

Integration Challenges in Australia

Daniel Rowe | Project Leader

Workshop on Renewables and Energy Systems Integration, Denver

September 2014

ENERGY FLAGSHIP

www.csiro.au





Boulder

- Population: 5,359¹
- Kalgoorlie Airport elevation 365m (1197ft)²
- 595 km (370mi) from Perth
- Gold Mine Super Pit
- Largest Open Pit in Australia
(3.6km x 1.6km x 0.6km)
(2.2mi x 1mi x 0.4 mi)³
- Produces up to 850,000 ounces of gold every year³
- On-grid: connected to main grid via 665km (413mi) feeder^{4,5}

Sources: ¹http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/SSC50079

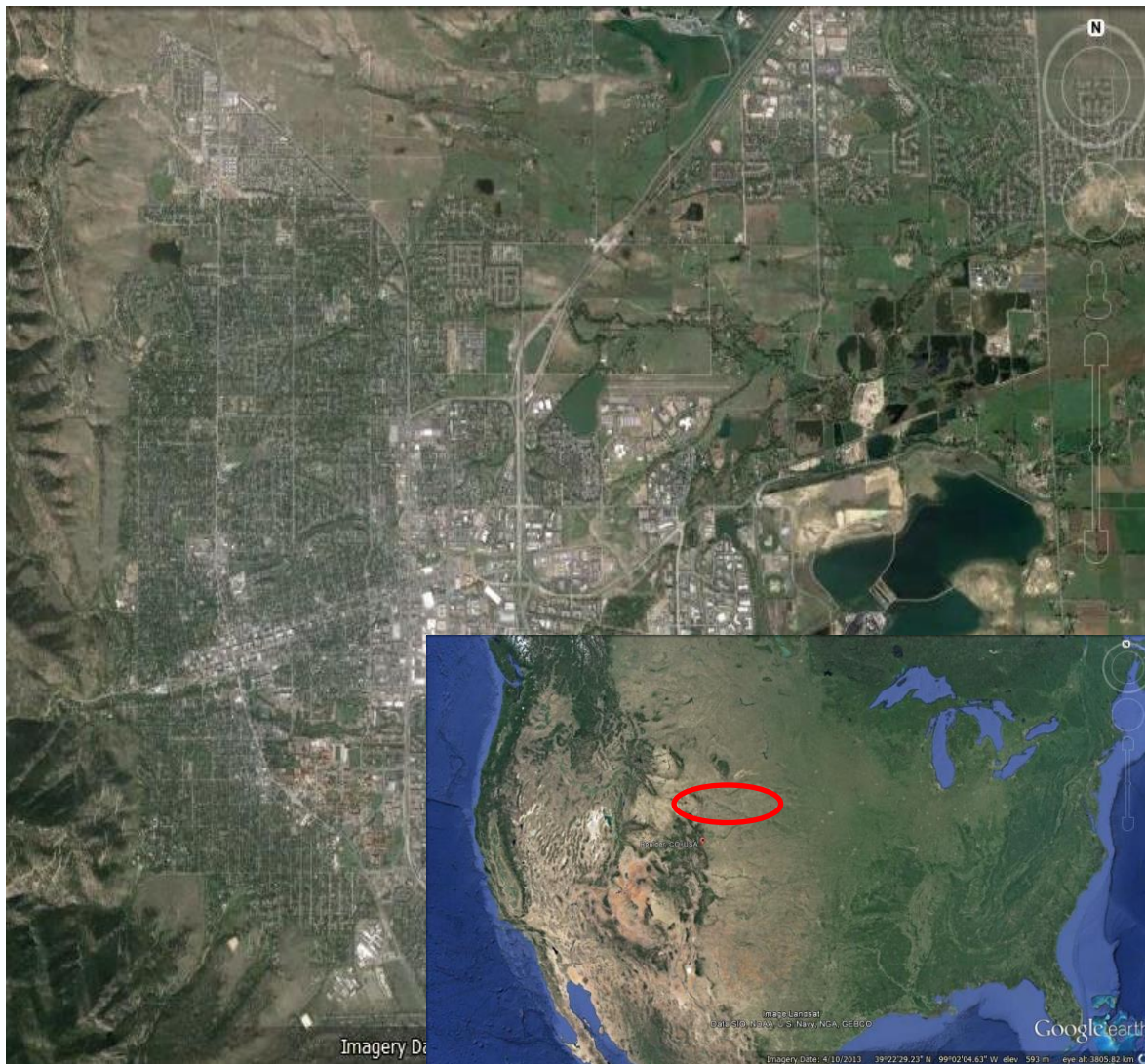
²http://www.bom.gov.au/climate/averages/tables/cw_012038.shtml

³<http://www.superpit.com.au/AboutKCGM/Overview/tabid/88/Default.aspx>

⁴<http://services.westernpower.com.au/documents/reportspublications/2011apr/history.pdf>

⁵<https://www.aer.gov.au/sites/default/files/Chapter%207%20Beyond%20the%20national%20electricity%20market%202007.pdf>

Images adapted from: Google Earth – Image CNES/Astrium, 2014 Digital Globe, Landsat Data SIO, NOAA, US Navy, NGA, GEBCO, US Dept of State Geographer



Boulder

- Population: 103,166¹
- Elevation 1655m (5430ft)²
- 45 km (27.8mi) from Denver³
- Gold Hill gold production
- On-grid: connected to main grid

Source: ¹<http://quickfacts.census.gov/qfd/states/08/0807850.html>

²<http://www.bouldercoloradousa.com/>

Images adapted from: Google Earth Image Landsat Data SIO, NOAA US Navy, NGA, GEBCO

Introduction - CSIRO

- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Established in 1926
- Australia's national science body
- 6000+ employees
- Federal Government agency



Flagships

- National Facilities & Collections
- Agriculture, Food & Health
- Energy & Resources
- Environment
- Manufacturing, Productivity & Services

Introduction – CSIRO

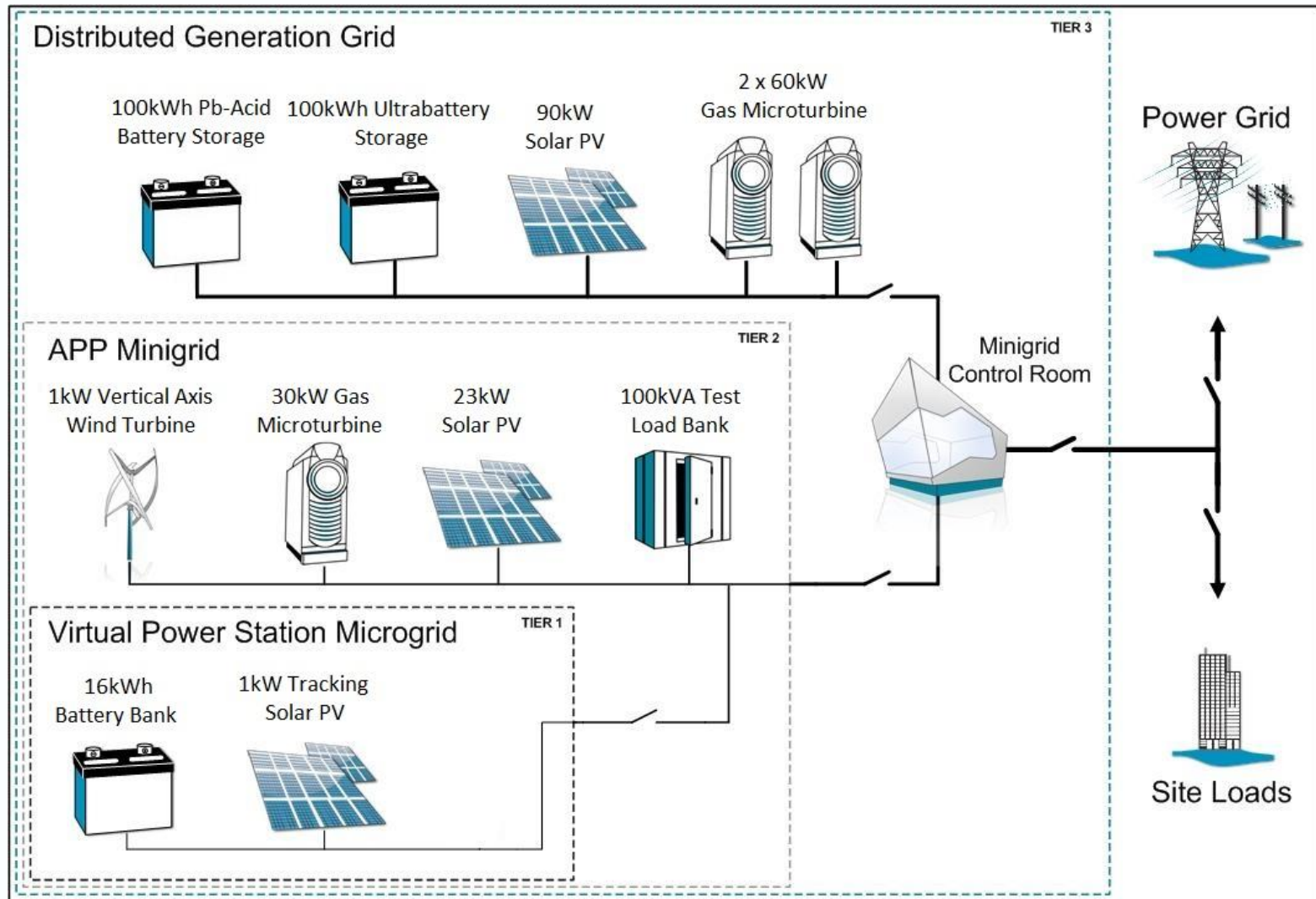
- CSIRO holds over 3,900 granted or pending patents, including:
 - Extended wear contact lenses
 - Polymer banknotes
 - World's first anti-influenza drug
 - 802.11 Wireless LAN protocol
- Produce around 4000 scientific publications per year
- Total revenue '12-13 of AU\$1.2billion
 - Federal Government funding of \$733.8million
 - External revenue of \$512.2million (incl. \$37.5million from IP revenue)



CSIRO Renewable Integration Laboratory



CSIRO Renewable Integration Laboratory







An Interesting Time

- Cost of generation ↓
- Energy consumption ↓
- Electricity bills ↑
- Peak load ↓
- Network variability ↑
- Network build for peak demand (MW) ↑
- Network cost recovery on energy (MWh) ↓
- Remote community needs ↑
- Off-grid industry needs ↑
- Resilience to impact of natural phenomena ↑
- Management of power quality and quality of supply ↑
- Distributed generation ↑
- Energy efficiency drivers ↑
- Response to energy costs ↑

Energy is a huge political, social and economic issue

Australia

- World's largest island and sixth largest country by area¹
- 5% of the world's land area 7,692,024 km² (2,969,907mi²)¹
- Single country continent
- No electrical interconnection with neighbours
- Abundant Resources – Solar, Natural Gas, Minerals
- Petroleum importer



Relative size of Australia to the UK, Europe, USA and Japan¹

Source: <http://www.ga.gov.au/scientific-topics/geographic-information/dimensions/australias-size-compared>

Solar Irradiance

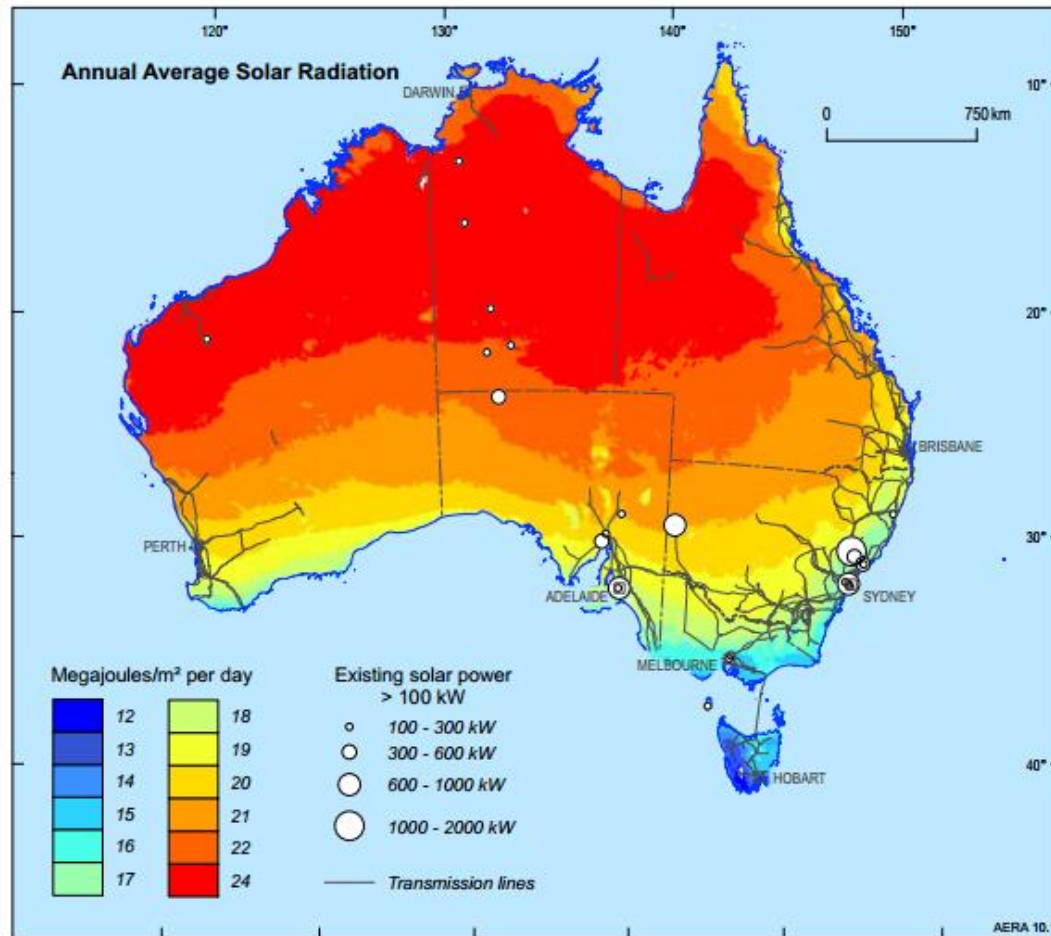


Figure 10.1 Annual average solar radiation (in MJ/m²) and currently installed solar power stations with a capacity of more than 10 kW

Source: Bureau of Meteorology 2009; Geoscience Australia

Source: AUSTRALIAN ENERGY RESOURCE ASSESSMENT <http://arena.gov.au/files/2013/08/Chapter-10-Solar-Energy.pdf>

Cost of Electricity

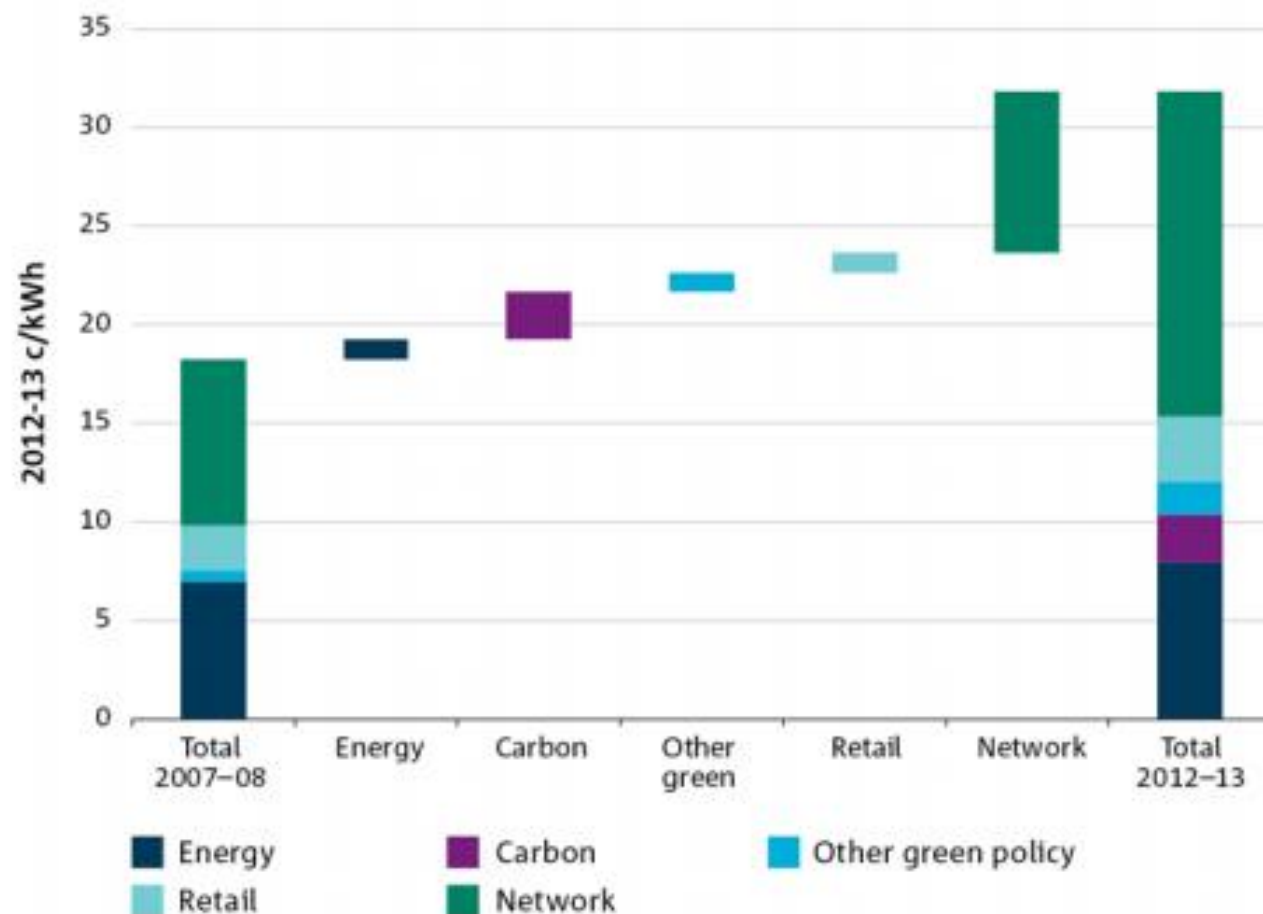


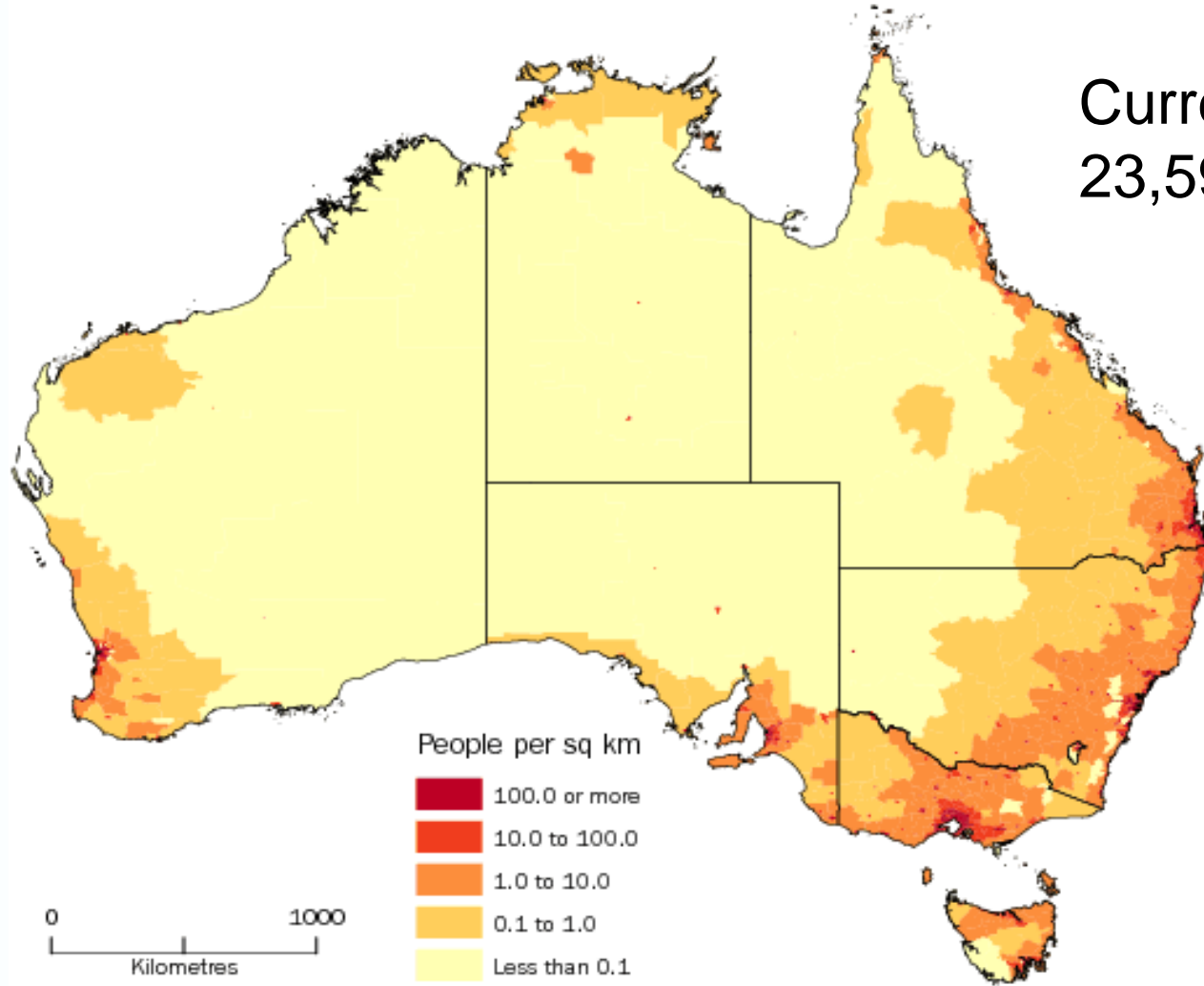
Figure 2: Changes in real regulated residential retail electricity price components (New South Wales, 2012-13 dollars)

Source: IPART (2013);
AEMC (2013a)

Source: <http://www.csiro.au/Organisation-Structure/Flagships/Energy-Flagship/Future-Grid-Forum-brochure.aspx>

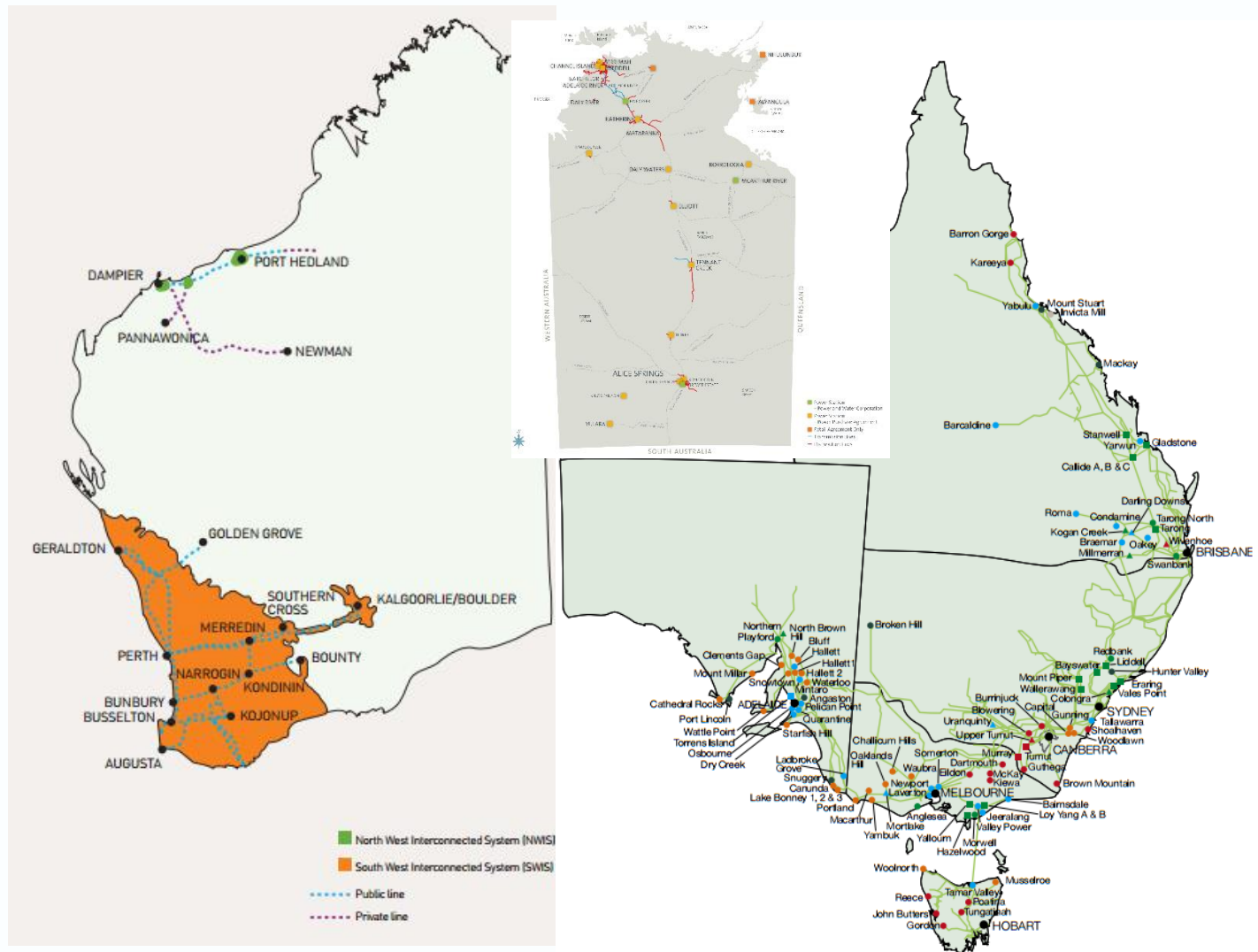
Population Density

Current Population:
23,590,297



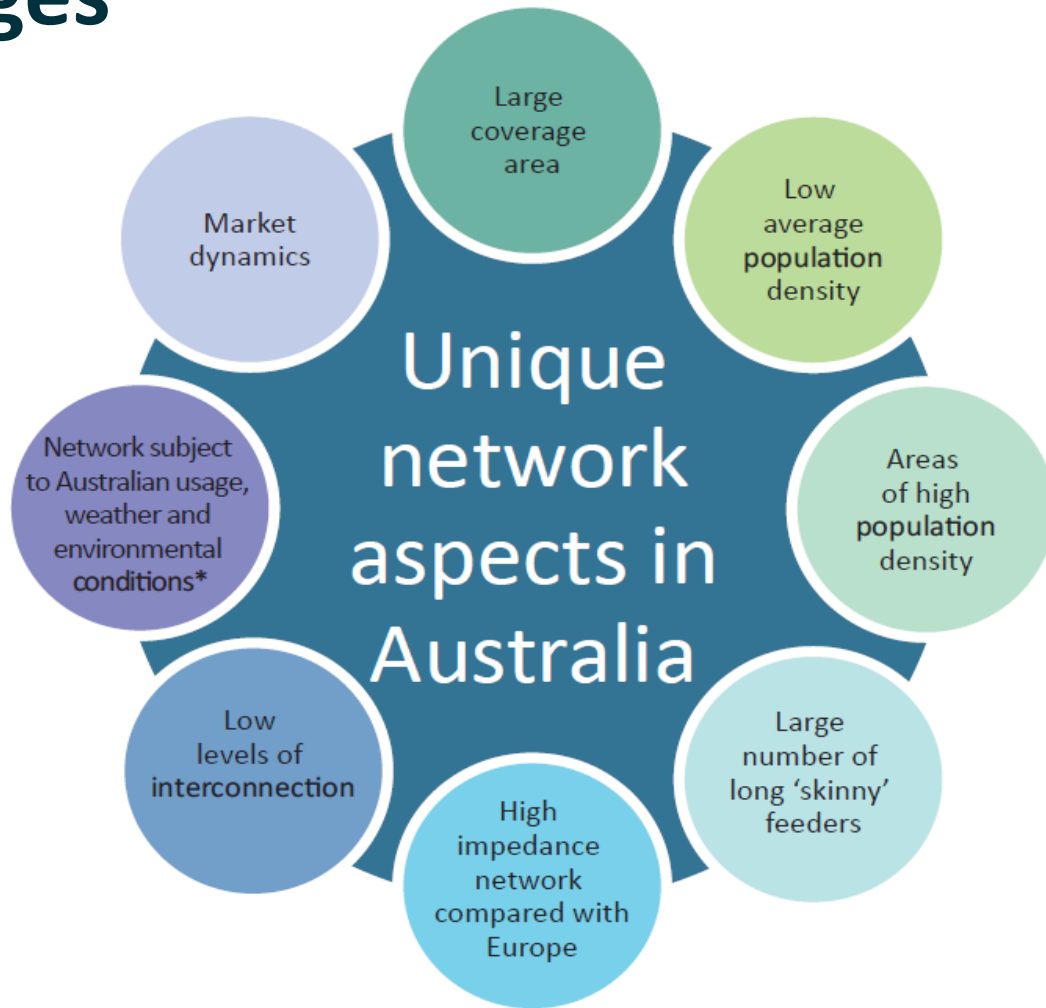
Source: <http://www.abs.gov.au/ausstats/abs@.nsf/Products/3218.0~2012-13~Main+Features~Main+Features>

Grids



Sources: <https://www.aer.gov.au/sites/default/files/Chapter%207%20Beyond%20the%20national%20electricity%20market%202007.pdf>
https://www.powerwater.com.au/community_and_education/student_resources/maps/electricity_map
<http://www.aer.gov.au/sites/default/files/Chapter%201%20-%20National%20electricity%20markets%20A4.pdf>

Challenges



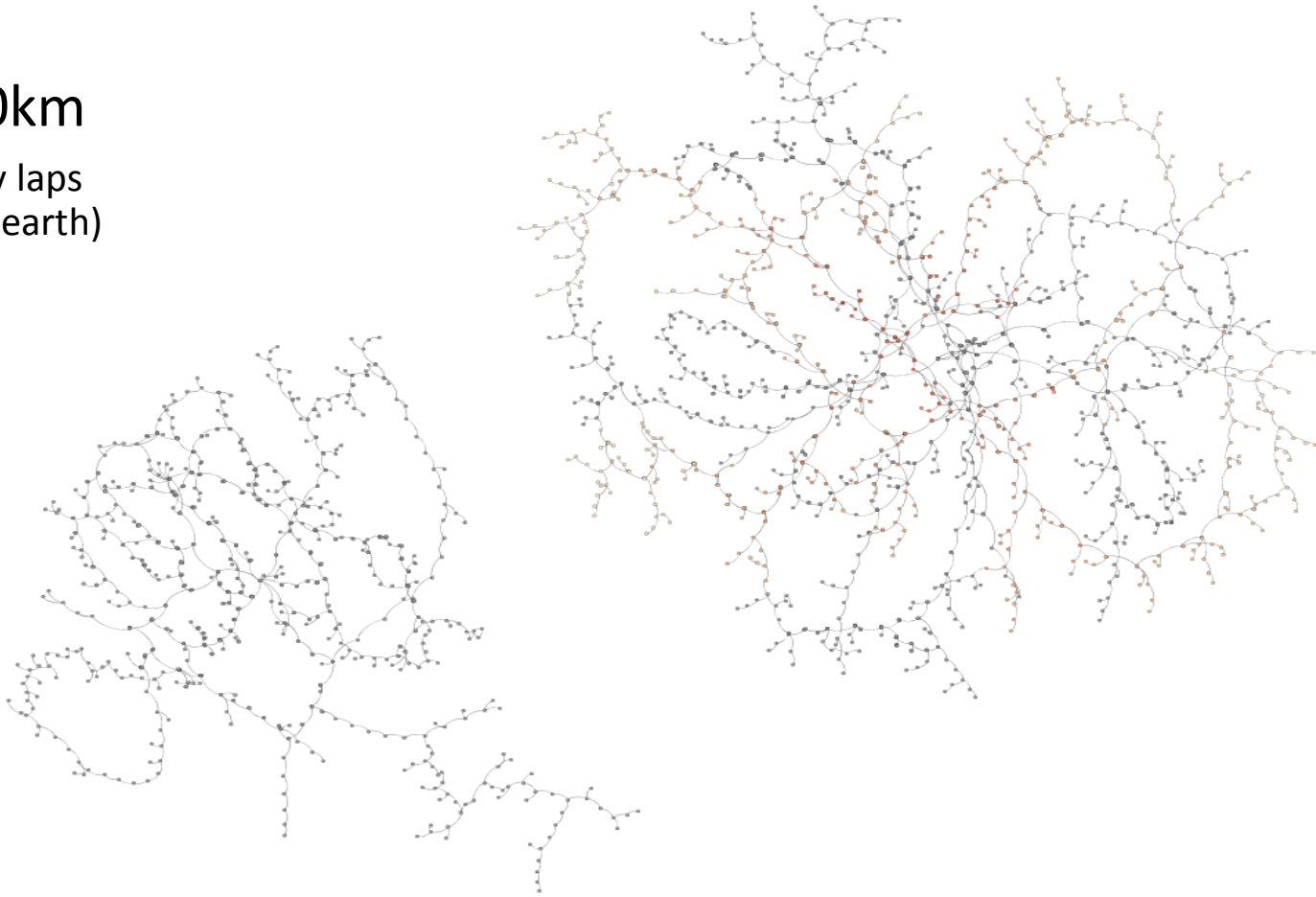
*Australian load profiles and environmental conditions such as fire and flood

Source: Solar intermittency: Australia's clean energy challenge <http://www.csiro.au/Organisation-Structure/Flagships/Energy-Flagship/Solar-Intermittency-Report.aspx>

Australia's Electricity Distribution Network

850,000km

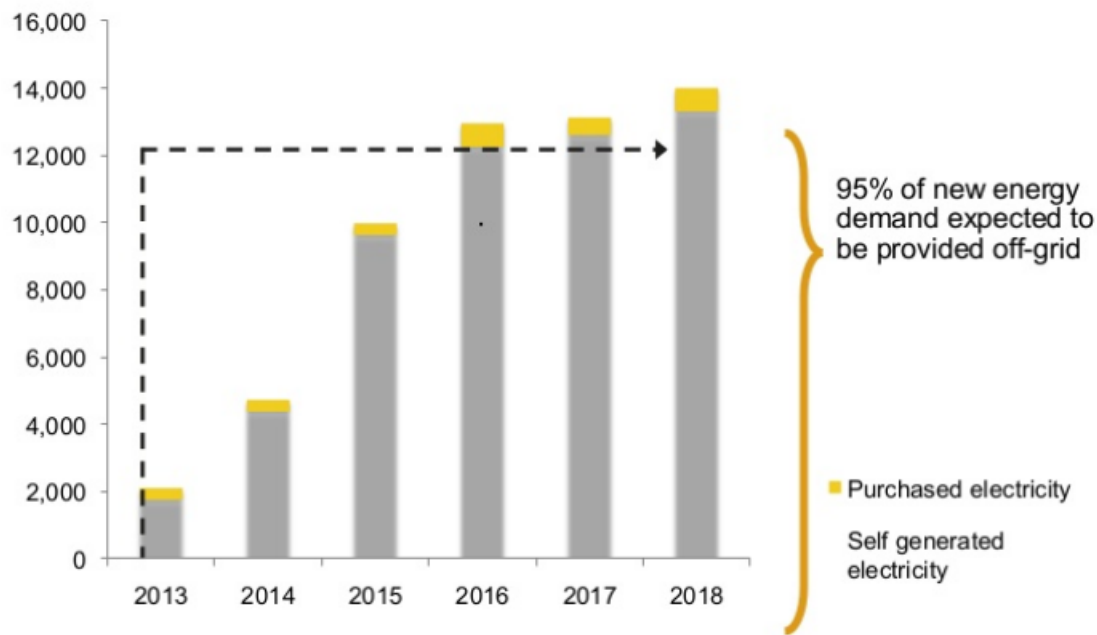
(about forty laps
around the earth)



Source: CSIRO Australian Feeder Taxonomy

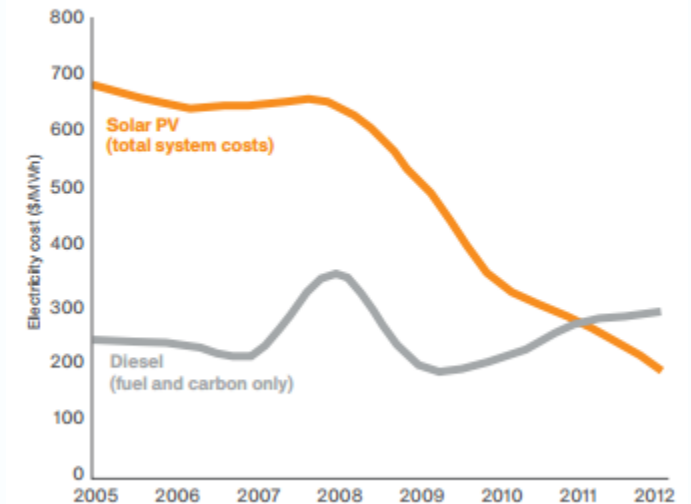
Off-Grid

- 2% of Australia's population live in remote regions yet they represent 6% of energy demand¹



Source: WA State Growth Outlook 2013, PwC 2012

Figure 5: Historical comparison of electricity generation cost from Solar PV and Diesel



Source: AECOM

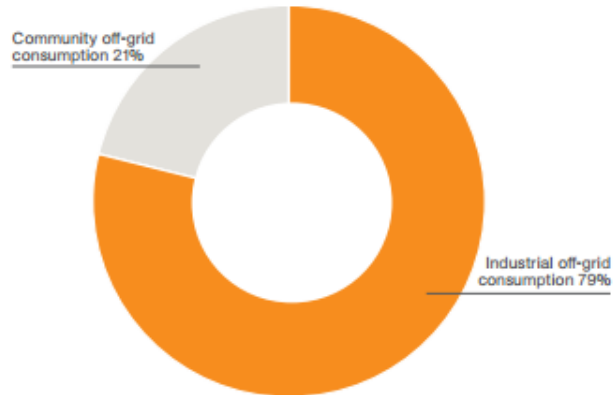
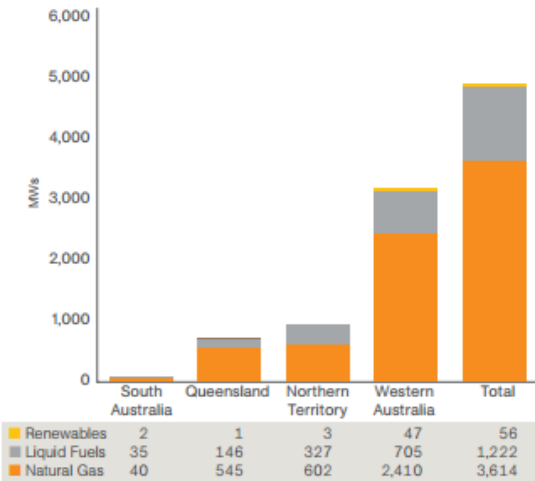
Source: ¹Australia means opportunities, Clean Energy Week 2013 Conference <http://www.cleanenergyweek.com.au/dam/cew/presentations/2013-presentations/day-2/off-grid/CRAIG-CHAMBERS-Market-Sector-Director-Power-Generation-AECOM-SANDRA-FOX-Senior-Manager-Investment-Operations-Australian-Trade-Commission/Craig-Chambers-Market-Sector-Director-Power-Generation-AECOM-Sandra-Fox-Senior-Manager-Investment-Operations-Australian-Trade-Commission.pdf>

²Increasing renewable energy off the grid presentation, Remote Area Power Supply Conference 2014, <http://www.slideshare.net/informaoz/ivor-frischknecht> (left image)

³<http://www.austrade.gov.au/ArticleDocuments/2786/Australian-Remote-Renewables-Opportunities-for-Investment.pdf.aspx> (right image)

Off-Grid Opportunity

Figure 4: Existing off-grid generation by fuel type



Source: AECOM and BREE

Remote Energy Subsidies



Community Service Obligation

>\$700m



Diesel Rebate Fuel Scheme

\$5bn

(~\$2bn Miners)

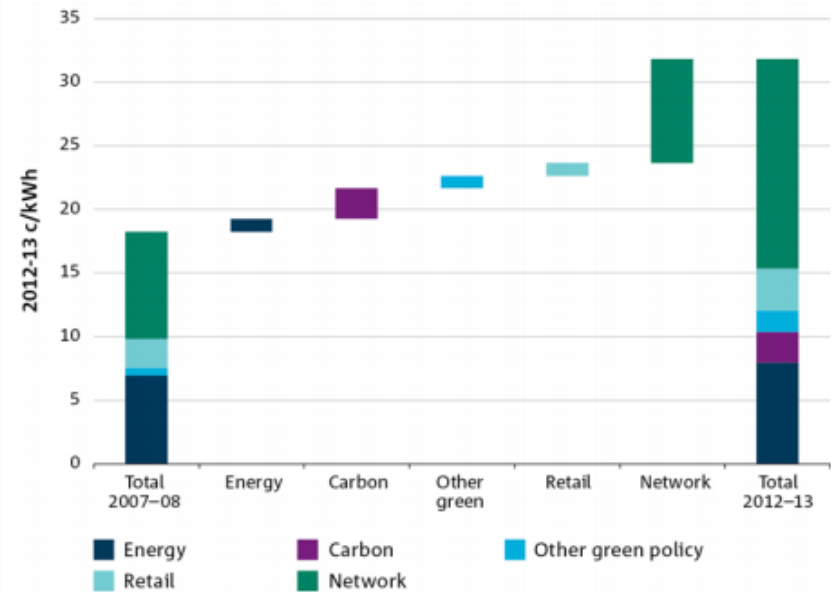
Electricity markets	Capacity		Consumption		Emissions CO ₂ -e/MWh
	GW	Share	TWh	Share	
NEM	49.0	83%	199	86%	0.93
SWIS (WA)	5.5	9%	17.7	8%	0.82
Off-grid Remote Industrial Market	3.9	6%	12.4*	5%	0.61
Off-grid Remote Community Market	1.0	2%	3.4*	1%	

Source: <http://www.austrade.gov.au/ArticleDocuments/2786/Australian-Remote-Renewables-Opportunities-for-Investment.pdf.aspx>

Australia means opportunities, Clean Energy Week 203 Conference <http://www.cleanenergyweek.com.au/dam/cew/presentations/2013-presentations/day-2/off-grid/CRAIG-CHAMBERS-Market-Sector-Director-Power-Generation-AECOM-SANDRA-FOX-Senior-Manager-Investment-Operations-Australian-Trade-Commission/Craig-Chambers-Market-Sector-Director-Power-Generation-AECOM-Sandra-Fox-Senior-Manager-Investment-Operations-Australian-Trade-Commission.pdf> (top-right image only)

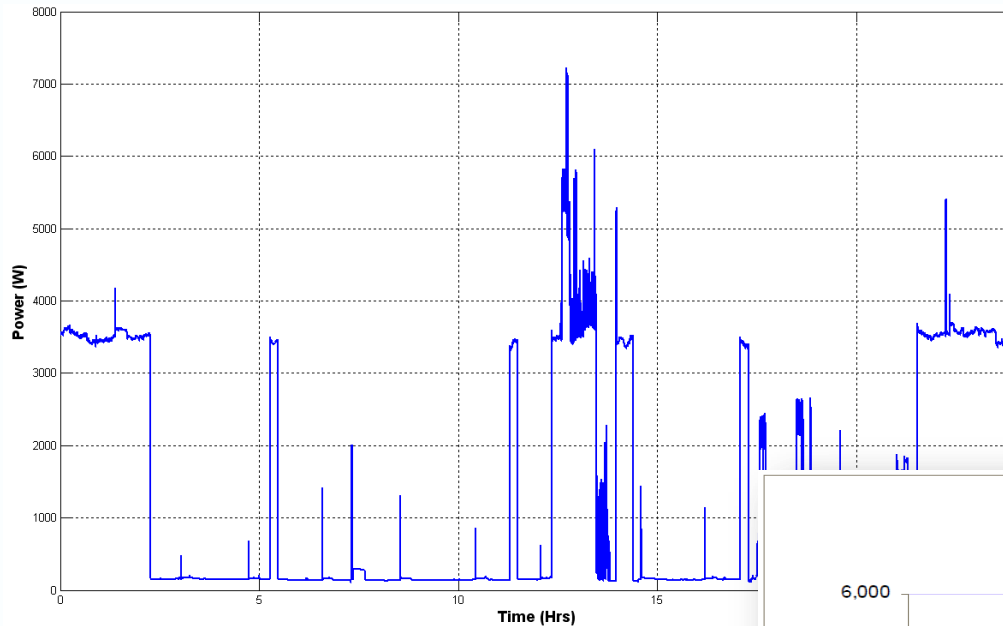
On Grid Challenges

- 3.5GW of solar generation installed with most comprising small-scale rooftop installations¹
- Uncertainty surrounding voltage management, self-consumption, export arrangements in future
- The emergence of demand management, distributed storage and electric vehicles
- Managing new information flows
- Grid planning and investment in this new context



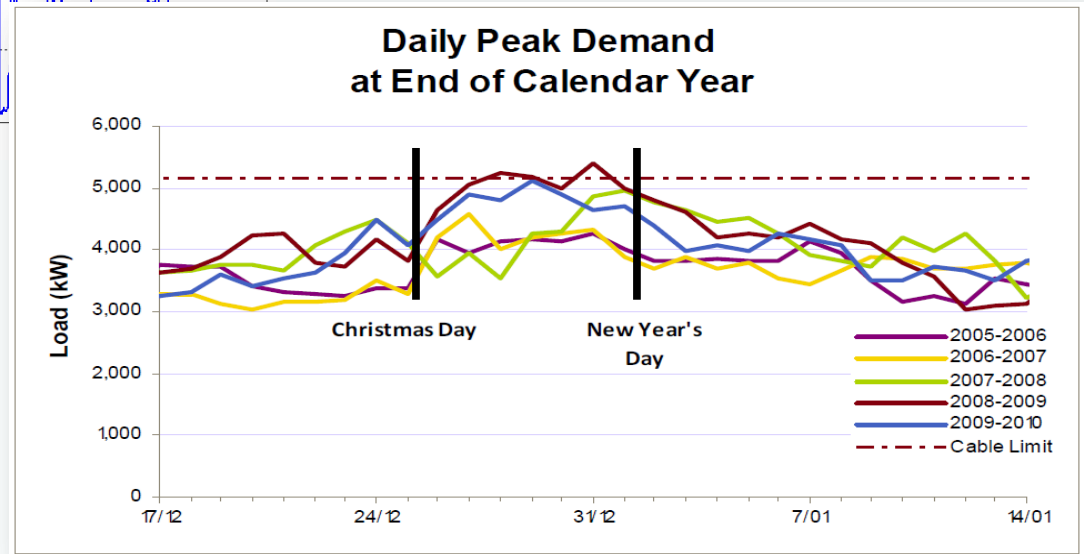
Source: ¹To June 2014 <http://pv-map.apvi.org.au/analyses>
<http://www.csiro.au/Organisation-Structure/Flagships/Energy-Flagship/Future-Grid-Forum-brochure.aspx>

It's Not Just Generation That's Intermittent



- Load integration and management
- Peak demand management

- Requirement for ease of use and robustness
- Consumer acceptance essential



Source: CSIRO (left image)
Townsville Queensland Solar City Annual Report 2010, http://www.ergon.com.au/__data/assets/pdf_file/0006/19608/Townsville-Solar-City-Annual-Report-2010a.pdf

Coordination and Cooperation

Australia has:

- a large number of opportunities and challenges related to grid integration
- already developed a number of reports which are available in the public domain
- significant history in managing off-grid systems

Quicker, cheaper and enhanced solution development may be unlocked via a coordinated approach - avoiding “trial-itis”

Cooperation and Knowledge Sharing - Resources

- Future Grid Forum Report

<http://www.csiro.au/Organisation-Structure/Flagships/Energy-Flagship/Future-Grid-Forum-brochure.aspx>

- Solar Intermittency Characterisation Report

<http://www.csiro.au/Organisation-Structure/Flagships/Energy-Flagship/Solar-Intermittency-Report.aspx>

- Power of Choice

<http://www.aemc.gov.au/Markets-Reviews-Advice/Power-of-Choice-Stage-3-DSP-Review>

- Smart Grid Smart City Report and Data

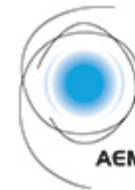
<http://www.smartgridsmartcity.com.au/>

- Intelligent Grid Report

<http://www.csiro.au/Organisation-Structure/Divisions/Energy-Technology/Intelligent-Grid.aspx>

- Example: Generation Management Requirements

http://www.horizonpower.com.au/renewable_energy_generation_management.html



Australian
Energy
Market
Commission



smartgrid smartcity



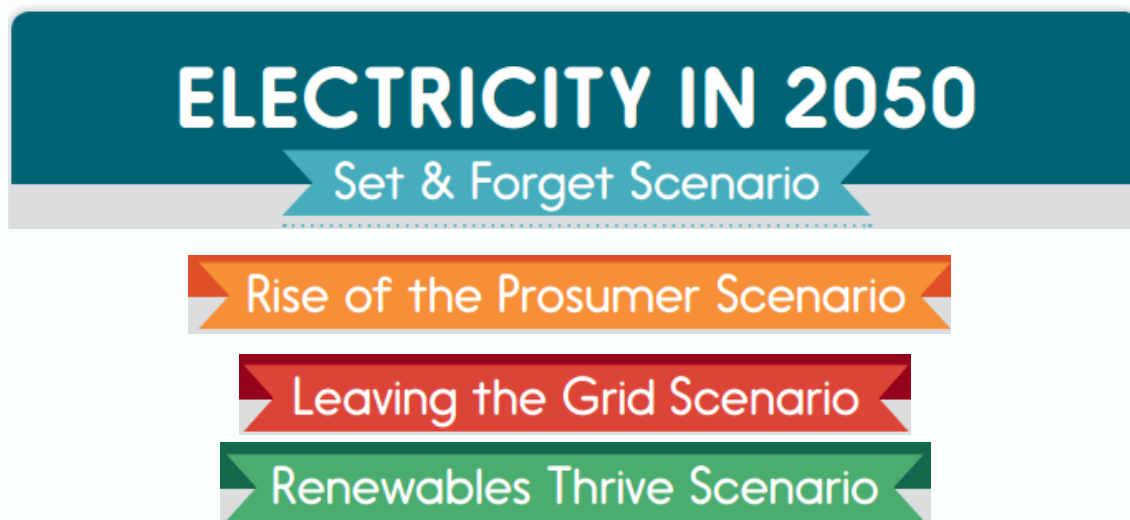
Future Grid Forum

- 15 month activity involving 120 whole-of-system representatives of the electricity industry, government and community
- **Long-term orientation to 2050** enabled identification of key policy and technology choices
- **Whole-of-system** focus provided credible projections and quantitative analytics especially of the future role of networks
- **Industry-led** exercise facilitated bold and informed discussion that examined benefits and drawbacks of different outlooks

Future Grid Forum


Report published “Change and choice: The Future Grid Forum’s analysis of Australia’s potential electricity pathways to 2050” (December 2013) involving:

- Whole-of-system evaluation asking:
 - What might Australia’s electricity system look like in 2050?
 - What are the risks and opportunities that might arise along the way?
 - What can the electricity sector and its stakeholders do to most effectively respond?
- Four key scenarios developed



Source: <http://www.csiro.au/Organisation-Structure/Flagships/Energy-Flagship/Future-Grid-Forum-brochure.aspx>

Generation Management



[Faults and emergencies 13 23 51](#) | [Careers](#) | [Contact Us](#) | [OFF](#)

[HOME](#)
[RESIDENTIAL](#)
[BUSINESS](#)
[SAVING ENERGY](#)
[PROJECTS](#)
[COMMUNITY](#)
[CONTRACTORS / SUPPLIERS](#)
[ABOUT US](#)

[Home](#) > [Saving Energy](#) > [Renewable energy](#) > [Generation management](#)

Energy Efficiency

Renewable energy

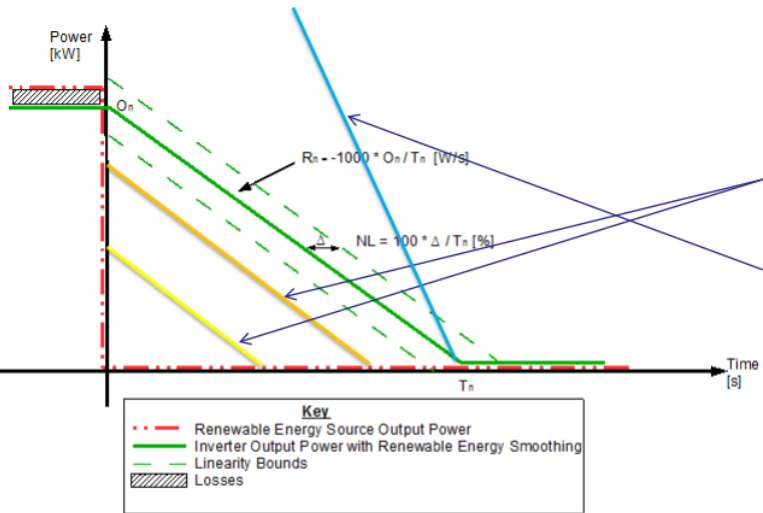
- How renewable energy works
- A guide to installing renewable energy
- Savings from your renewable energy system
- What you are eligible to apply for
- Eligibility calculator
- Your agreement and buyback price
- Technical requirements

Generation management

Horizon Power recognises that many systems. One of the challenges electricity systems is the impact on supply.

On 1 July 2012, Horizon Power initiated new installations. Included in the new renewable energy installations - with reliability of our power supply to a

The availability of generation may vary about the size of renewable energy to be installed across our el



Key

- Renewable Energy Source Output Power
- Inverter Output Power with Renewable Energy Smoothing
- Linearity Bounds
- Losses

Parameters

- R_n := Nominal Ramp Down Rate [W/s]
- T_n := Nominal Ramp Down Time [s]
- O_n := Nominal Rated Inverter Output [kW]
- Δ := Maximum Input Deviation [s]
- NL := Percentage Non-linearity [%]

- Nominal **Ramp Down** Time T_n = 720 seconds (12 mins)
- Nominal **Ramp Up** Time T_n = 360 seconds (6 Minutes)
- In this example if the inverter is running at reduced capacity then the ramp down is as shown
- However because T_n is defined it follows that a 5 kW inverter will reach T_n at the same time as a 100 kW inverter.
- Thus the ramp rate varies with inverter capacity

Ramp Down $R_n = -1000 \times O_n / T_n$ [W/s]

Ramp Up $R_p = 1000 \times O_n / T_n$ [W/s]

Source: http://www.horizonpower.com.au/renewable_energy_generation_management.html

Demand Response Experience

Solutions to manage household demand reduction

- Air-conditioning - REDUCE
- Pool filtration - OFF
- Electric hot water - OFF
- EV charging – REDUCE or OFF
- Battery storage – OFF or EXPORT TO GRID
- Solar PV – EXPORT TO GRID

Demand Response Experience

Solutions to manage household demand reduction achievable through Demand Response Modes (DRMs)

- DRM 3 - 75%
- DRM 2 - 50%
- DRM 1 - OFF

The screenshot shows the PeakSmart air-conditioning website. The navigation bar includes links for Home, Contact us, Power outages, Residential & business, Safety, The network, About us, and Careers. The breadcrumb trail is: Home > Residential & business > Positive Payback > Positive Payback for Households > PeakSmart air-conditioning. The page title is "PeakSmart air-conditioning". The introductory text states: "Many Queenslanders use their air conditioner during peak times, usually on days of extreme temperature. Everyone using their air-conditioner at the same time, increases stress on the electricity network." It then explains that users can be rewarded up to \$500 by choosing a PeakSmart air-conditioner. A table lists the rewards based on cooling capacity. The table has four columns: Reward, \$150, \$250, and \$500. The rows are: Cooling Capacity, Less than 4kW, 4kW but less than 10kW, and 10kW or more. Below the table, there is a link "Ready to apply for your reward?". The section "What is PeakSmart air-conditioning?" explains that the program helps reduce peak demand without affecting performance, operating similarly to the economy setting of an air-conditioner, with energy consumption capped for short periods on a few days of the year.

Home > Residential & business > Positive Payback > Positive Payback for Households > PeakSmart air-conditioning

PeakSmart air-conditioning

Change text size: A+ larger A- smaller | Print page | [f](#) [t](#) [s](#)

Many Queenslanders use their air conditioner during peak times, usually on days of extreme temperature. Everyone using their air-conditioner at the same time, increases stress on the electricity network.

If you are replacing or purchasing a new air-conditioner, help manage peak demand by choosing a PeakSmart air-conditioner, you will be rewarded by up to \$500 by connecting it to the PeakSmart program.

Households and businesses can claim up to five rewards (per premise) for any type of PeakSmart enabled air-conditioner where a signal receiver is installed.

Reward	\$150	\$250	\$500
Cooling Capacity	Less than 4kW	4kW but less than 10kW	10kW or more

[Ready to apply for your reward?](#)

What is PeakSmart air-conditioning?

PeakSmart air-conditioning helps reduce peak demand without affecting your air-conditioner's performance. It operates similar to the economy setting of an air-conditioner. The energy consumption is capped for short periods on a few days of the year and the system continues to produce cool air. The technology is designed to be set and forget so you won't have to do anything or notice a difference to your comfort.

Australian National Feeder Taxonomy

Cluster	Reliability Classification	Voltage (kV)	Load (kVA)	Load Points	Customers	Overhead (km)	Underground (km)	SWER (km)	Total Length (km)	Load per Load Point (kVA)	Load per Customer (kVA)	Load per km (kVA)	Voltage Regulators	Description
1	Long Rural	33	3429	247	267	303.8	0.0	1524.4	1828.3	14	12.8	2	6	33kV remote area feeder
2	Long Rural	11	3810	570	881	468.1	0.0	129.8	597.9	7	4.3	6	4	11kV long rural with low SWER levels
3	Long Rural	22	7812	285	875	273.4	0.0	316.3	589.7	27	8.9	13	2	22kV long rural feeder with high SWER levels
4	Short Rural	11	4287	232	954	141.0	0.4	0.0	141.5	18	4.5	30	1	11kV short rural, moderate length, very low load density
5	Short Rural	22	6900	436	1511	180.7	0.9	37.3	218.9	16	4.6	32	0	22kV rural with low SWER
6	Short Rural	33	6859	53	58	81.9	0.0	5.0	86.9	129	118.3	79	0	Agricultural/small mining (agricultural loads such as irrigation pumps or dairies)
7	Short Rural	11	4287	105	479	49.9	0.8	0.0	50.8	41	8.9	84	0	11kV short rural, short length, very low load density
8	Short Rural	11	5700	39	1464	11.5	5.2	0.0	16.7	146	3.9	342	0	11kV suburban fringe feeder, principally residential
9	Urban	22	11989	61	3158	14.0	18.6	0.0	32.6	197	3.8	367	0	22kV suburban fringe feeder, principally residential
10	Urban	11	5697	23	1073	5.7	1.8	0.0	7.5	248	5.3	760	0	11kV medium density residential, majority overhead
11	Urban	11	6440	15	1264	0.6	5.7	0.0	6.3	429	5.1	1024	0	11kV medium density residential, majority underground
12	Urban	22	10098	26	1285	7.9	1.7	0.0	9.6	388	7.9	1048	0	22kV medium density residential
13	Urban	22	8975	15	140	1.5	3.6	0.0	5.1	598	64.1	1752	0	22kV industrial
14	Urban	11	5700	7	440	2.6	0.7	0.0	3.4	814	13.0	1684	0	11kV medium/high density residential
15	Urban	11	5700	11	60	2.2	2.7	0.0	4.9	518	95.0	1167	0	11kV industrial
16	Urban	11	5297	10	162	0.7	2.6	0.0	3.3	530	32.7	1628	0	11kV mixed industrial/commercial
17	CBD	11	14061	18	114	0.0	2.4	0.0	2.4	781	123.3	5879	0	Brisbane CBD

Prototypical Feeders

Cluster	Reliability Classification	Voltage (kV)	Description
1	Long Rural	33	33kV remote area feeder
2	Long Rural	11	11kV long rural with low SWER levels
3	Long Rural	22	22kV long rural feeder with high SWER levels
4	Short Rural	11	11kV short rural, moderate length, very low load density
5	Short Rural	22	22kV rural with low SWER
6	Short Rural	33	Agricultural/small mining (agricultural loads such as irrigation pumps or dairies)
7	Short Rural	11	11kV short rural, short length, very low load density
8	Short Rural	11	11kV suburban fringe feeder, principally residential
9	Urban	22	22kV suburban fringe feeder, principally residential
10	Urban	11	11kV medium density residential, majority overhead
11	Urban	11	11kV medium density residential, majority underground
12	Urban	22	22kV medium density residential
13	Urban	22	22kV industrial
14	Urban	11	11kV medium/high density residential
15	Urban	11	11kV industrial
16	Urban	11	11kV mixed industrial/commercial
17	CBD	11	Brisbane CBD

In Summary

Australia:

- Shares many drivers for enhanced grid integration with the rest of the world including increasing:
 - distributed generation
 - requirements for grid flexibility
 - resilience and consumer cost expectations and
 - focus on system economic and plant efficiencies
- Experiences unique conditions that increase both the challenges and opportunities surrounding the application of advanced grid integration technologies - particularly in off and fringe of grid scenarios

Thank You

Daniel Rowe
Project Leader
Grids and Energy Efficiency Systems
CSIRO Energy Flagship

Daniel.Rowe@csiro.au

ENERGY FLAGSHIP
www.csiro.au

