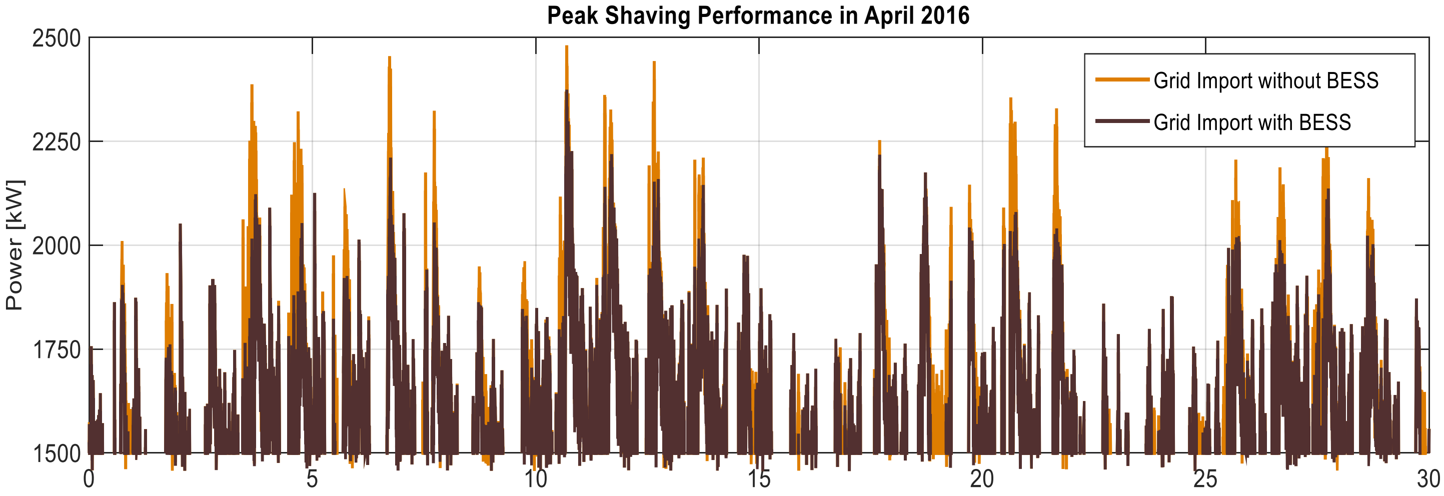


Demand curve - October

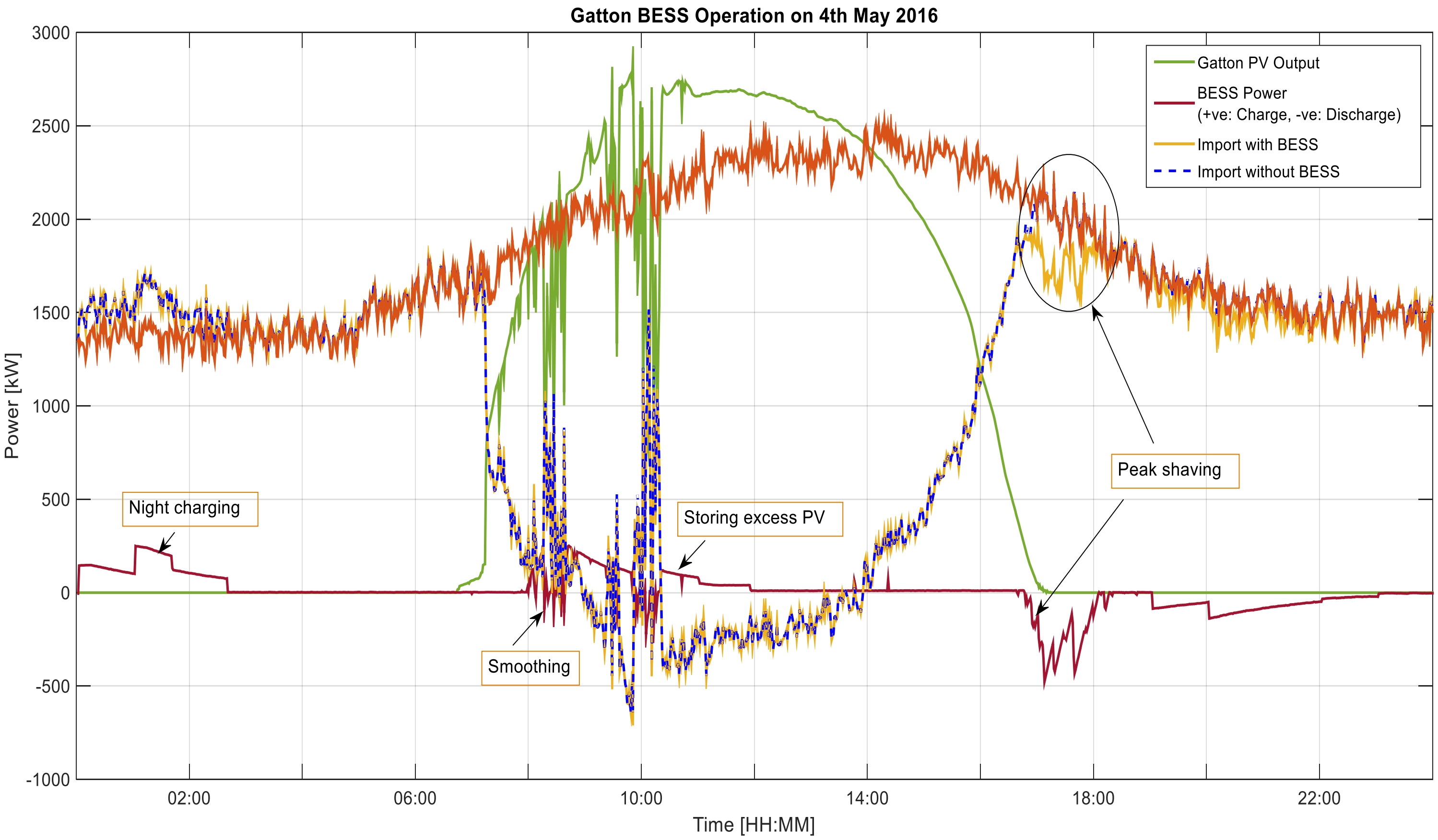


Peak shaving – performance

- Requires fine tuning of algorithm to predict and mitigate peak demand each month
- Issues with battery not being fully charged when needed
- Peak shaving needs to occur for more than than 1 hour, so 600 kW becomes 300 kW or less...
- Experience shown average of 150 kVA achievable consistently

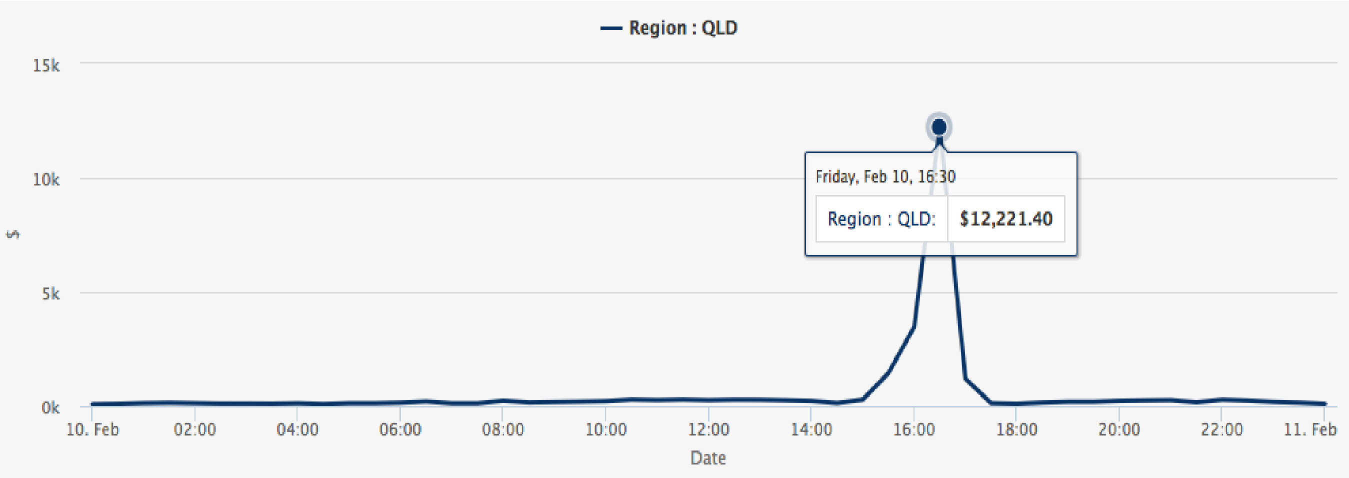


Operating modes in action



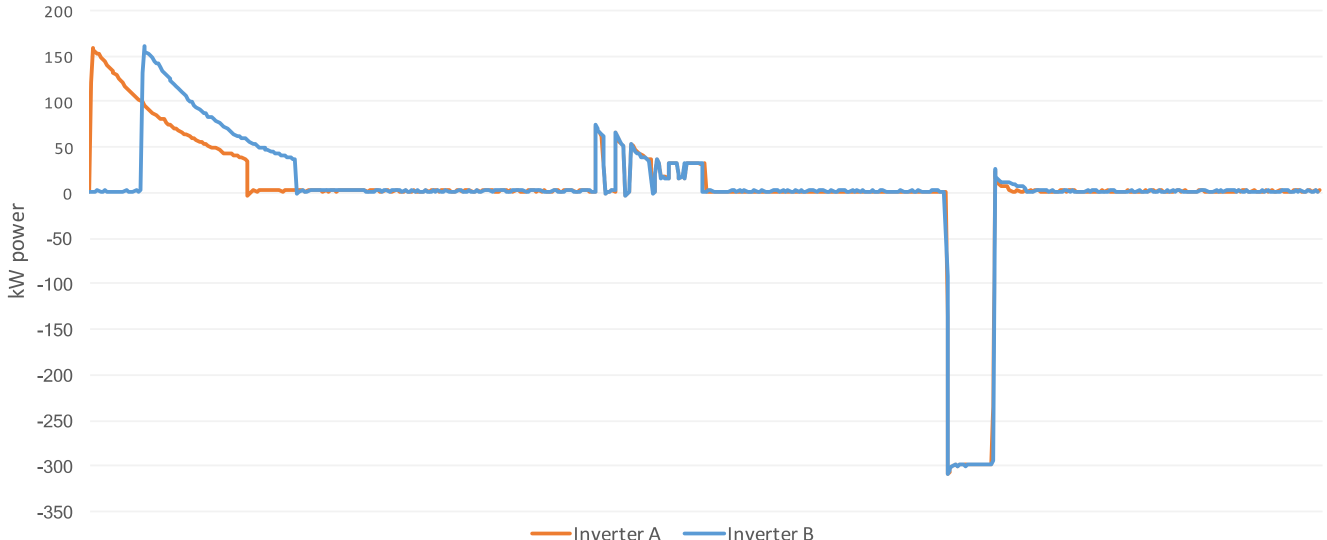
Spot market participation

- All electricity supply and demand settled via 30 minute spot market run by AEMO
- Retailers use physical and financial hedging to provide a fixed price for customers
- Financial incentive to drop load or generate during high price events (over ~$1,000/MWh), typically Summer afternoons



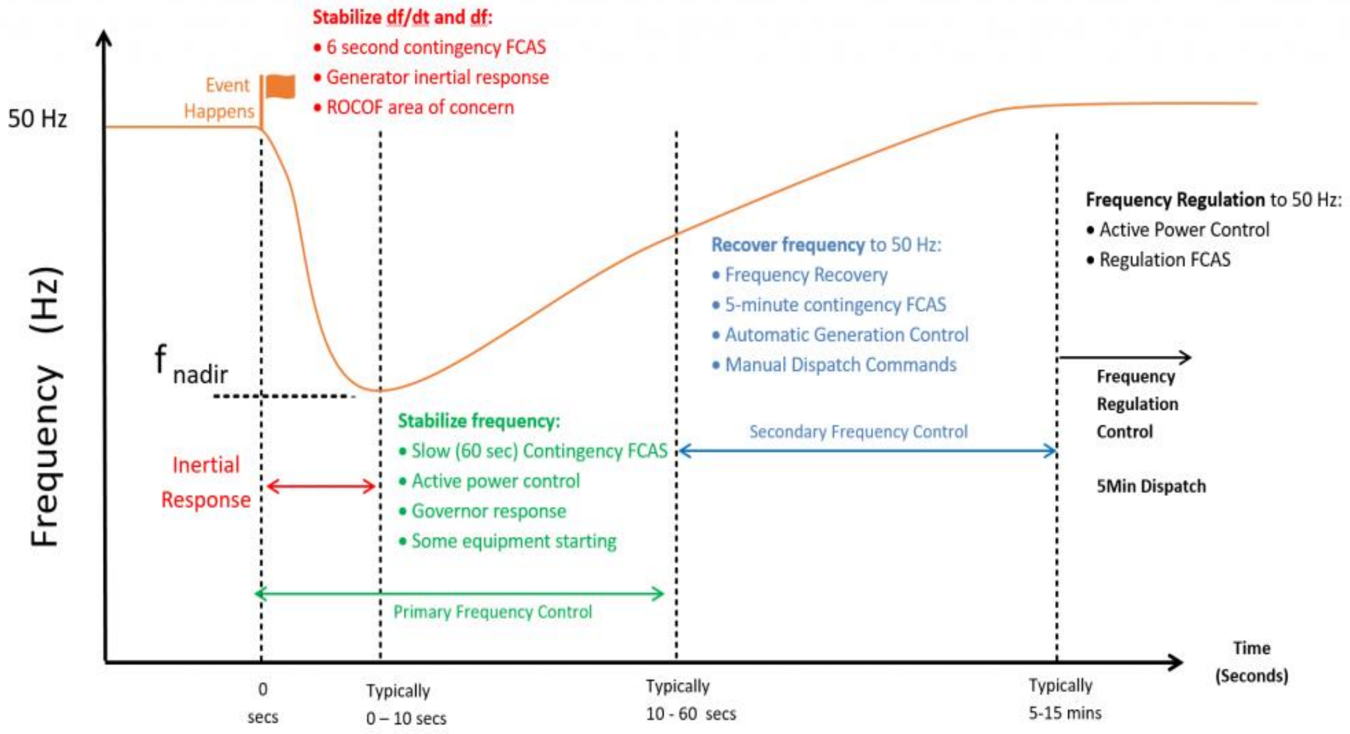
Spot market participation

- Already participate in retailer DR program with gensets
- Opportunity arose to use Gatton BESS more reactively
- Revenue = 50% of spot price + $250/MWh capacity payment
- 19 discharge events in Q1 2017 = $14,800 net value to UQ
- Average value of $17 per minute, $1.85 per kWh (net)



FCAS market participation

FCAS = Frequency Control Ancillary Services



Source: Jonathon Dyson (WattClairty)

FCAS market participation

- Traditionally limited to large generators only, but recent rule changes have opened up market to demand side participants
- If grid frequency drops, need to be able to reduce demand or increase generation within 6 seconds to halt system fail
- Needs to last for 10 minutes, happens <10 times per annum
- The capacity to achieve this is bid into a spot market every half hour of every day – get paid whether needed or not
- Small player like UQ requires the assistance of an aggregator like Enernoc who bids capacity portfolio & shares revenue
- Normally look at ways to hard load shed via circuit breakers (eg. cold room compressors), but <1 second response time of battery means it can be used in same way
- Indicative revenue = $40,000 per MW per annum

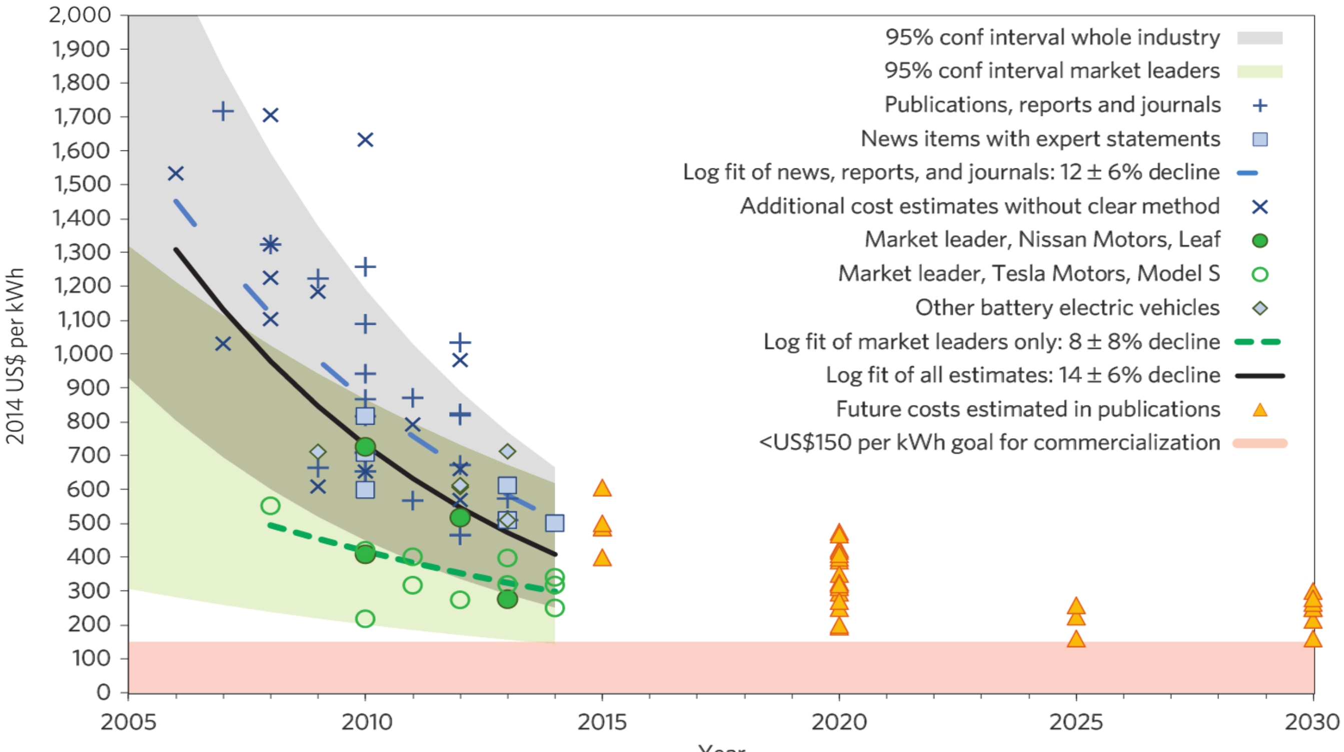
The theoretical business case

UQ didn’t have to pay for the Gatton BESS, but let’s pretend...

- Capex:
  - BESS size = 760 kWh / 600 kW
  - ~$700/kWh (supplied & installed)*
  - Total = ~$540,000
- Revenue (per annum):
  - Load shifting = ~$23,500 (150 kVA per month x $13/kVA)
  - Spot market = ~$15,000* p.a.
  - FCAS market = ~$24,000 (.6 MW @ $40,000/MW p.a.)
  - Total = ~$62,500 per annum
- Payback = ~8.5 years
  - Excludes Opex – relatively unknown

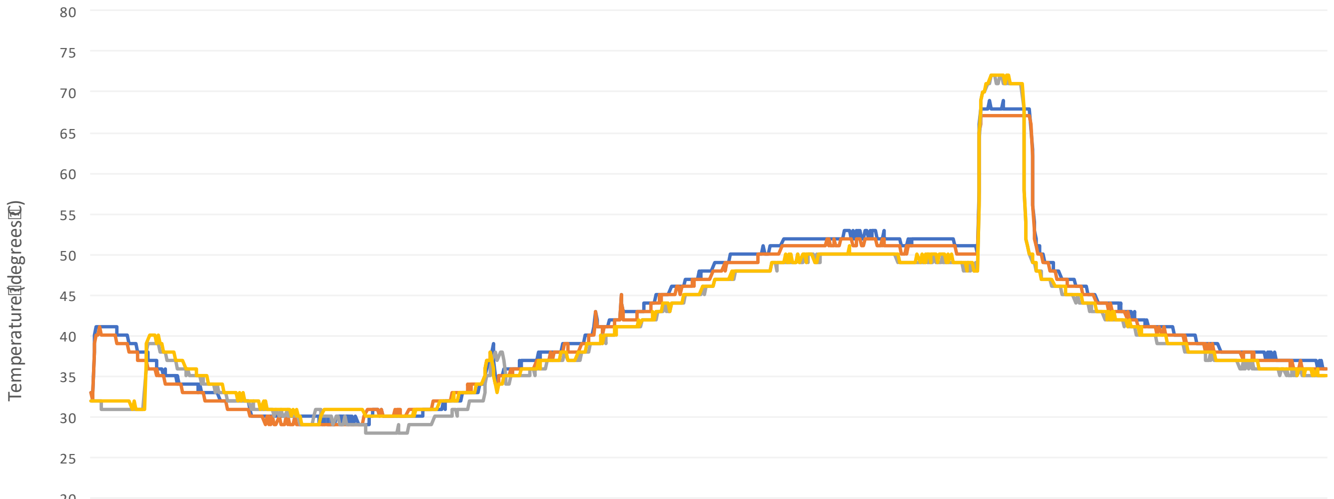
The theoretical business case

- If costs drop to $500/kWh, payback = ~6 years
- If costs drop to $250/kWh, payback = ~3 years



Learnings

- Software and hardware should be integrated from the factory
- The BESS will continue to operate in high temps, but output will be down-rated and ancillary energy usage higher
- Round trip efficiency is around 85%, and slowly degrading
- Clever modes of discharge such as spot market participation require clever modes of controlling recharge as well...



The future - Heron Island

- Research station in the Great Barrier Reef, off Gladstone coast
- Co-located with privately run resort – they provide power, sewage, water treatment etc.
- Some reliability issues with resort power in the past
- Power is provided by diesel generators = cost of $0.65+ per kWh which means solar + BESS is economical today
- Energy usage of ~485,000 kWh per annum, peak load of 110 kW

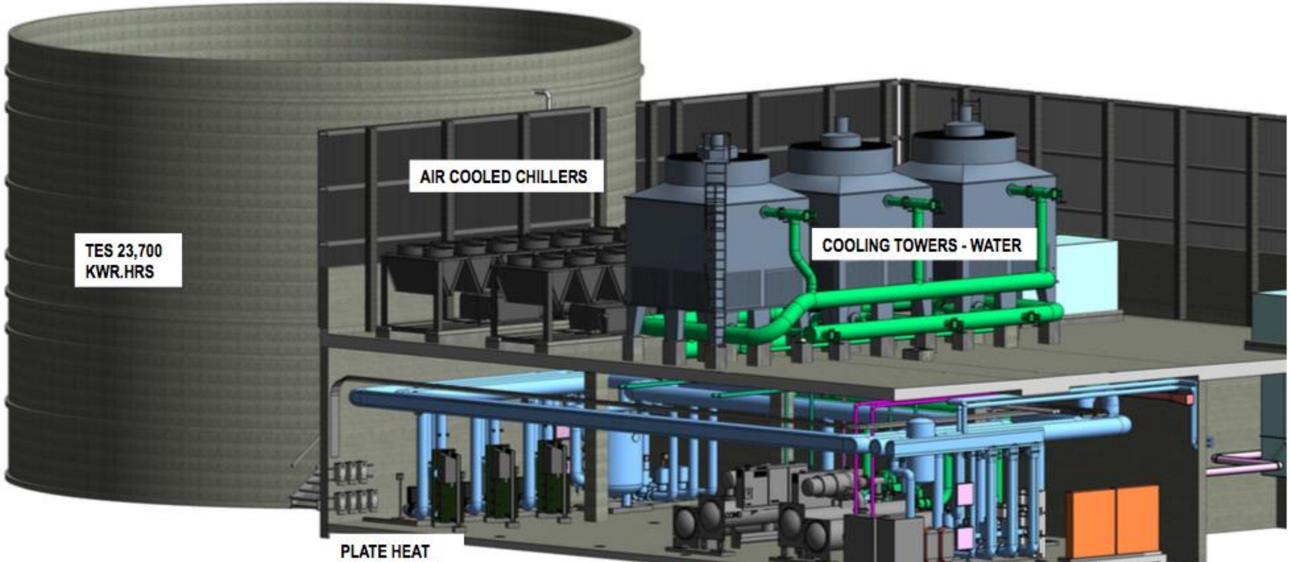
The future - Heron Island

- Solution involves 344 kW_{dc} of high-efficiency (SunPower) solar modules to maximize generation from roof space
- Coupled with 500 kWh containerized Vanadium-Flow battery
- A number of technologies carefully considered – space issues with lead acid, climate (temp, humidity, salt) issues with Lithium
- System will allow for ~85% energy self-sufficiency – returns diminish quickly when trying to achieve a higher %
- Capital cost of ~$2 million, with Year 1 net saving (after O&M) of ~$230,000
- NPV of ~+$930,000 (assuming 6% discount rate), IRR of 12%
- Funding just approved – construction to start early 2018
- May couple with own (small) diesel genset in future to enable complete energy independence

The future - Heron Island

Rethinking what a ‘battery’ can be

- Gatton Central Energy Plant due for completion start 2019
- ~25 million litres = 23,700 kWh_r = 4,700 kWh_e @ COP of 5
- Will be able to supply summer campus load for 24+ hours without running chillers or cooling towers (pumps still needed)
- Most cost effective form of energy storage, but size issues



Thank you

Questions?

Andrew Wilson

Manager – Energy & Sustainability

University of Queensland

a.wilson@pf.uq.edu.au