Energy Storage: Disruption - Development - Deployment

presentation to
Australian Institute of Energy
Sydney Branch

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Is this the future?

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PV uptake

"It cannot be said that a non-incentivized PV revolution is underway in a manner that policy makers can no longer control".

"However, the fundamental conditions for such a revolution are moving into place in different countries at an accelerated pace and policy makers have an opportunity to anticipate and react to the potential for large-scale PV uptake in the near term"

Source:IEA-RETD Residential Prosumers - Drivers And Policy Options (June 2014)

Storage - the "Holy Grail"?

As the Electric Power Research Institute (EPRI) in the United States pointed out in 2003 - *"In the broadest sense, storage devices may be the most important element of the power systems of the future".*

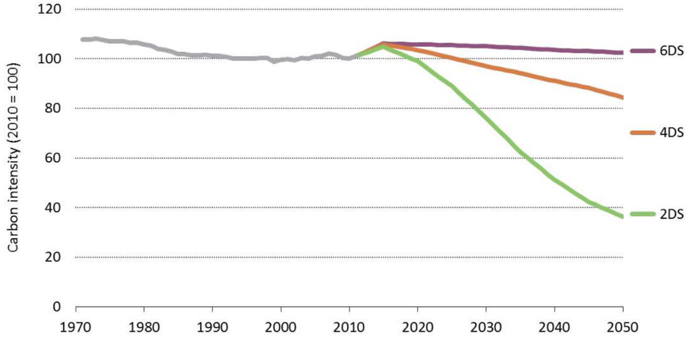
- Why the recent rapid growth in storage interest?
- The prospect of PV+storage at household level

Source: EPRI-DOE Handbook of Energy Storage for Transmission and Distribution Applications, 2004

IEA - carbon intensity must drop for <2 °C

Carbon Intensity of supply is stuck

ETP 2014



The political will to make meaningful progress at a global scale has yet to be demonstrated

International Energy Agency

Source:IEA - ETP2014

IEA - renewables must increase from 20 to 65%

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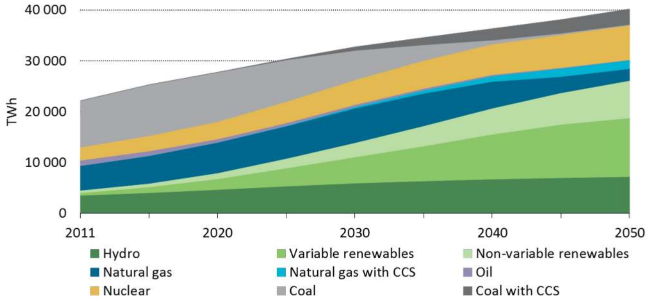
Electricity Generation: a share reversal

ETP 2014



- Generation today:
  - Fossil fuels: 68%
  - Renewables: 20%
- Generation 2DS 2050:
  - Renewables: 65%
  - Fossil fuels: 20%

International Energy Agency

Source:IEA - ETP2014

Hawaii - 2014

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Hawaiian Electric

O‘ahu Energy Storage System
EPC Request for Proposal

REQUEST FOR PROPOSALS

Hawaiian Electric Company, Inc. (“Hawaiian Electric”) hereby requests a proposal for a firm lump- sum price proposal to Engineer, Procure, and Construct (“EPC”) energy storage systems (“ESS”) from 60 megawatts (MW) up to 200 MW for 30 minutes to grid, to be installed on the island of O‘ahu in the state of Hawai‘i. This Request for Proposals (“RFP”) is being sent to you and others as potential contractors. Hawaiian Electric requires that responsive proposals be submitted consistent with the requirements set forth herein.

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Source: www.hawaiianelectric.com

Some recent observations & analyses

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WORLD ECONOMIC FORUM

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Global Agenda

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Grid-scale Electricity Storage

Electricity cannot be directly stored, so electrical grid managers must constantly ensure that overall demand from consumers is exactly matched by an equal amount of power fed into the grid by generating stations. Because the chemical energy in coal and gas can be stored in relatively large quantities, conventional fossil-fuelled power stations offer dispatchable energy available on demand, making grid management a relatively simple task. However, fossil fuels also release greenhouse gases, causing climate change – and many countries now aim to replace carbon-based generators with a clean energy mix of renewable, nuclear or other non-fossil sources.

Clean energy sources, in particular wind and solar, can be highly intermittent; instead of producing electricity when consumers and grid managers want it, they generate uncontrollable quantities only when favourable weather conditions allow. A scaled-up nuclear sector might also present challenges due to its preferred operation as always-on baseload. Hence, the development of grid-scale electricity storage options has long been a "holy grail" for clean energy systems. To date, only pumped storage hydropower can claim a significant role, but it is expensive, environmentally

Nanowire Lithium-ion Batteries

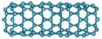
As stores of electrical charge, batteries are critically important in many aspects of modern life. Lithium-ion batteries, which offer good energy density (energy per weight or volume) are routinely packed into mobile phones, laptops and electric cars, to name just a few common uses. However, to increase the range of electric cars to match that of petrol-powered competitors – not to mention the battery lifetime between charges of mobile phones and laptops – battery energy density needs to be improved dramatically.

Batteries are typically composed of two electrodes, a positive terminal known as a cathode, and a negative terminal known as an anode, with an electrolyte in between. This electrolyte allows ions to move between the electrodes to produce current. In lithium-ion batteries, the anode is composed of graphite, which is relatively cheap and durable. However, researchers have begun to experiment with silicon anodes, which would offer much greater power capacity.

One engineering challenge is that silicon anodes tend to suffer structural failure from swelling and shrinking during charge-discharge cycle. Over the last year, researchers have developed

Low cost batteries - a "disruptive" technology?

McKinsey - Disruptive technologies: Advances that will transform life, business, and the global economy

	**Energy storage**	Devices or systems that store energy for later use, including batteries
	**3D printing**	Additive manufacturing techniques to create objects by printing layers of material based on digital models
	**Advanced materials**	Materials designed to have superior characteristics (e.g., strength, weight, conductivity) or functionality
	**Advanced oil and gas exploration and recovery**	Exploration and recovery techniques that make extraction of unconventional oil and gas economical
	**Renewable energy**	Generation of electricity from renewable sources with reduced harmful climate impact

SOURCE: McKinsey Global Institute analysis

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Citi Research

Equities

30 April 2013 | 27 pages

Solar Power (Citi)
Global

Battery storage – the next solar boom?

Germany leads the way with storage subsidies

- **Solar is a parasitic technology** — Solar is already cost competitive at a residential level in many countries, and its dramatic learning rates mean that it will become so in more very quickly. Not only does it take share of new electricity demand, it parasitically steals demand from previously installed generation, and does so at the most valuable peak part of the day.
- **Conventional generation becomes uneconomic** — Having already 'stolen' German summer peak electricity demand in its entirety from gas, as it expands further solar will eat into baseload, plant whose economics dictate that it must run all the time. However,

- Industry Overview

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Australia - Why store electricity in the grid?

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].

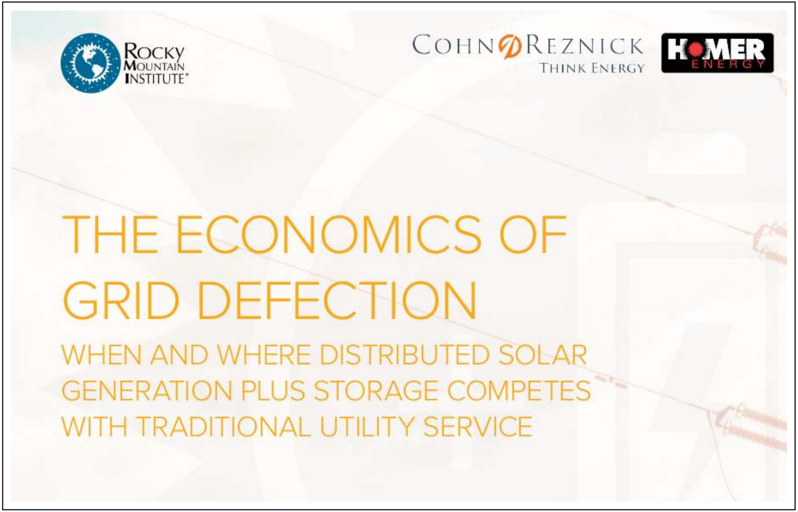
- Electricity is the only major commodity that cannot easily be stored in large quantities
- Lack of storage drives wholesale electricity price volatility from -$100 to $12,500 /MWh
- Electricity supply system must be sized to cope with maximum demand, which may only represent a few hours/year
- Load shifting and peak shaving using storage can increase utilisation of existing assets

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

Why store electricity in the grid?

- Increasing penetration of variable renewables
  - Storage allows better matching of generation and demand
- Storage can provide multiple customer and network benefits
  - Customer can tailor generation/consumption to lowest cost tariffs
  - Storage can provide some/complete autonomy, UPS etc
  - Utility can utilise customer-owned storage for network services if/when required (e.g. Vector in NZ)

Can storage become a “threat”?



Source: RMI 2014 “The Economics Of Grid Defection - When And Where Distributed Solar Generation Plus Storage Competes With Traditional Utility Service”

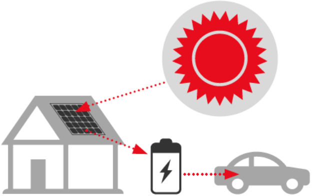
Can storage accelerate "Change and choice"?

Scenario 3: 'Leaving the grid'

The continued dominance of volume-based pricing among residential and small commercial consumers encourages energy efficiency without accompanying reductions in peak demand growth. The subsequent declining network utilisation feeds increases in retail prices.

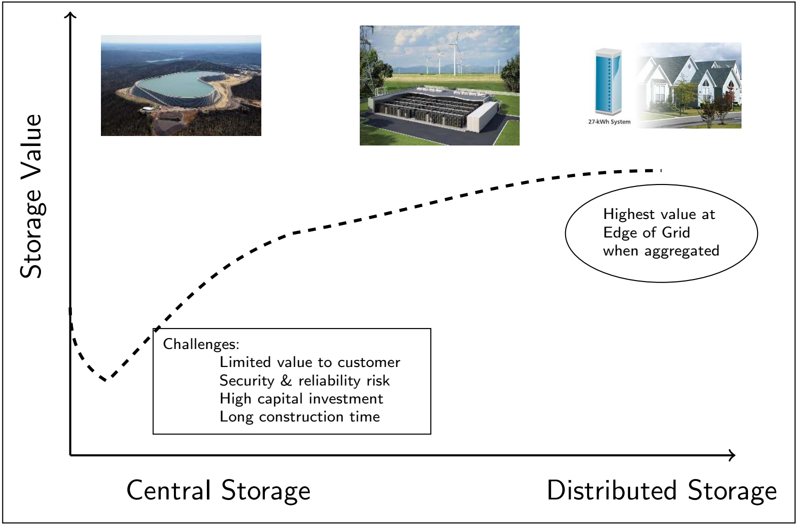
New energy service companies sensing a market opportunity invite consumers to leave the grid, offering an initially higher-cost solution but one that appeals to a sense of independence from the grid. Consumers have already become comfortable using small amounts of storage on-site and in their vehicles and a trickle of consumers takes up the offer.

By the late 2030s, with reduced storage costs, disconnection becomes a mainstream option and the rate of disconnection accelerates. Customers remaining on the system are those with poor access to capital and industrial customers whose loads can't be easily accommodated by on-site generation.



Source: CSIRO Future Grid Forum: Change and choice - The Future Grid Forums analysis of Australias potential electricity pathways to 2050

Why residential storage?



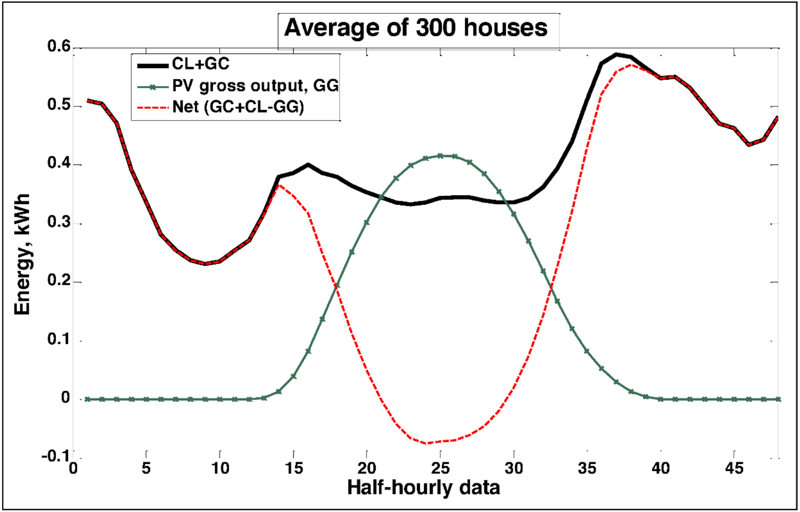
Adapted from Nourai, DNV-GL blog: Where is the energy storage market heading and where is the disruptive change? (Part 1)

Why residential storage?

- Cost of electricity at the home is highest in the network
- Load profiles with peaks
  - peak shifting has value to both consumer and network operator
- On site PV is popular but output not in phase with demand
  - Storage can triple/quadruple the value of PV to the home owner in some instances

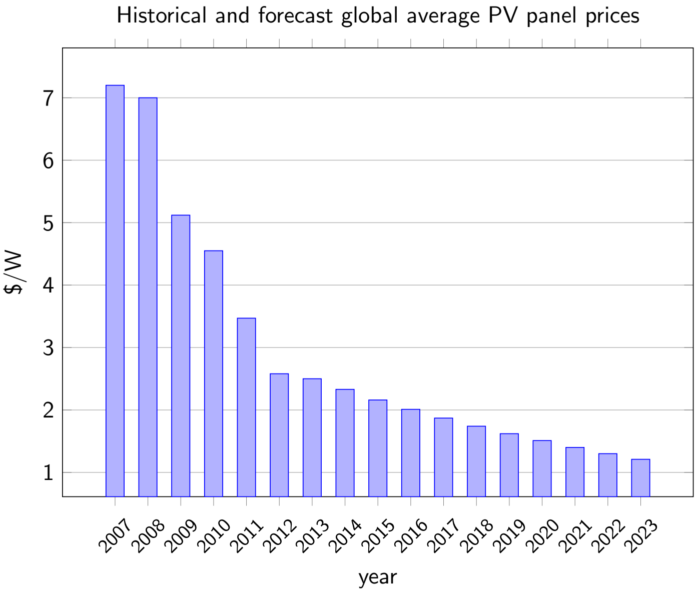
Why residential storage?

Average Ausgrid data for some Sydney homes - daily average



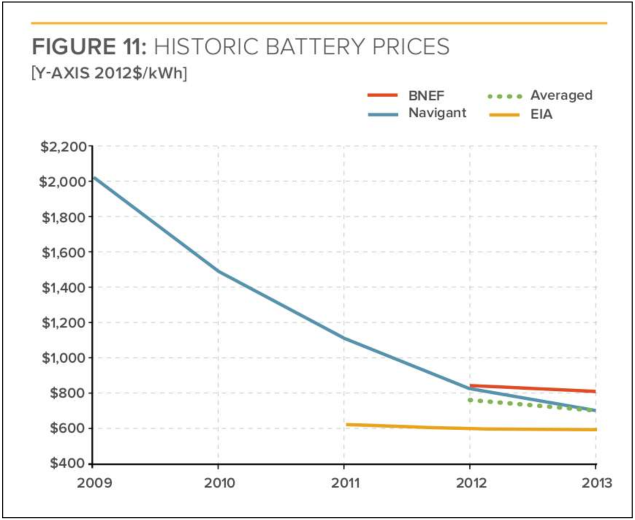
GC = General Consumption (primary tariff, either inclining block or time of use rates)
CL = Controlled Load Consumption (off peak 1 or 2 hot water)
GG = Gross Generation
Source: www.ausgrid.com.au - Solar home electricity data - 1 July 2010 to 30 June 2011

What price trajectory for storage - same as PV?



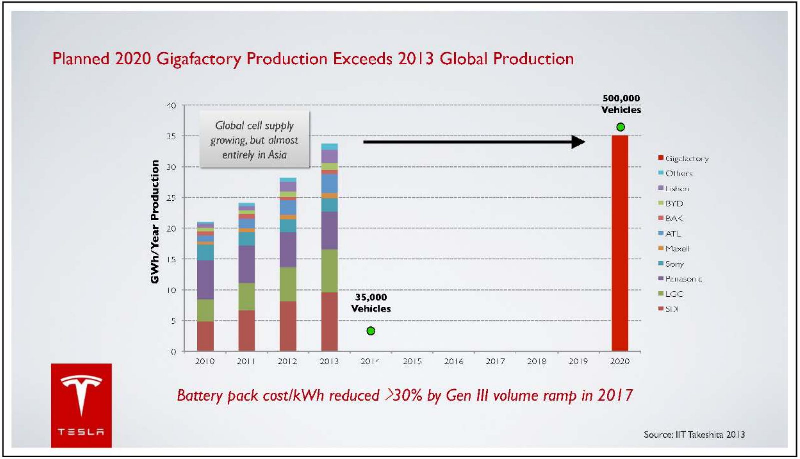
Source: Clean Energy Trends 2014, Clean Edge

The prospect of affordable batteries...



Source: RMI - The Economics Of Grid Defection - When And Where Distributed Solar Generation Plus Storage Competes With Traditional Utility Service

Tesla Gigafactory for battery maufacture



Source: Tesla corporation

Our work on storage at USyd

Improved materials for zinc-bromine flow batteries

- ARC Linkage project with Redflow Ltd
- Low cost, long life plastic electrodes
- High efficiency, low cost sequestering agents

Role of energy storage in future grids

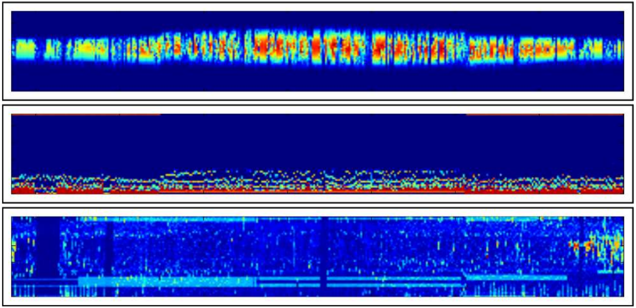
- CSIRO Future Grid Research Cluster (futuregrid.org.au)
- What "systems" will households (and some commercial, light industrial) find financially feasible/attractive?
- What combination of cost/size/performance will emerge?
- Where, when and how will it be deployed?
- *How will extensive deployment affect grid operation and planning*

What are break-even PV+battery costs?

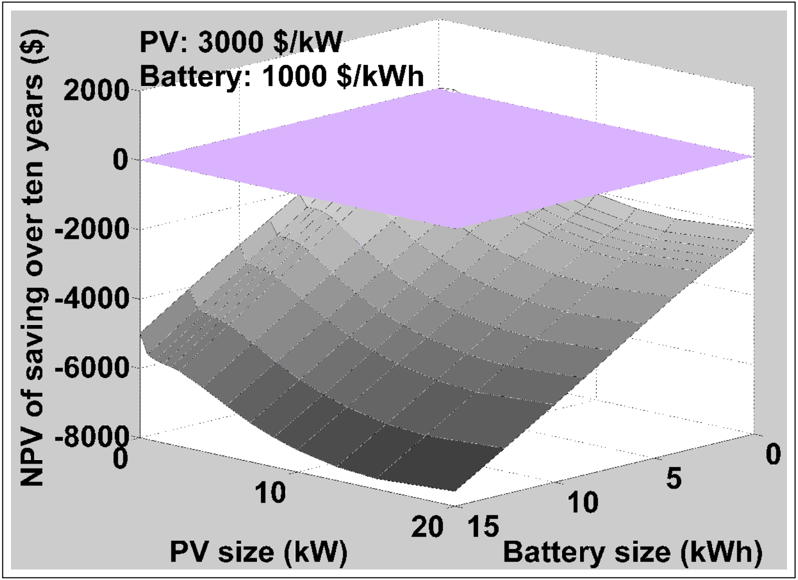
Example - Sydney home "1" (3.8 kW PV 8544 kWh):

Four scenarios:

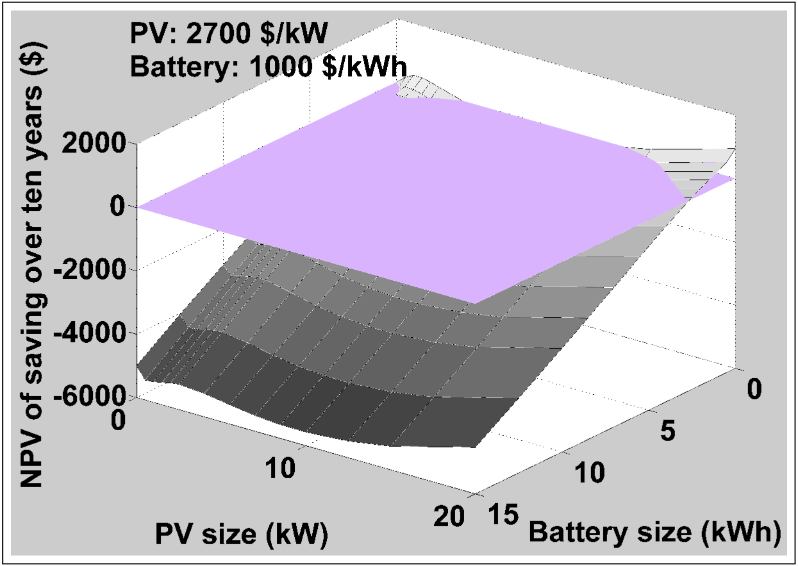
1. PV: $3000/kW, B: $1000/kWh
2. PV: $2700/kW, B: $1000/kWh
3. PV: $2300/kW, B: $700/kWh
4. PV: $1600/kW, B: $400/kWh



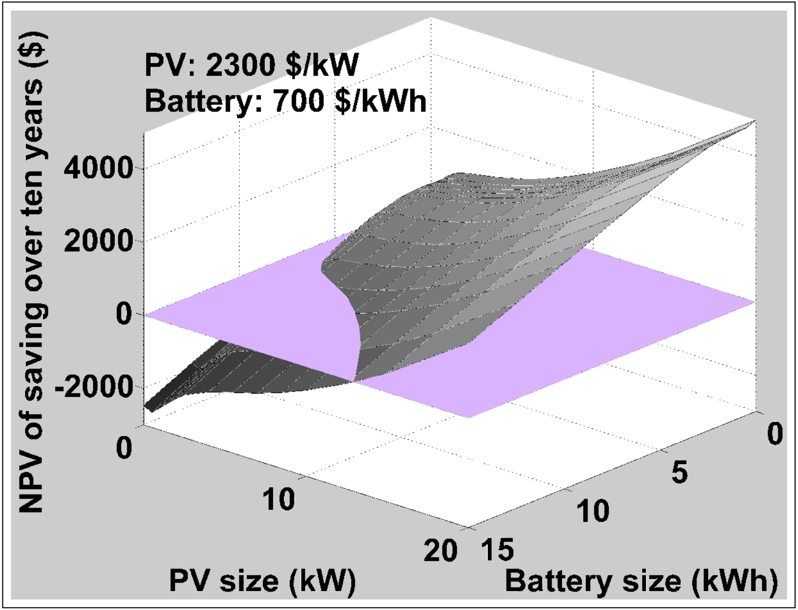
Scenario 1


PV: 3000 $/kW
Battery: 1000 $/kWh
NPV of saving over ten years ($)
2000
0
-2000
-4000
-6000
-8000
0
10
20
15
10
5
0
PV size (kW)
Battery size (kWh)

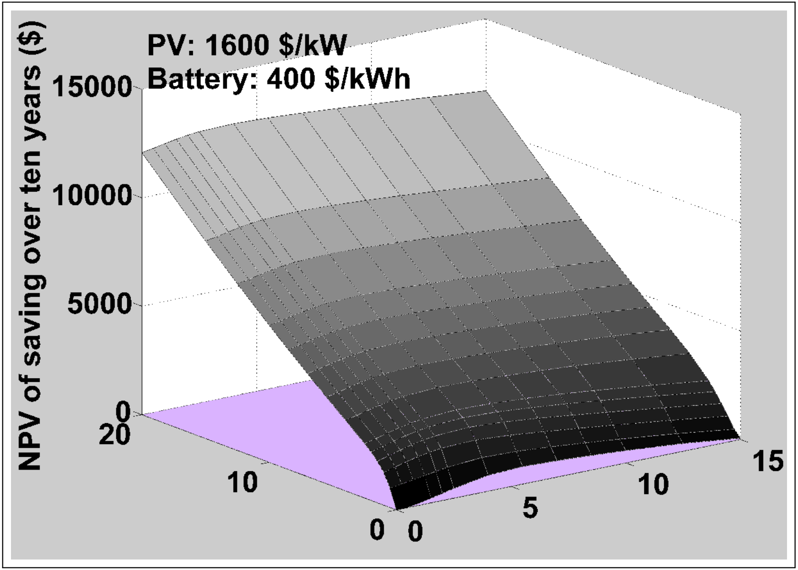
Scenario 2


PV: 2700 $/kW
Battery: 1000 $/kWh
NPV of saving over ten years ($)
2000
0
-2000
-4000
-6000
0
10
20
PV size (kW)
15
10
5
0
Battery size (kWh)

Scenario 3


PV: 2300 $/kW
Battery: 700 $/kWh
NPV of saving over ten years ($)
4000
2000
0
-2000
0
10
20
PV size (kW)
15
10
5
0
Battery size (kWh)

Scenario 4



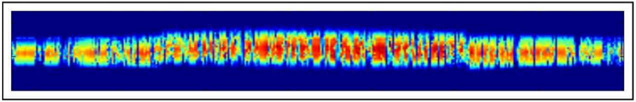
PV: 1600 $/kW
Battery: 400 $/kWh
NPV of saving over ten years ($)
15000
10000
5000
0
20
10
0
0
5
10
15

What are break-even PV+battery costs?

Example - Sydney home "189" (2.0 kW PV 7004 kWh):

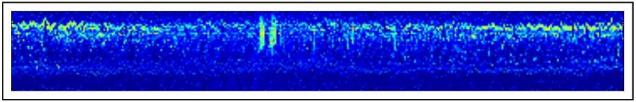
Four scenarios:

1. PV: \$3000/kW, B: \$1000/kWh
2. PV: \$2700/kW, B: \$1000/kWh
3. PV: \$2300/kW, B: \$700/kWh
4. PV: \$1600/kW, B: \$400/kWh



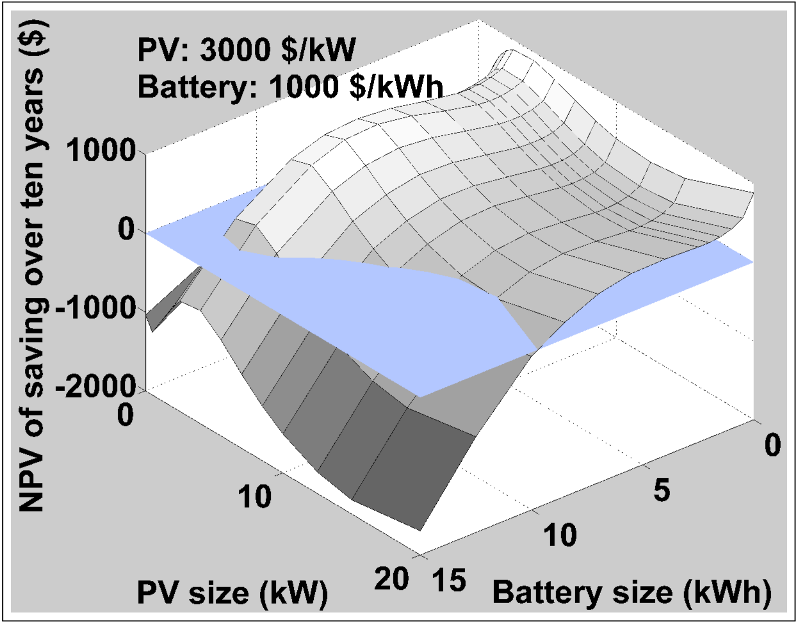
PV

Controlled Load



Gross Load

Scenario 1



PV: 3000 $/kW
Battery: 1000 $/kWh
NPV of saving over ten years ($)
1000
0
-1000
-2000
0
10
20
PV size (kW)
15
10
5
0
Battery size (kWh)

The grid-connected storage "opportunity"

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If residential storage works for consumers:

- Utilities can rent storage capacity when required
- Infrastructure upgrades could be delayed
- Intermittent renewables can be managed
- Improved utilisation of existing poles & wires
- Possibly lower line losses
- Less GHG if done properly

But without some planning and policy thought:

- Customer may become "competitor" of utility
- New business models using storage are emerging - all put pressure on existing utilities - the "death spiral"?
- "Grid connection to grid defection"!

Other thoughts...

- Possible future deployment of DC appliances (LEDs, Laptops, TVs, appliances) will make DC battery systems more attractive
- Decline in standards (in line with other community services - health, roads, education...) necessitating choice (i.e. expenditure) of quality standard
- Do we really need 99.985% reliability and 50 ± 0.15Hz for 99% of the time, for toaster, hot water, stove etc?
- What about low-cost, low-reliability, grid connection with in home/premises storage+power conditioning...
- New business models that will provide power services in very different ways

Final thought. . .

"Often, the most striking and innovative solutions come from realizing that your concept of the problem was wrong"

Eric S. Raymond, in The Cathedral and the Bazaar.

Acknowledgments

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- CSIRO FutureGrid Research Cluster
- AusGrid data