UNSW AUSTRALIA | Institute of Environmental Studies
Science

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A Sustainable Energy Future for Australia

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Why do we need Sustainable Energy?

Our Climate is Changing!


Additional Impacts of Fossil Fuels

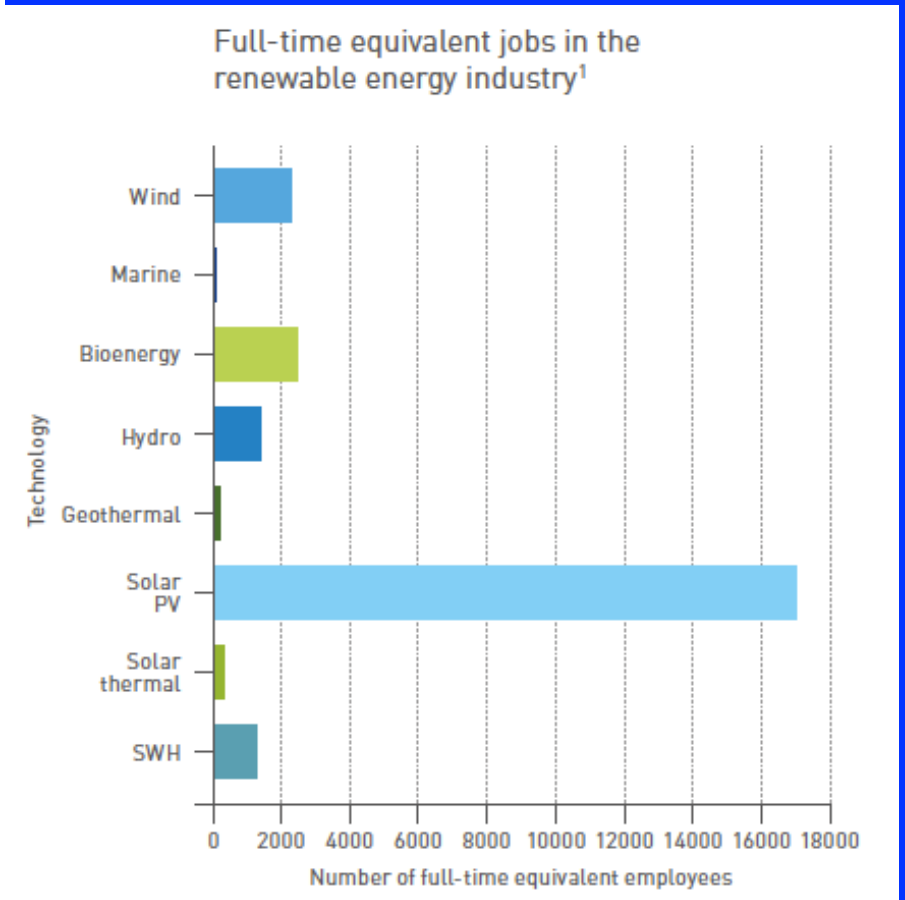
- Peak in global oil production
- Peak in global coal in a few decades
- Gas prices escalating in eastern Australia
- Air pollution and respiratory diseases
- Water pollution
- Land degradation
- Few jobs in fossil fuels

LA teenager's lungs

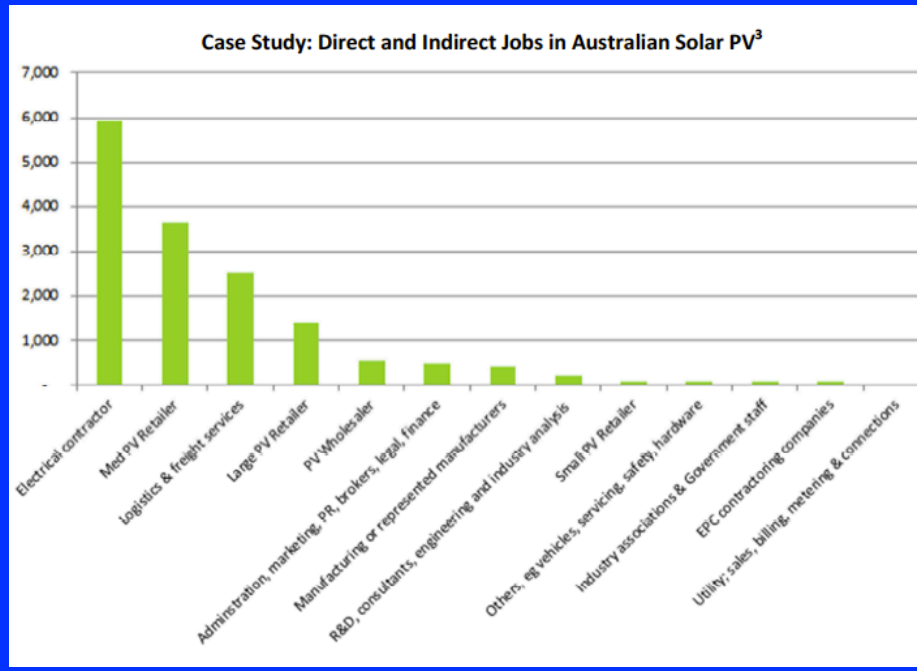
Why do we need a transition?

Jobs in Renewable Energy

24,000 direct jobs in renewable energy in Australia at end 2012



Case study:: Solar PV jobs, incl. indirect



If RET is axed ➔ huge job losses

Direct Local Jobs per Unit of Electricity Generated by Power Stations

Source of electricity	Relative number of job-years per kWh in Australia
Coal electricity + coal mining	1
Wind power with 50% Australian content	2–3
Bio-electricity with 50% Australian content	Approx. 3.5 (mostly rural)
Wind power with 80% Australian content	3.5–5

Principal source: MacGill, Watt & Passey (2002)

Energy Efficiency saves Energy and Money

Christie Walk, Adelaide

Domestic Refrigeration - 6 Star

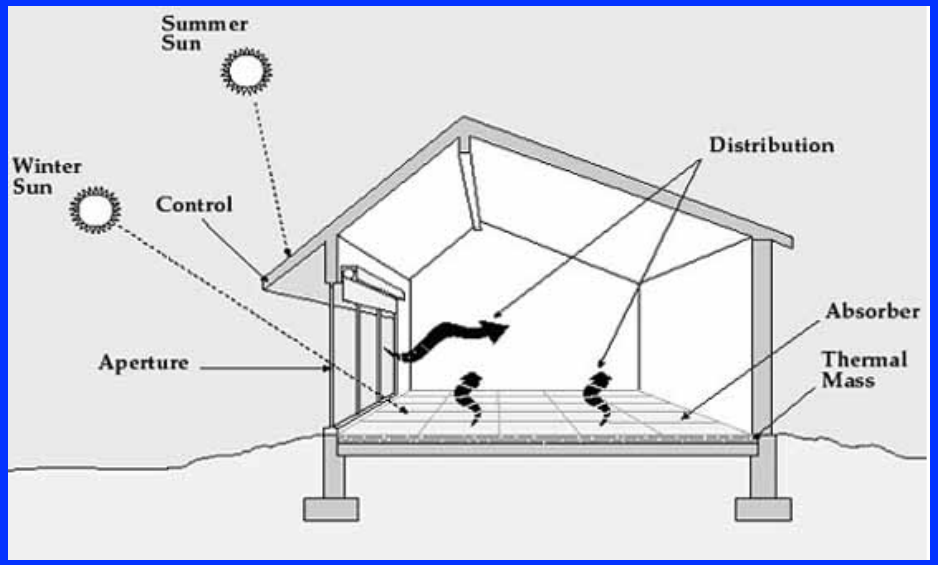
Water efficient shower

Heat pump hot water

Ceiling fan

LED lights

Sustainable Space Heating and Cooling



New building

Passive solar design, accepting winter sun & excluding summer sun

All residential buildings

- Insulation of ceiling and, if possible, walls and under floor
- Exclude drafts in winter
- Encourage drafts in summer
- Ceiling fans
- Efficient reverse cycle air conditioners
- Add thermal mass, especially if it can be exposed to winter sun

Jobs

- For energy audits, sales, Installation
- Auditors, salespersons, electricians, plumbers, IT experts, architects

How can Renewable Energy replace Fossil?

Energy end-use at present	Energy end-use	Future renewable energy contribution
Electricity **Currently mostly coal**		Could be supplied entirely by renewables in Australia & many countries within a few decades.
Transport **Currently mostly oil**		Electric vehicles for urban transport; inter-city high-speed rail; biofuels (initially) for rural vehicles & some air travel.
Heat (non-electrical) **Currently mostly gas**		Low temperature heating & cooling from direct solar & electric heat pumps; high temperature from renewable electricity

Electricity will play a greater role in heating/cooling and transport.
Hence this presentation focuses on electricity.


CST with thermal storage, Spain

Renewable Electricity

Wind
Biomass
Solar PV
Concentrated solar thermal
Hydro
Wave?
Geothermal electricity?

Australia has the lot!


Wind, Albany, WA


PV solar tiles, Sydney


Seawater pumped hydro, Japan


Bioenergy, Rocky Point, Qld


Wave
Pelamis sea trials

Jobs in manufacturing, installation, grid connection; a few in operation & maintenance

Countries and States with Strong Renewable Electricity Targets

Country/state	2013 or 2014 Renewable Electricity	Target
Denmark	39% of electricity consumption from wind + bioenergy from ag. residues	100% renewable electricity and heat by 2035; 100% transport 2050
Germany	26% from renewables.	80% renewable electricity by 2050
Scotland	44% from renewables, mostly wind followed by hydro	100% renewable electricity by 2020
China	Biggest wind capacity and solar hot water; biggest PV manufacture	15% of all primary energy from 'low-carbon' by 2020
California, USA	About 24% in total from hydro, geothermal, wind, biomass, etc	33% renewable electricity by 2020
Schleswig-Holstein, Germany	About 100% net in 2014 – mostly wind	300% under discussion

In Australia Renewable Energy is under Attack by Federal and State & Territory Governments

- Review of Renewable Energy Target by biased committee – **Reported**
- Australian Renewable Energy Agency (ARENA) to be closed – **Announced, subject to Senate vote**
- Clean Energy Finance Corporation to be closed – **Announced, subject to Senate vote**
- 20th inquiry into sham wind turbine 'syndrome' – **Announced**
- Election promise, to subsidise one million solar roofs – **Broken**
- Most state governments removed mandatory feed-in tariffs for residential RE or banned feed-in; some removed energy efficiency programs – **Done**
- Anti-RE myths spread by politicians & others – **Continuous**

Vested Interests are spreading False Myths about Renewable Energy (RE)

- Myth: 'Base-load power stations, either coal or nuclear, are necessary, and RE cannot provide them'
- Myth: 'Base-load power stations must run continuously as backup for RE'
- Myth: 'RE is too variable to make the predominant contribution to grid electricity supply without vast amounts of expensive electrical storage'
- Myth: 'RE is too expensive'
- Myth: 'RE is too diffuse to run an industrial society'
- Myth: 'RE is not ready to replace fossil fuels'
- Myth: 'RE is responsible for the big increases in electricity prices
- Myth: 'Wind & solar have severe environmental and health impacts'

Why the Attacks?

Renewable Electricity threatens big greenhouse gas emitting industries, state gov't revenue, & utility business models

- ‘Merit Order Effect’ at wholesale (generation) level
  - Wind farms, with very low operating cost, are displacing coal-fired power stations and reducing wholesale price of electricity, especially in South Australia
- ‘Death Spiral’ at distribution/retail level
  - Growth in rooftop solar PV and increased energy efficiency are reducing demand for grid electricity
- Result
  - Utilities & big business lobbying federal & state governments to stop growth in RE
  - Government policies try to stop growth of RE
  - False myths disseminated by malicious and lazy media

Mythbusting by Two Methods

- Practical experience
  - Denmark: wind supplied 39% of electricity consumption in 2014
  - South Australia 31% wind + 5.5% solar PV in 2013;

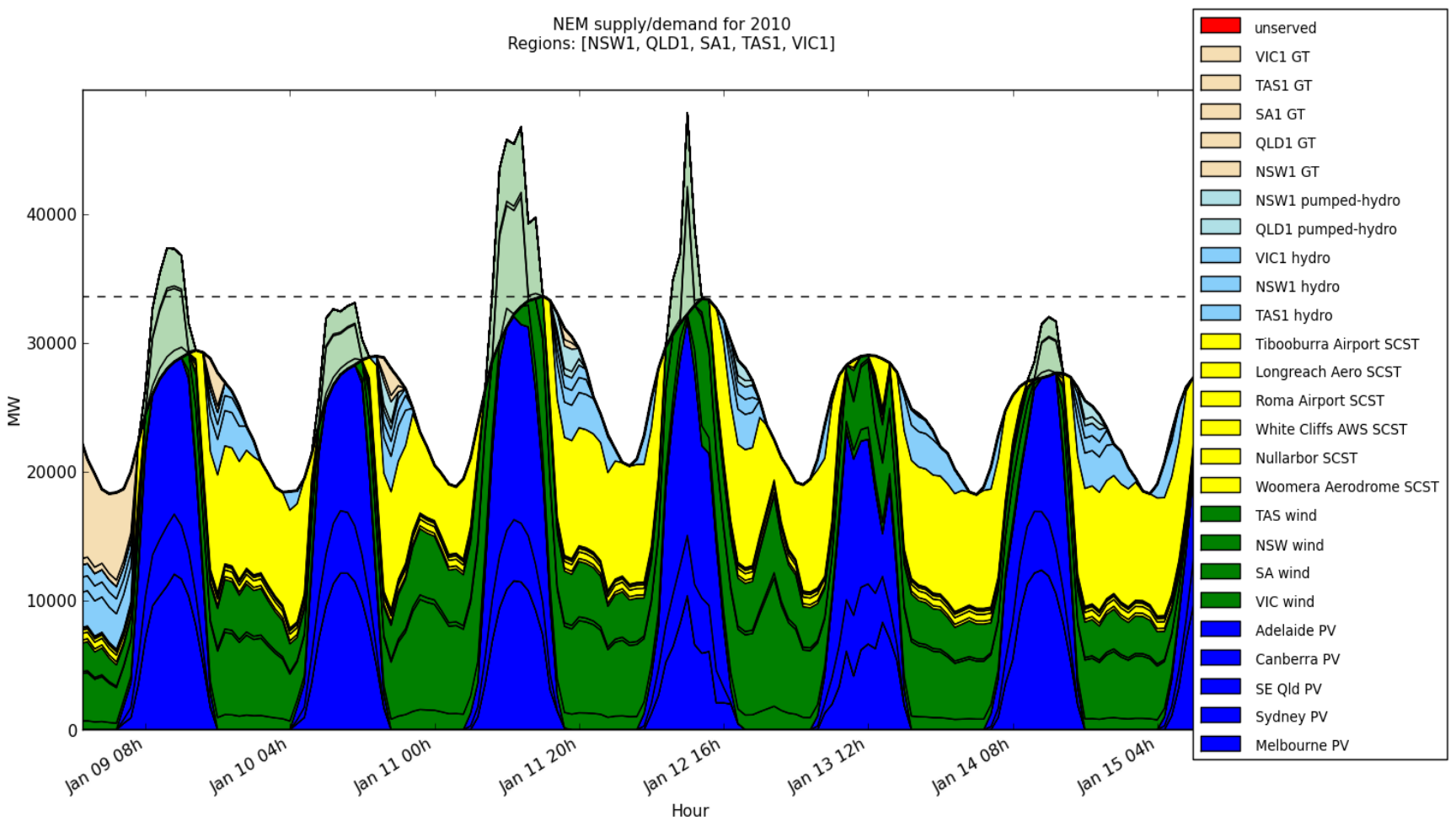
- Hourly computer simulations of demand and supply by 80−100% renewable electricity in many countries
  - Over 30 studies of states/provinces, countries, regions and whole world
  - These find that renewable electricity systems can be just as reliable as conventional systems
  - Predominantly renewable electricity systems are affordable
  - Myths hostile to RE are busted

UNSW Simulation Models of 100% Renewable Electricity (RE) in National Electricity Market (NEM)

(Journal papers by Elliston, MacGill and Diesendorf 2012, 2013, 2014)

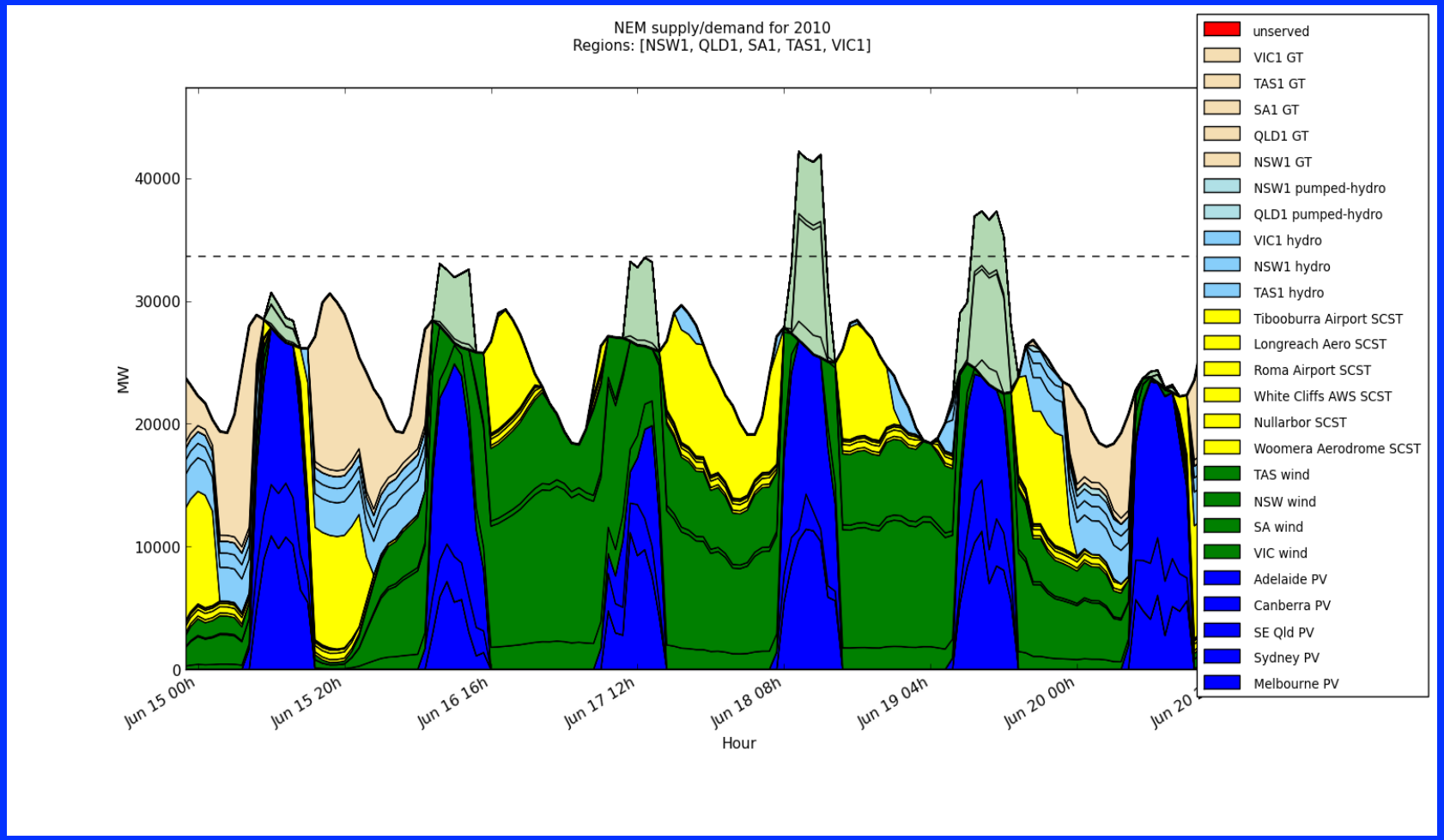
- Hourly data on electricity demand, solar & wind for NEM, initially spanning 2010
- All commercially available RE technologies scaled up
- Simulation model built by Ben Elliston: hourly time-steps through 2010, balancing supply and demand; maintaining reliability
- Cost projections to 2030 by BREE (2012)
- Economic optimal mix evaluated
- Simplified transmission model
- Comparison fossil fuelled scenarios

Supply and Demand for a Typical Week in Summer 2010 – Optimal Mix of RE in NEM



Supplying base-load demand is easy in summer; negligible gas turbine energy used.

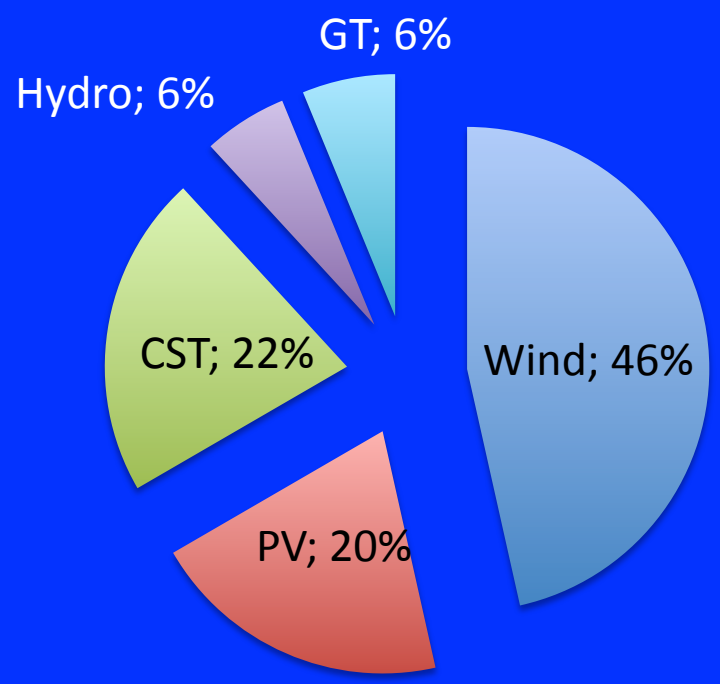
Supply and Demand for a more Challenging Period in Winter 2010 – Optimal Mix of RE in NEM



In calm winter evenings following cloudy days, gas turbines & demand management are important.

100% RE Least-Cost Energy Generation Mix 2030 projected costs by BREE

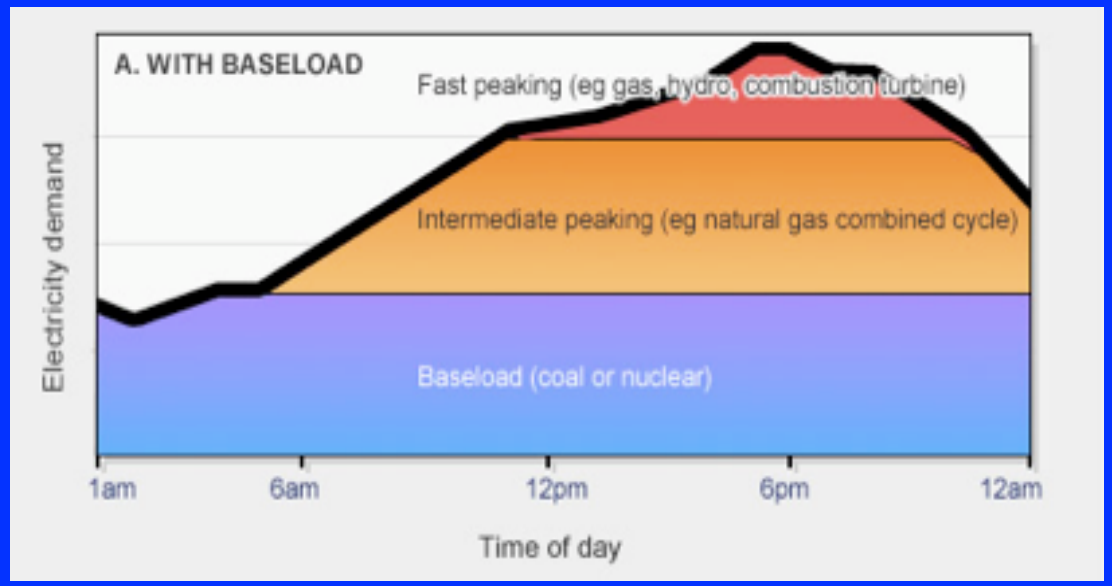
5% Discount Rate; no extra transmission

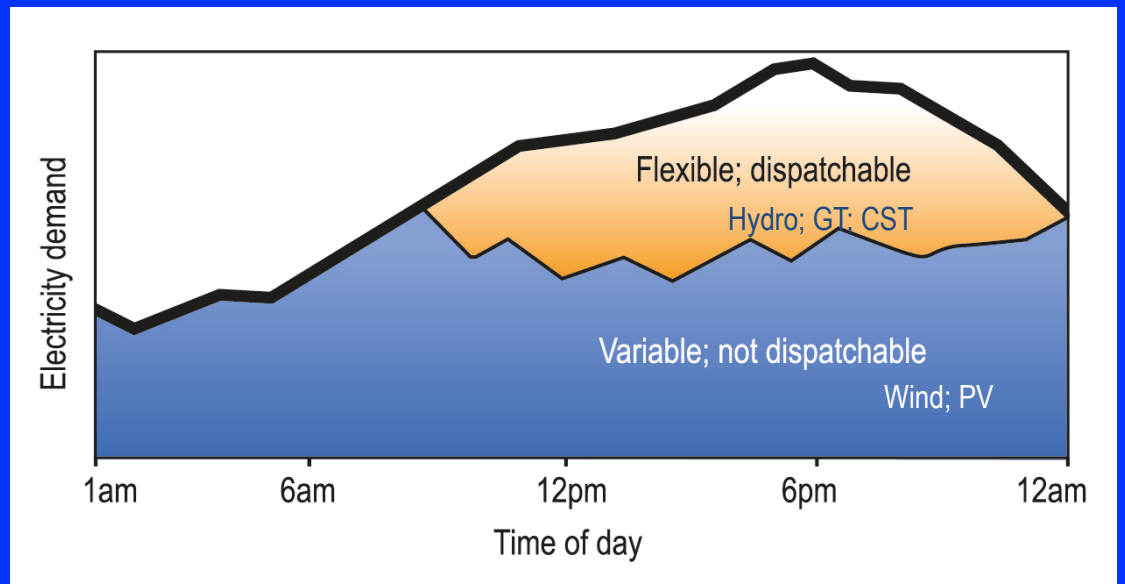


Note: Variable RE contributes two-thirds of annual energy and reliability is maintained!

Technology costs projected to 2030 by BREE (2012).
GT is gas turbines burning renewable fuels;
CST is concentrated solar thermal with thermal storage.

Myth: “Base-load power stations are needed”





Traditional concept

(base-load power stations supply base-load demand)

busted

New concept replaces traditional

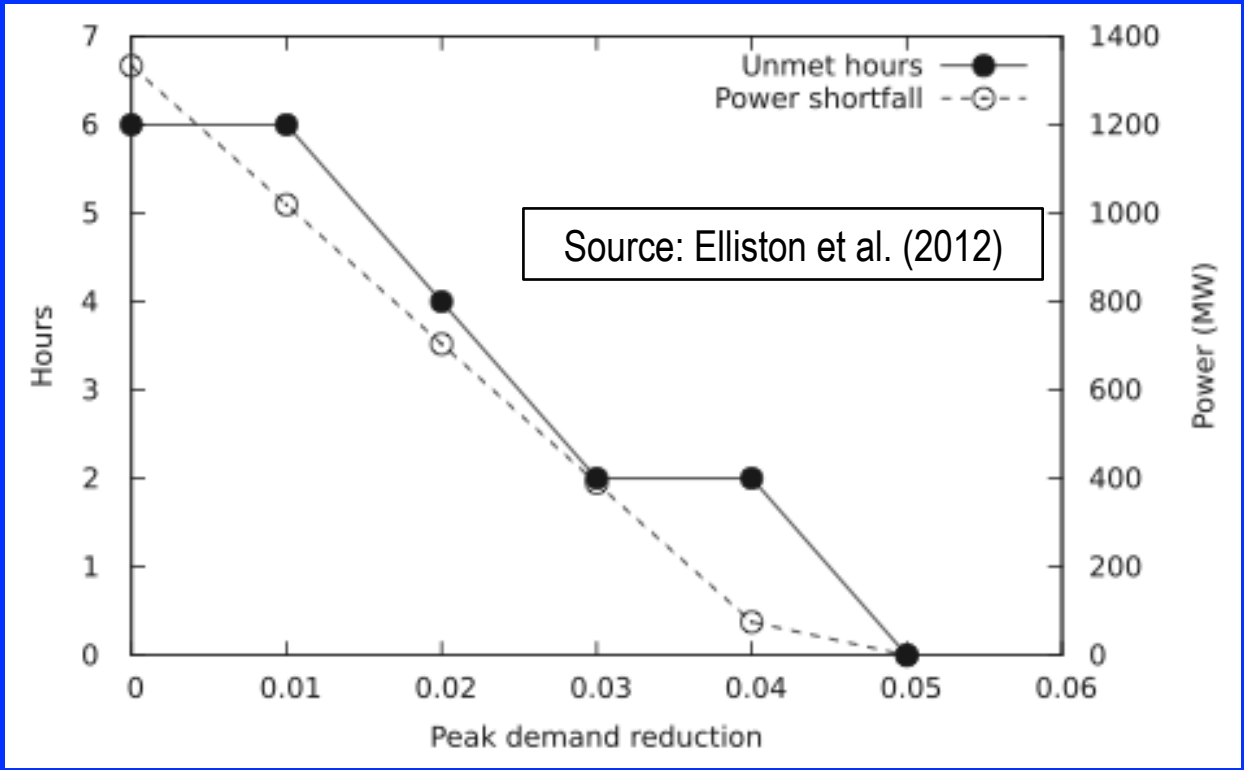
100% RE without base-load power stations; variable + flexible stations meet demand reliably

Meeting Demand without Base-load Stations

- Renewable electricity supplied by mix of variable plants (wind and PV without storage) and flexible/dispatchable plants (CST with thermal storage, hydro with storage, biofuelled gas turbines)
- Flexible plants (together with improved weather forecasting) balance the fluctuations in power output from inflexible plants
- Demand management in a ‘smart grid’ can also play an important low-cost role.
- Key parameter is reliability of the whole supply-demand system, not reliability of individual technologies. Reliability criterion satisfied in all simulations: unmet annual energy < 0.002% of annual demand

Making RE even more Reliable: Reduce Peak Demands using 'smart' Meters and smart Pricing

Unmet hours



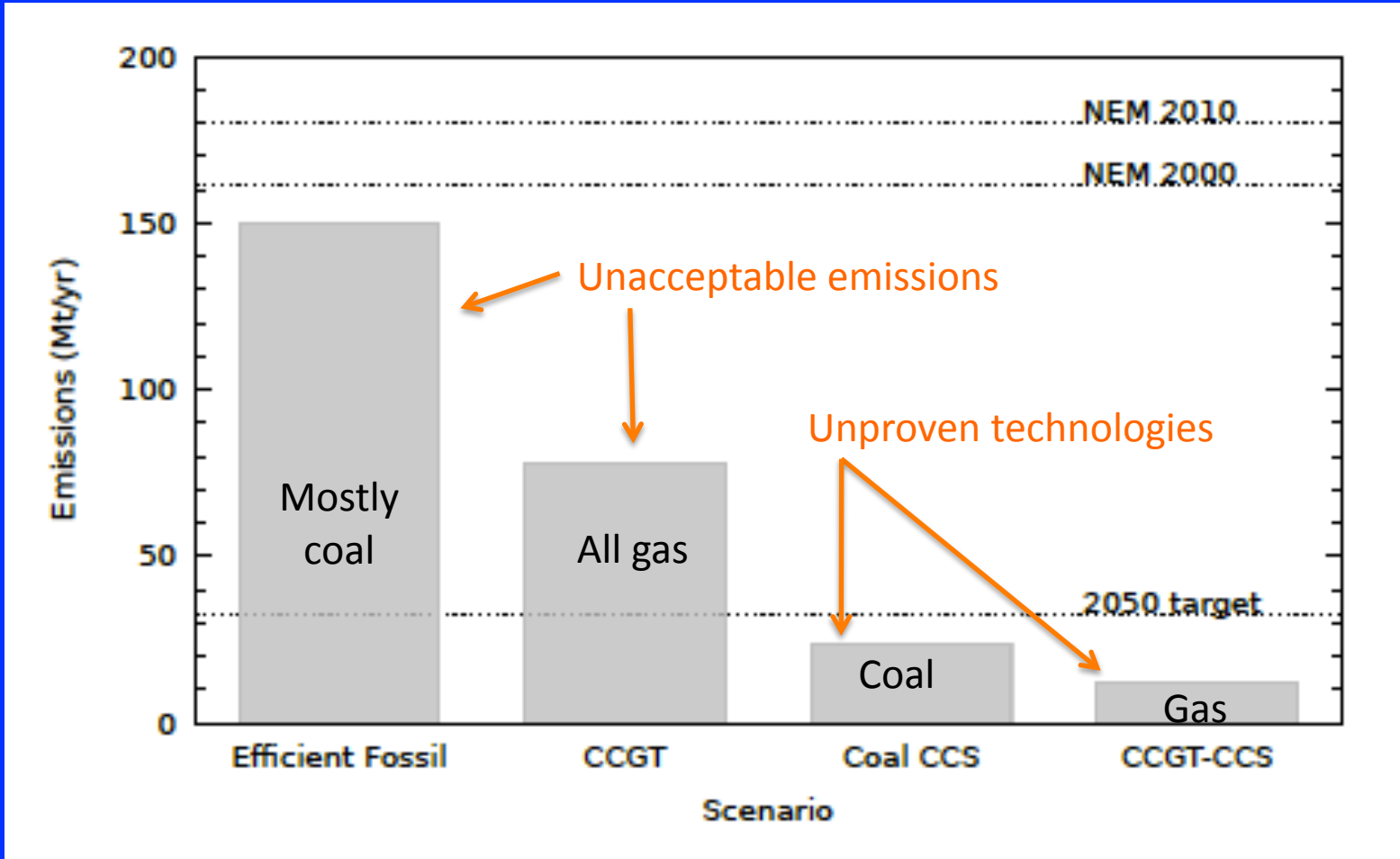
5% reduction in the 6 winter demand peaks, that produce unmet hours in baseline simulation, eliminates all unmet hours and unmet power.
GT capacity is fixed

UNSW's Four Comparison Scenarios

None in AEMO (2013) study

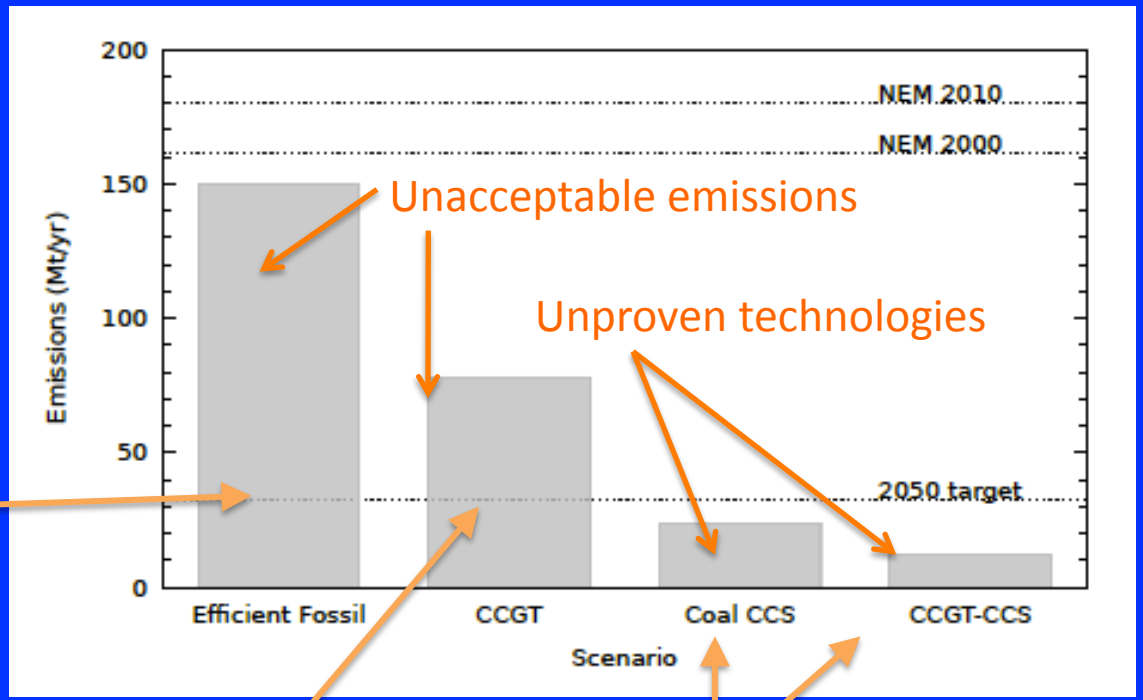
1. Most efficient commercially available fossil power stations (no CCS); GHG emissions still 81% of existing system – **unacceptable!**
2. All gas (no CCS), base-load combined cycle and peak-load open cycle; GHG emissions 40% of existing – **unacceptable!**
3. Base-load coal with CCS **(unproven technology)** + peak-load gas turbines
4. Base-load gas with CCS **(unproven technology)** + peak-load gas turbines

Annual CO_2 Emissions from 4 comparison Fossil Fuel Scenarios in NEM



Summary: Economics of the Four Fossil-Fuelled Comparison Scenarios

CCS is hypothetical carbon capture and storage; CCGT is combined cycle gas turbine



Efficient fossil: 100% RE competes either if CO_2 price is $50-100 per tonne, or fossil subsidies of $10 billion p.a. transferred to RE

All gas: 100% RE competes if domestic gas prices increase to near export prices; already happened in Qld.

Fossil + CCS: 100% RE competes almost everywhere

Myth: "Renewable energy is too diffuse"

Back-of-envelope with NEM Electricity Demand 250 TWh/y

- Wind farms provide 50% of electricity = 125 TWh/y
  - Assume Elliston et al. (2013) for optimal mix of 100% renewable electricity
  - Capacity factor 0.3, each turbine 3 MW; square array with spacing 1 km; land occupied only 1–2% of ag. land spanned
  - Wind capacity = 48 GW; 16,000 turbines span 16,000 km^2, but only occupy 160–320 km^2 = $(13–18\ km)^2$
- Rooftop solar PV supplies 25% of total electricity demand: 0 land area
- Hydro and gas turbines provide 10% of electricity & occupy negligible additional land if GTs fuelled by ag. & plantation forestry residues
- On-ground solar supplies 15% of electricity.
  - Assume capacity factor 0.2 & 1 GW occupies 100 km^2 (Gemasolar)
  - Then, 21.4 GW occupies 2140 km^2 = $(46\ km)^2$
- Total land area occupied = 0.056–0.086% of NEM states' total land area

Busted Myths about Renewable Energy

- Myth: ‘Renewable energy cannot provide base-load power.’ Myth is based on false notion that base-load demand must be supplied by base-load power stations − BUSTED as irrelevant
- Myth: ‘Renewable energy is too variable or intermittent to make the predominant contribution to grid electricity supply − BUSTED
- Myth: ‘Coal-fired power stations must run continuously as backup’ − BUSTED by both experience & simulations
- Myth: ‘Renewable energy is too expensive’ − BUSTED
- Myth: ‘Renewable energy is too diffuse to run an industrial society’ − BUSTED
- Myth: ‘Renewable energy is still immature’ − BUSTED

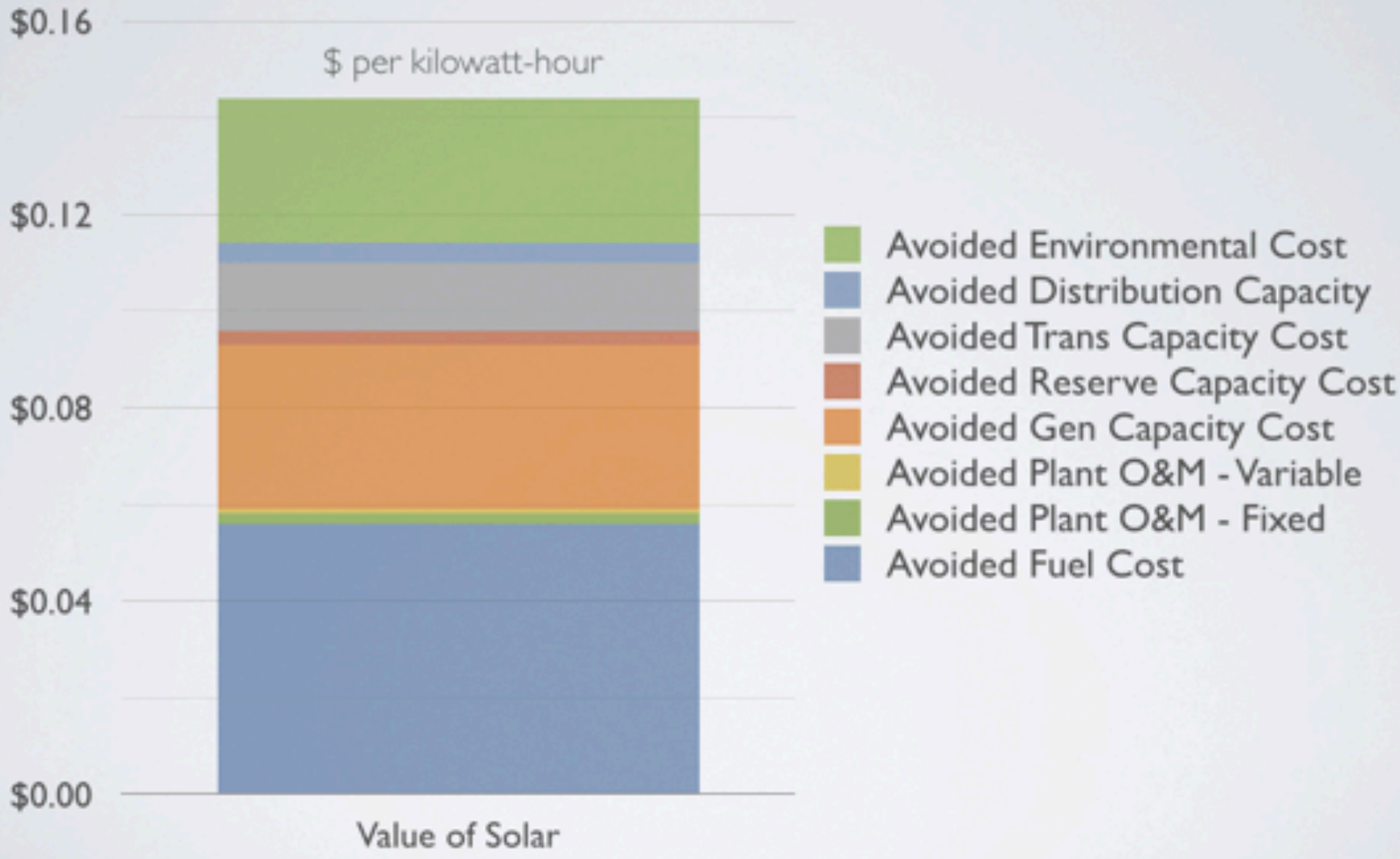
Policies needed in Australia

- Set stronger greenhouse targets
- Re-introduce a carbon price, preferably as a tax rather than ETS
- Terminate subsidies to production & use of fossil fuels (> $10B+ p.a.).
- Increase RET for 2020 and set much higher targets for 2025 & 2030
- Keep ARENA & CEFC
- Upgrade transmission system for large-scale RE: priority SA−NSW link
- Upgrade local distribution networks for 2-way flows of electricity
- Expand seeding grants & info for community renewable energy projects
- Expand energy ratings for buildings, appliances & equipment; mandatory energy labelling and energy performance standards

Additional Energy/Climate Policies for NSW

- ✸ Set energy efficiency (EE) target and expand EE programs
- ✸ Set 20% NSW emissions reduction target for 2020 (in absence of national carbon price); develop & implement strategy for zero emissions by 2050
- ✸ Set target for renewable electricity equivalent to pro rata national RET of 41 TWh per year in 2020, and much higher targets for 2025 & 2030
- ✸ Government agencies to purchase green electricity
- ✸ Implement 'smart' grid; set fair electricity price structures
- ✸ Make it illegal for electricity companies to refuse feed-in of RE; set fair mandatory feed-in tariffs
- ✸ Build solar power station; partially fund new transmission spine to SA
- ✔ Fund seeding grants & information for community RE projects

Preliminary Minnesota Value of Solar Calculation



Source: Xcel Energy filing to MN PUC on Docket No. E999/M-14-65, 2/13/14

ILSR INSTITUTE FOR Local Self-Reliance

Hepburn Community Wind Farm

near Daylesford, central Victoria

- Community projects were foundation in Denmark & Germany
- Hepburn is Australia's first medium-scale community RE project
- 2 turbines, 4.1 MW total
- Cooperative with about 2000 members
- $9.6M from members +$1M Vic gov't grant + $3M loan
- Revenue returned to members and local community trust fund
- Spin-off group Embark is facilitating other community projects in Australia

See <hepburnwind.com.au>

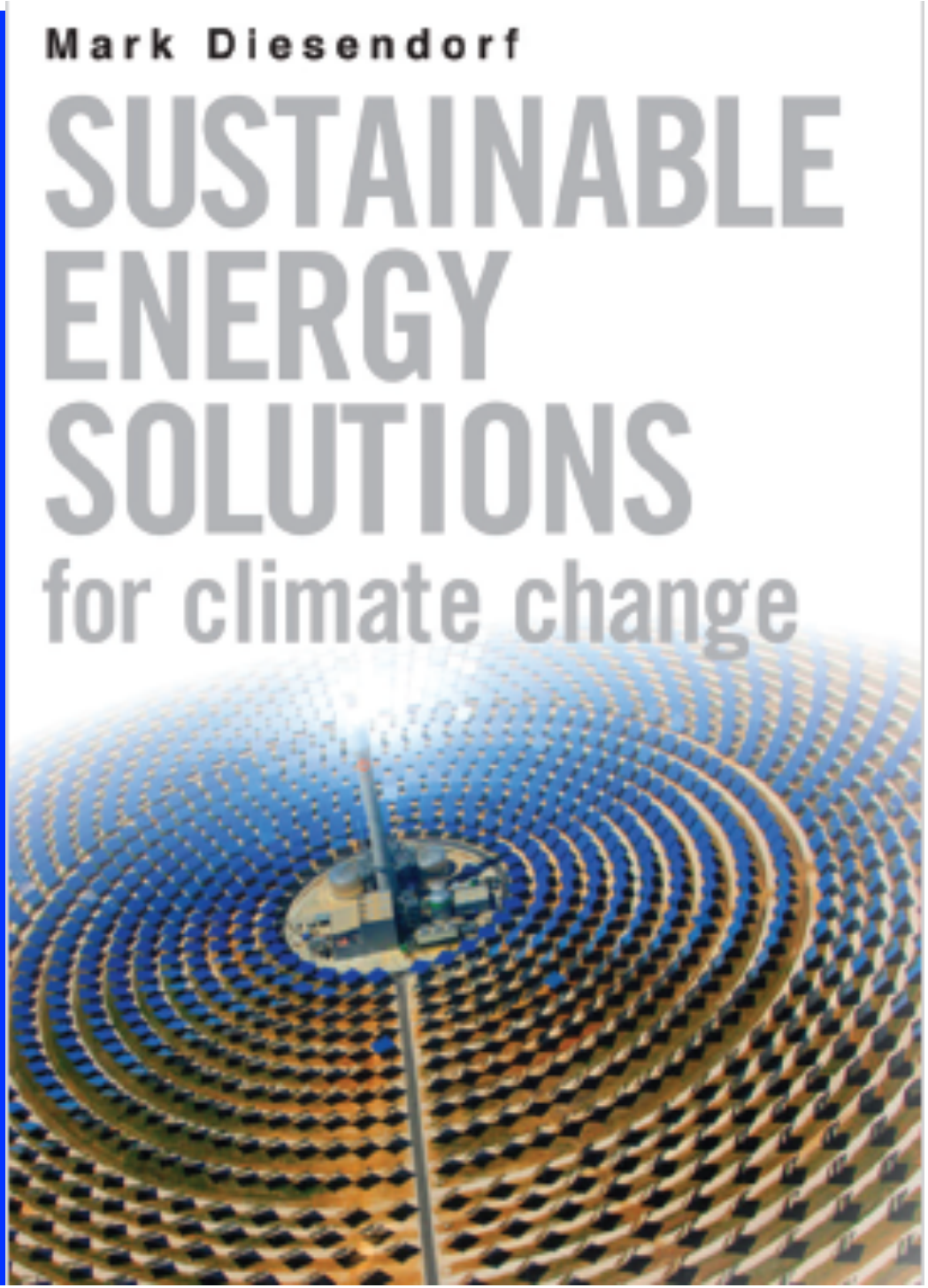
Further Information

Research papers & non-technical articles

http://www.ies.unsw.edu.au/our-people/associate-professor-mark-diesendorf

New book

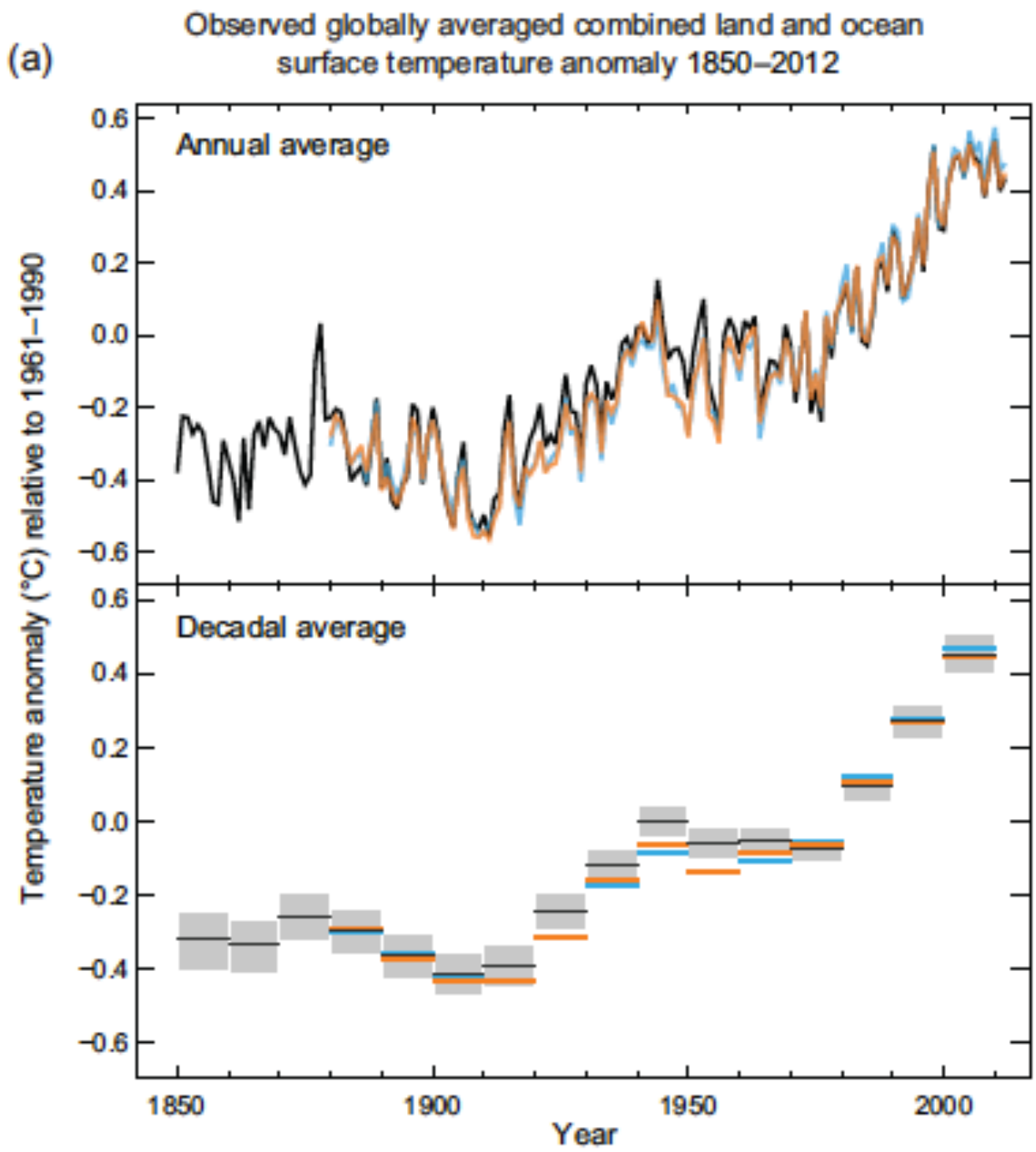
Sustainable Energy Solutions for Climate Change, UNSW Press and Earthscan, 2014



Supplementary Slides

Trend in Global Average Temperature, 1850—2012

Source: IPCC 2013



The Fingerprint of Climate Change is Human

- Warming of surface and troposphere coupled with cooling of stratosphere
- Night-time minimum temperatures are rising faster than day-time maxima
- (Northern) winters are warming faster than (northern) summers
- Solar radiation has been constant over past 50 years, apart from well-known 11-year solar cycle
- Land surface is warming faster than ocean surface
- High latitudes (eg Arctic, Antarctic) are warming faster than tropics

The fingerprint identifies the criminal. It's not the Sun, it's us… or, more precisely, mainly some of us.

90 companies caused 2/3 of warming since industrialisation.

Frequency Control in high Penetration RE Grid

- Frequency (50 Hz) set at present by rotating generators and maintained by balance between supply & demand
- If supply > demand, frequency increases and vice versa

Fast response (6 sec.)

- If supply > demand, balance restored rapidly by reducing output of wind farms slightly (including them in FCAS)
- If supply < demand, balance restored by reducing demand rapidly in a 'smart' grid. Air conditioners, fridges & electric hot water can be switched off briefly (subject to contract) by signal over power-line.

  OR: draw power from batteries of grid-connected electric vehicles (under contract)

Frequency Control in High RE Grid
(simplified)

Delayed response (5 min)

- If supply > demand, maintain reduced supply from wind farms
- If supply < demand, either start–up fast flexible reserve generators (hydro, biofuelled gas turbines & diesels), or off-load some big loads (under contract)

Why nuclear energy isn't a credible climate solution

- Too dangerous
  - Proliferation & terrorism
  - Rare but devastation accidents
  - High-level wastes
- Too expensive: eg Okiluoto; Flamanville; Hinkley C; Vogtle
- Too slow to plan and construct: convincing public + 15 years
- Too high a CO_2 emitter in long term: mining & milling low-grade U ore with diesel
- Generation 4 reactors are not commercially available and most are more dangerous and even more expensive
  - Fast breeder; integral fast; thorium; small modular

Subsidies proposed for Hinkley C Reactors, UK

2 x 1600 MW, capital cost £16 billion = AUD 32 billion

= AUD 10,000/kW

- Guaranteed price of electricity 9.25 p/kWh = AUD 18 c/kWh = twice UK wholesale price of electricity
- Guaranteed price escalated annually with inflation for at least 35 years
- Loan guarantee £10 billion
- Insurance coverage by UK government, i.e. taxpayers
- Additional confidential subsidies