Earth rise from Apollo 8,
24 December,1968

Climate change and renewables – challenges and opportunities

presentation for John Curtin Institute of Public Policy

Dr Paul Wilkes
Climate Reality Leader

15 June 2018

“ Blue Marble “ photo of Earth from NASA’s Apollo 17 as crew travelled towards the moon December 7, 1972

Outline

1. *Urgency of dealing with climate change*
2. *GHG, temperatures, sea level rise*
3. *Global issue not just Australia – carbon budgets*
4. *Rapid decrease in cost of renewable energy sources*
5. *Technical issues in transition*
6. *Opportunities – job creation, economic benefits*
7. *Role of electric vehicles*
8. *International examples*
9. *Australian examples*
10. *Some opportunities*

Climate is always changing. Why is climate change of concern now?

The speed of the current climate change is faster than most of the past events, making it more difficult for human societies and the natural world to adapt.

ref: Climate Change Evidence and Causes – Royal Society and the US National Academy of Science

"Global warming
is contributing to an
increased incidence of
extreme weather
because the environment
in which all storms form has
changed
from human activities."

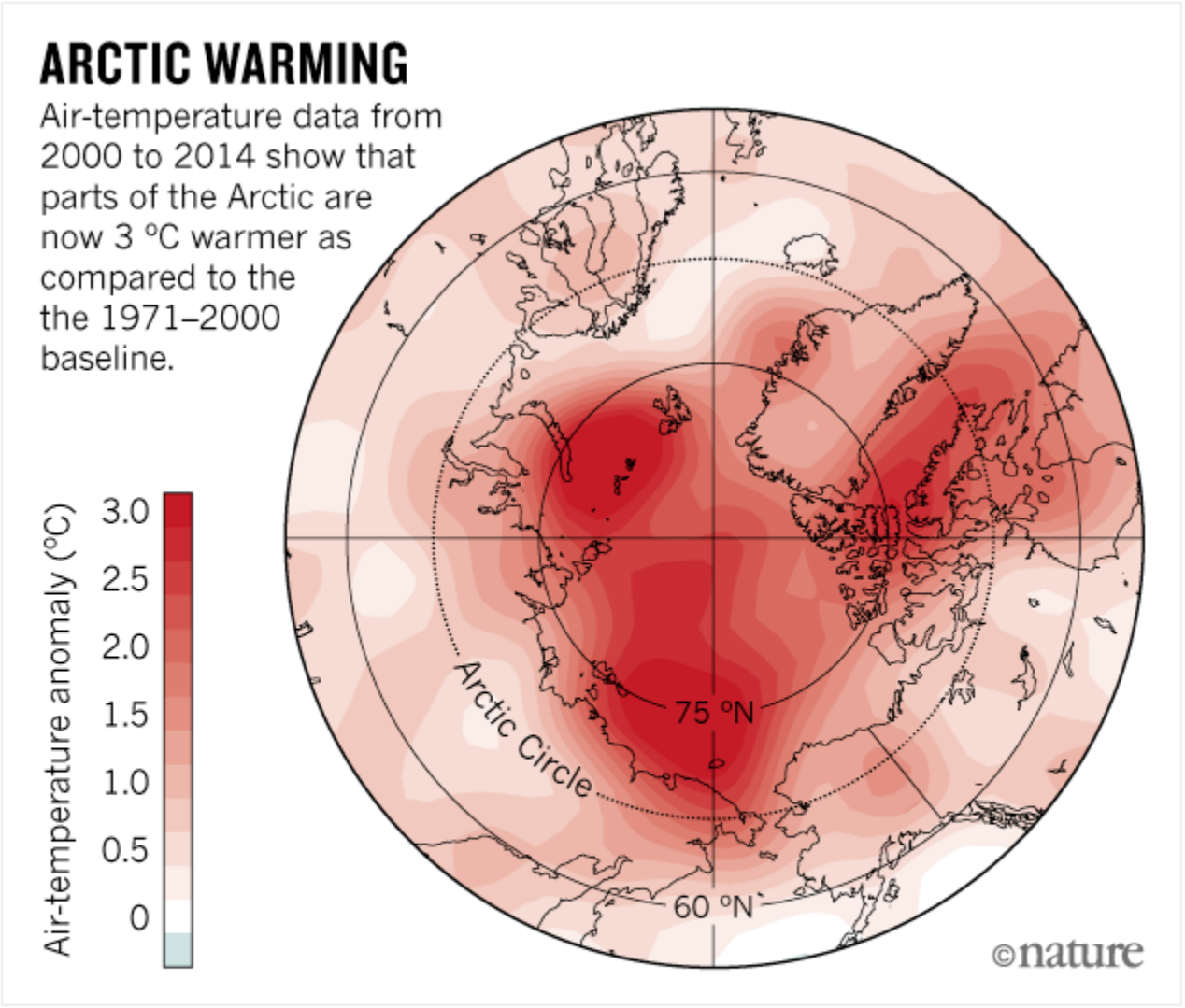
Kevin Trenberth

U.S. National Center for Atmospheric Research

June 15, 2011

Planet Earth is hotting up !

- *16 of the hottest years on record have been since 2000.*
- *Arctic temperatures increasing faster than elsewhere. Now typically 3 deg C higher than in 1950*



from :
Nature 28 April 2017

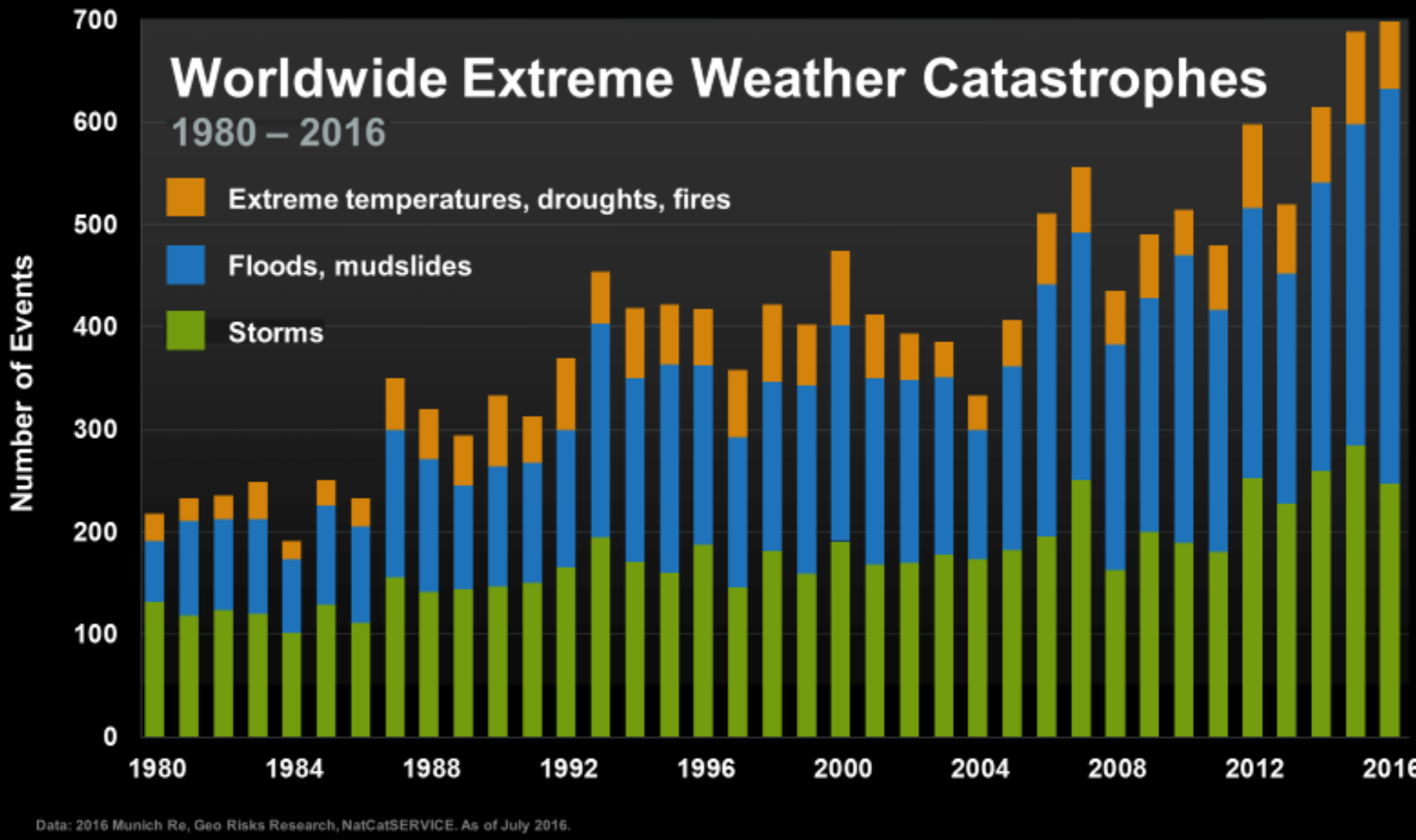
The report increases projections for global sea-level rise, which takes into account all sources of melting including the Arctic. Their new minimum estimates are now almost double those issued by the Intergovernmental Panel on Climate Change (IPCC) in 2013 for some emissions scenarios. In fact, the latest calculations suggest that the IPCC's middle estimates for sea-level rise should now be considered minimum estimates.

CO2 from human activity

- *The CO_2 level in 2012 was about 40% higher than it was in the nineteenth century. Most of this CO_2 increase has taken place since 1970, about the time when global energy consumption accelerated. Measured decreases in the fraction of other forms of carbon (the isotopes ^{14}C and ^{13}C) and a small decrease in atmospheric oxygen concentration (observations of which have been available since 1990) show that the rise in CO_2 is largely from combustion of fossil fuels (which have low ^{13}C fractions and no ^{14}C).*

- *CO_2 levels measured in air extracted from ice cores indicate that the current concentrations are higher than they have been in at least 800,000 years.*

ref : http://royalsociety.org

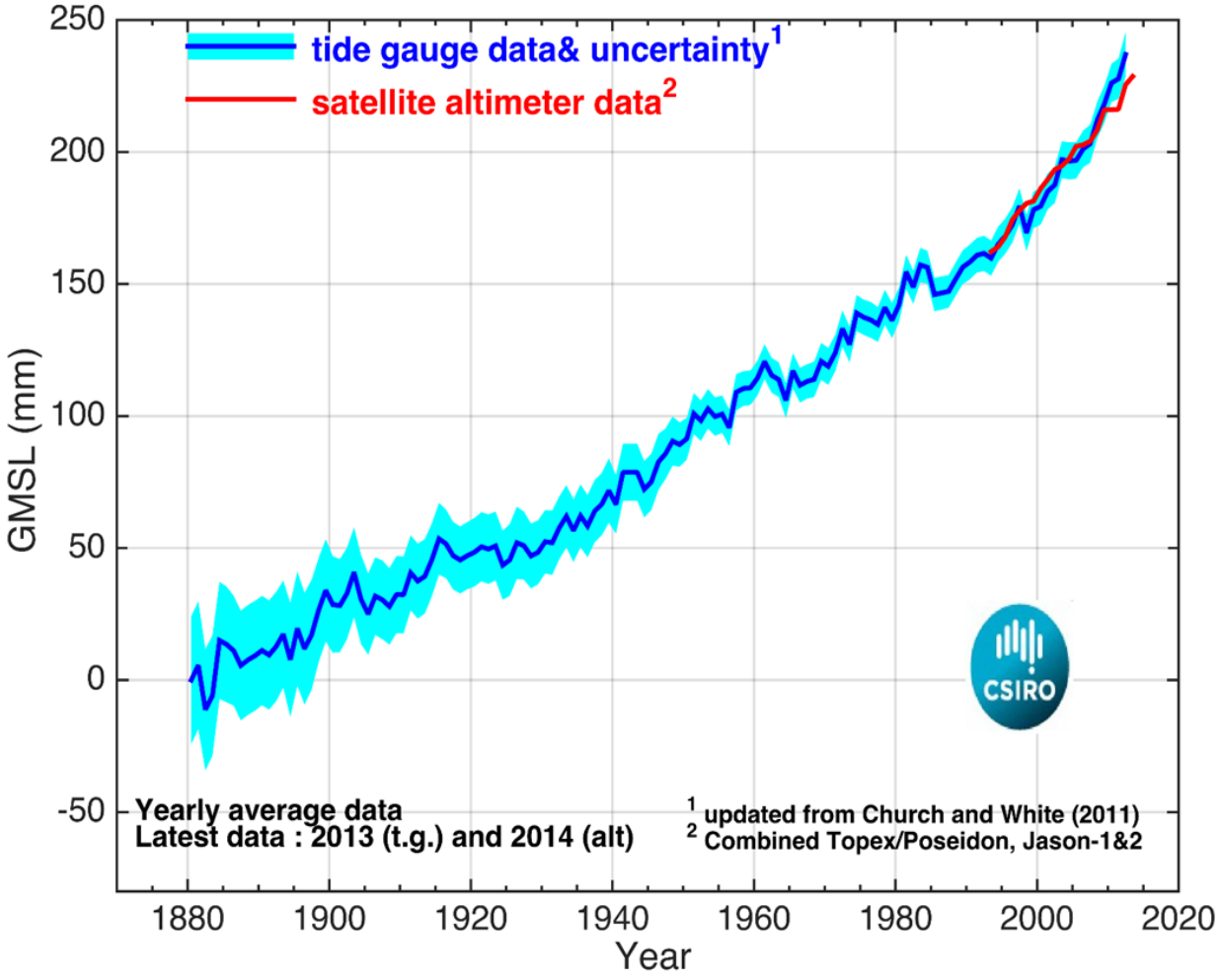


Data: 2016 Munich Re, Geo Risks Research, NatCatSERVICE. As of July 2016.

Sea level rise

- *Rise is due to increasing sea temperatures plus melt from glaciers and ice shelves.*
- *Previous IPCC reports suggested likely figures up to about 80 cm by 2100 but latest data shows likely to exceed 1 metre. Next IPCC report due in 2018.*
- *Sea level rise not the same everywhere. e.g off WA is now about 10 mm/yr (1 metre in 100 years)*
- *Many cities and some countries at risk from sea level rise*

Global sea level rise 1880 to 2016



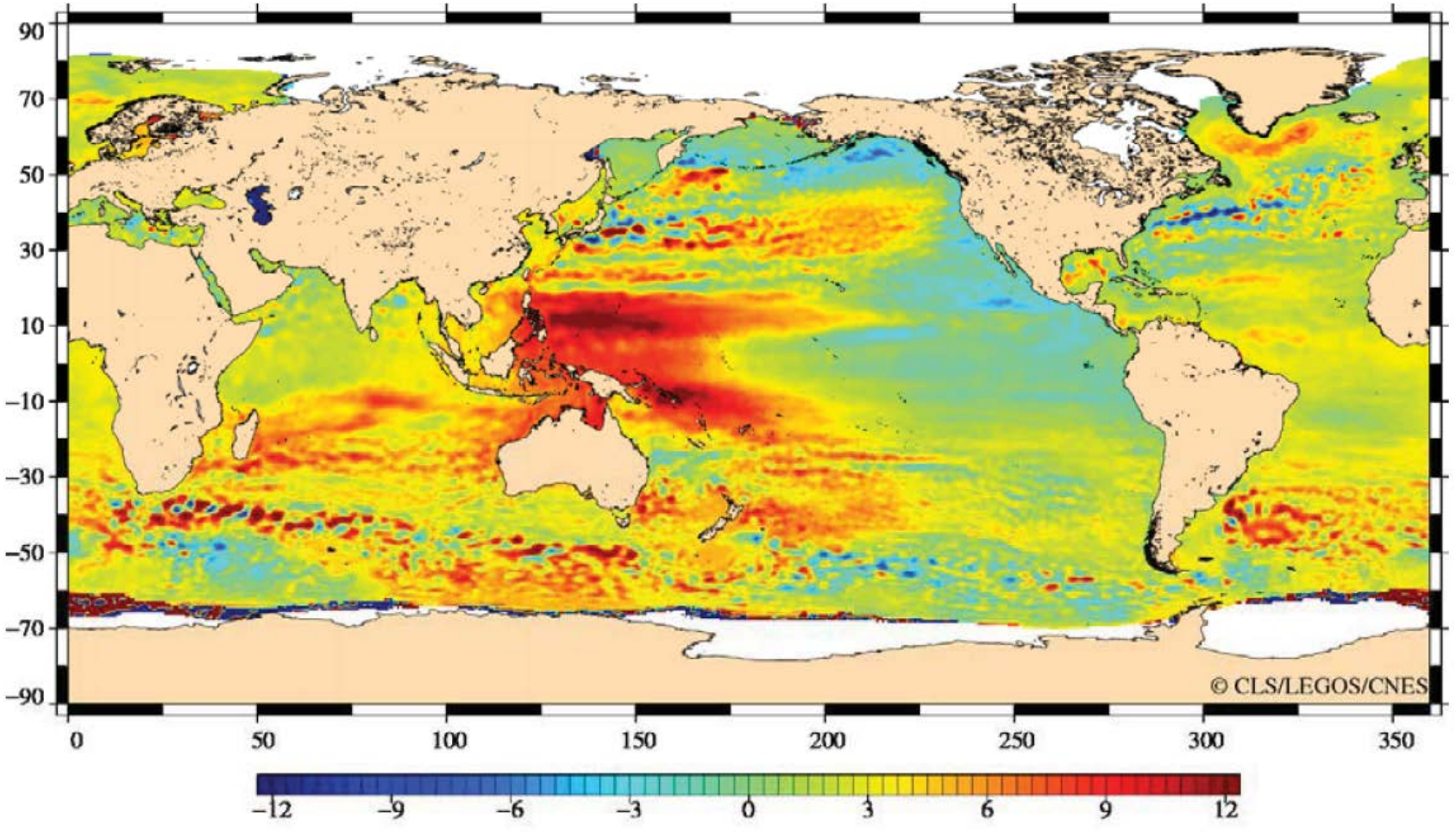


Figure 3 - Mean sea level trends from satellite altimetry (Oct 1992 to Jul 2009)[6]

Kiribati – the world's lowest lying country – average height 2 metres above sea level

113,000 people
Most live in Tarawa
33 tiny coral atolls
3.5 m sq km

'Our country will vanish': Pacific islanders bring desperate message to Australia

Sea levels set to 'rise far more rapidly than expected'
New research factors in collapsing Antarctic ice sheet that could double the sea-level rise to two metres by 2100 if emissions are not cut

Antarctica has the potential to contribute more than a metre of sea-level rise by 2100 and more than 15 metres by 2500, if emissions continue unabated. Nature 531, 591-597, 31 March 2016

The Changing Oceans

- *The oceans slow the rate of climate change by absorbing over a quarter of the carbon dioxide released by the burning of fossil fuels and by storing over 90% of the excess heat accumulating in the climate system. These two changes, together with nutrient input into the oceans from fertilizer use and other pollution, are affecting the marine ecosystem by increasing the acidity of the oceans, decreasing subsurface oxygen concentrations, and increasing coastal nutrient loads. At the same time, ocean changes affect the terrestrial environment, being the primary source of the water vapor that drives global rainfall patterns.*

- *Changes in ocean temperatures and currents and in the oceans' interaction with the atmosphere are already altering the frequency, intensity, and distribution of storms, droughts, floods, heat waves, and cold spells.*

- *By 2100, rising sea levels from ocean thermal expansion and increasing ocean mass (from melting glaciers, ice caps, and the Greenland and Antarctic ice sheets) will expose an additional tens of millions of people annually to the risk of coastal flooding.*

ref: John Church, 18 June 2010, The Changing Oceans, Science, vol 238, Issue 5985, page 1453

Paris December 2015 agreement (COP 21)

197 countries agreed to limit their greenhouse gas emissions and to review (reduce) these limits every 5 years to try to limit average global temperature rise to 2 deg C relative to pre-industrial levels. So far 141 countries have ratified the agreement.

The likely outcome of the first round of INDCs, for 2020–30, is estimated to be a temperature rise of 2.7°C, in a range of 2.2°C–3.4°C by the end of the century, compared with 3.7°C under 'business as usual'. *This means that additional, and more stringent, measures are likely in the future. The Paris Agreement provides for this to happen through a five-year review cycle in which parties will submit progressively more ambitious contributions.*

Ref J and B Mitchell, August 2016, Paris Mismatches –The impact of the COP 21 Climate Change Negotiations on the Oil and Gas Industries, Chatham House, UK

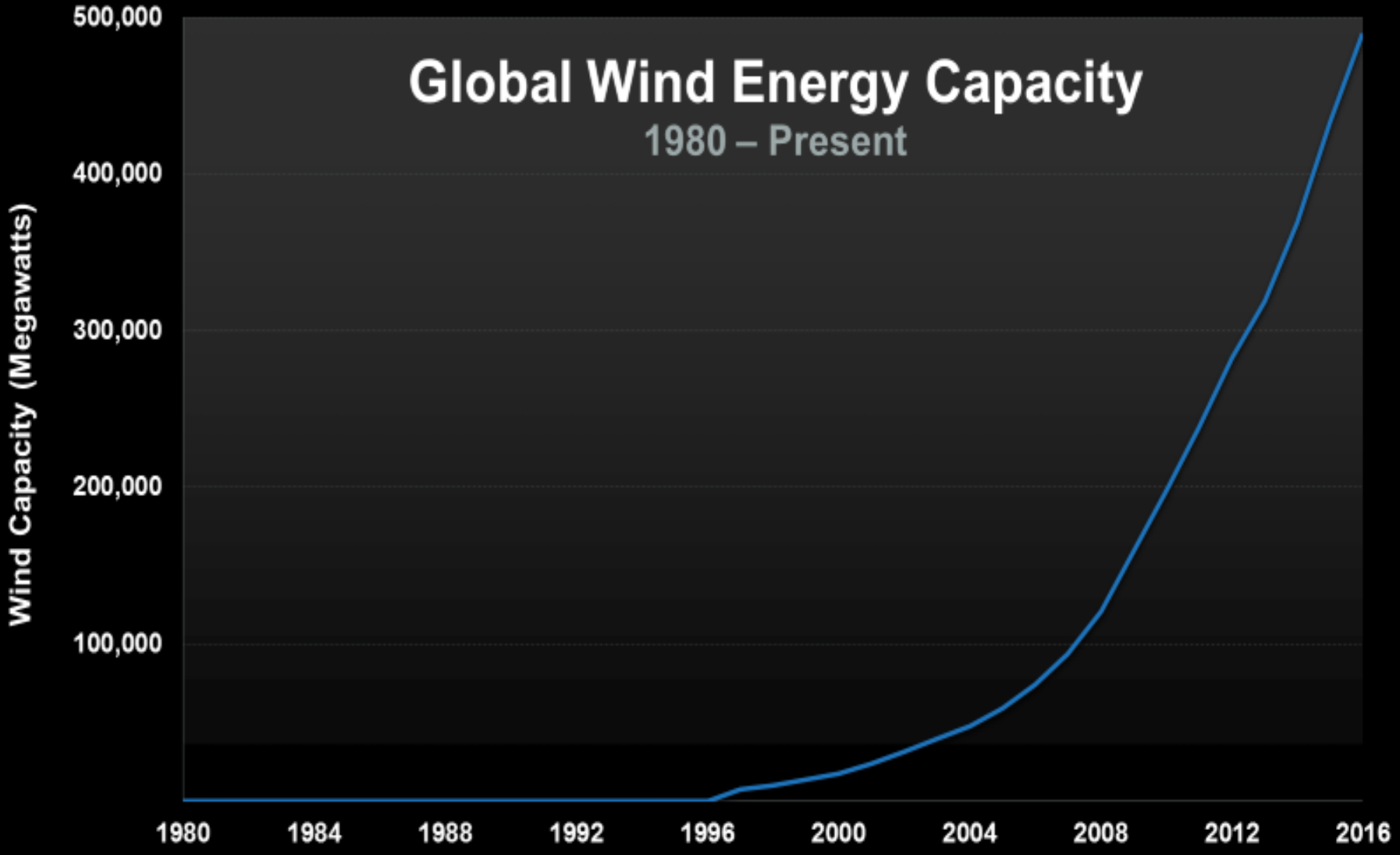
International examples of high penetration of renewable energy

Rapid growth in deployment of renewable energy

The world added 98 GW of solar energy in 2017 – more than any other energy sources. This included 53 GW added in China.

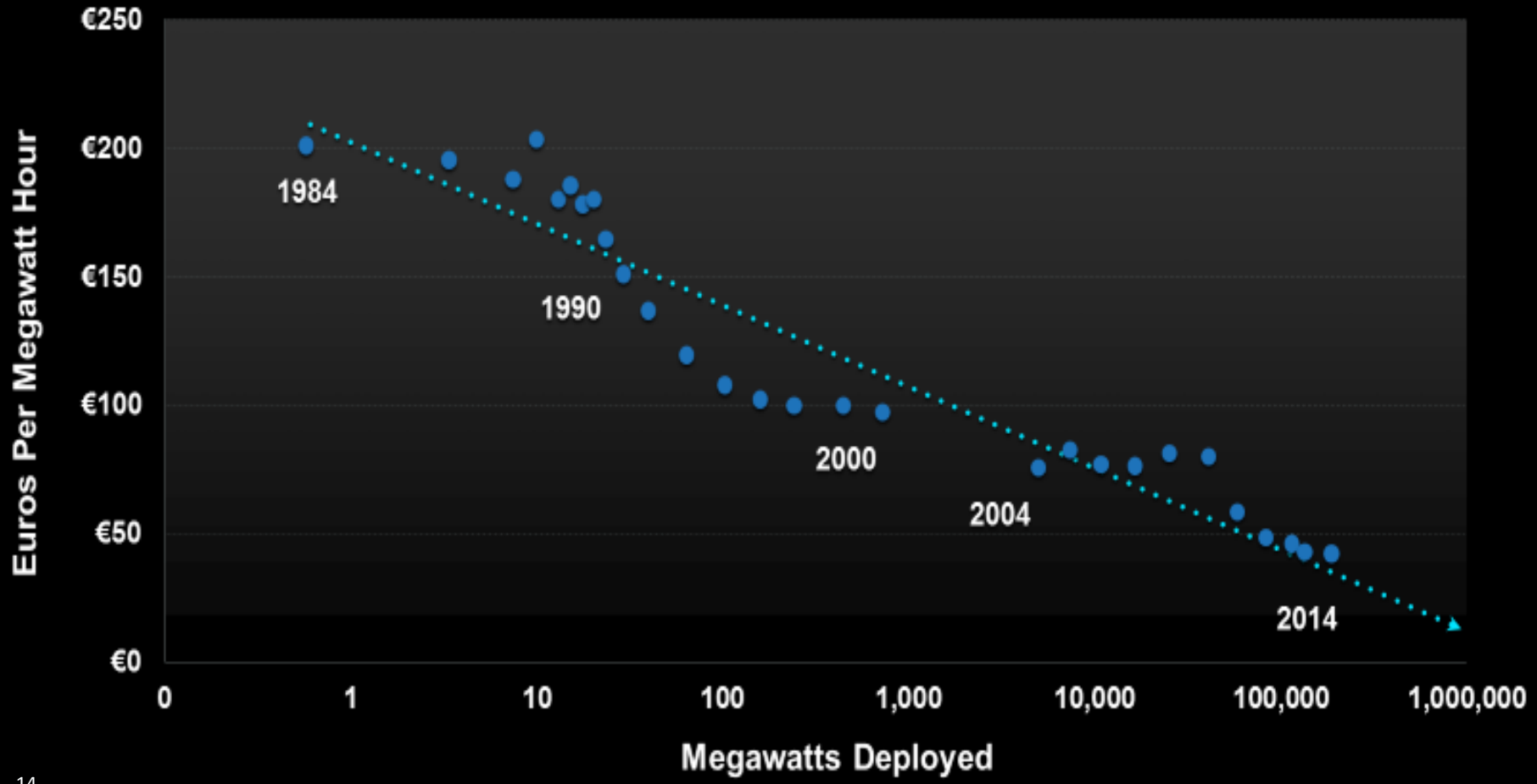
Ref: New Scientist, 8 June 2018

China is spending more on wind and solar combined than on coal and nuclear combined


Global Wind Energy Capacity
1980 – Present
Wind Capacity (Megawatts)
500,000
400,000
300,000
200,000
100,000
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016
Data: Earth Policy Institute/Bloomberg New Energy Finance

Onshore Wind Cost

1984 – 2014



Data: Bloomberg New Energy Finance

Europe in 2016 – 86 % of new power came from renewables

New capacity added: 24.5 GW of which 21.1 GW was wind

- *London Array in North Sea*
- *175 turbines*
- *630 MW*
- *100 sq km area*
- *construction cost 1.8 bn pounds*
- *The world's largest offshore windfarm*
- *Opened July 2014*

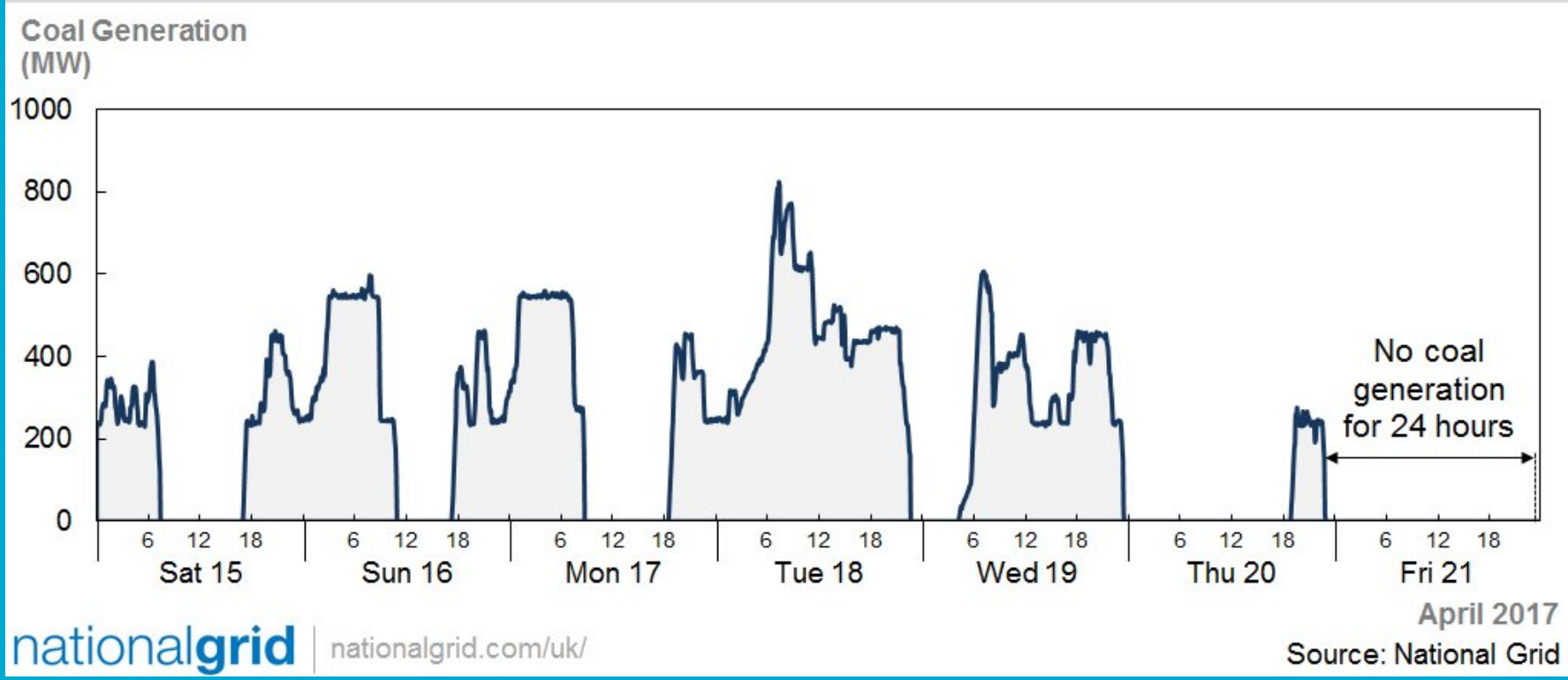
ref www.londonarray.com

Gemini windpark offshore Netherlands just opened

Dutch officials have opened what is being billed as one of the world's largest offshore wind farms 85 km offshore, with 150 turbines producing 600 MW. Cost: Aus $ 3 bn

Great Britain goes without Coal Generation for 24 hours

Friday 21st April 2017 was the first 24-hour period since the 1880s where Great Britain went without coal-fired power stations.

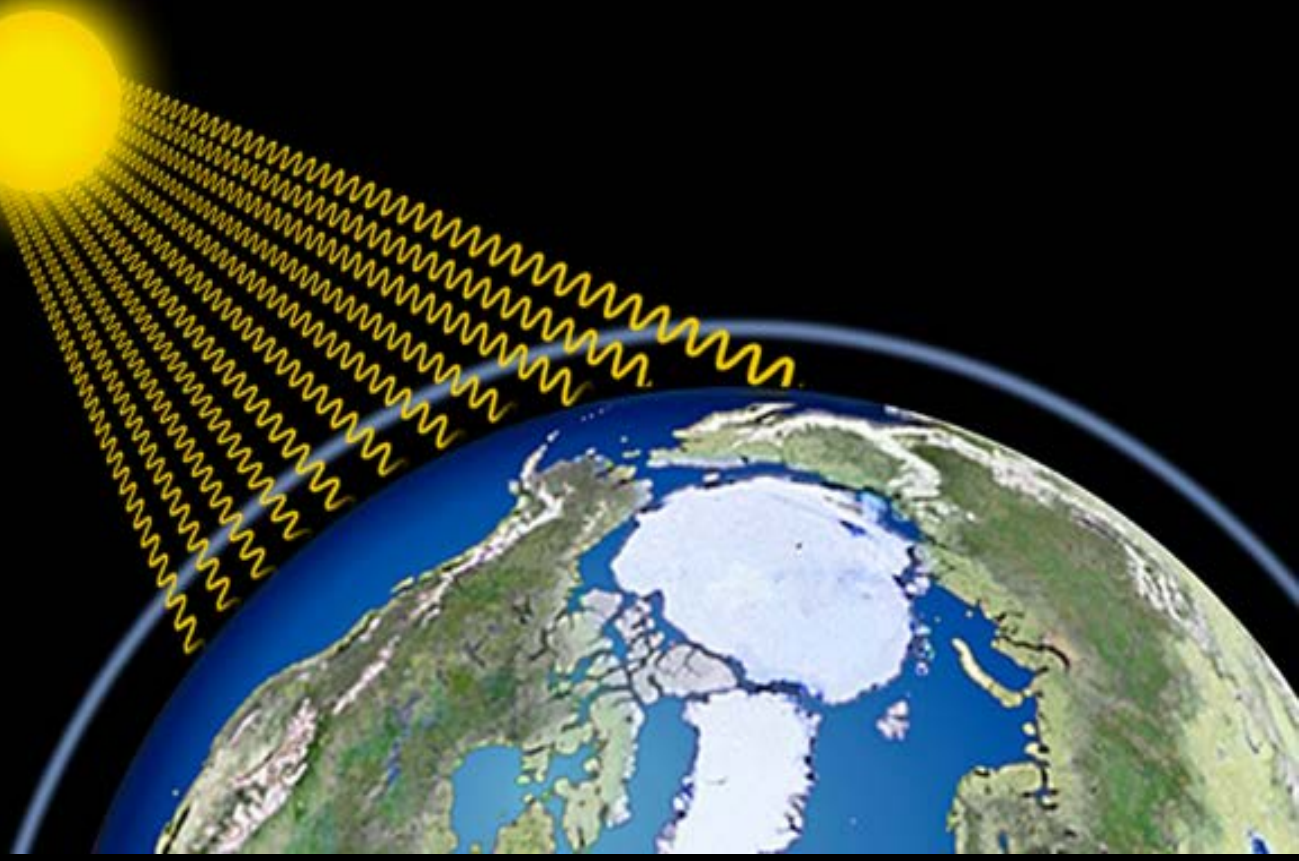


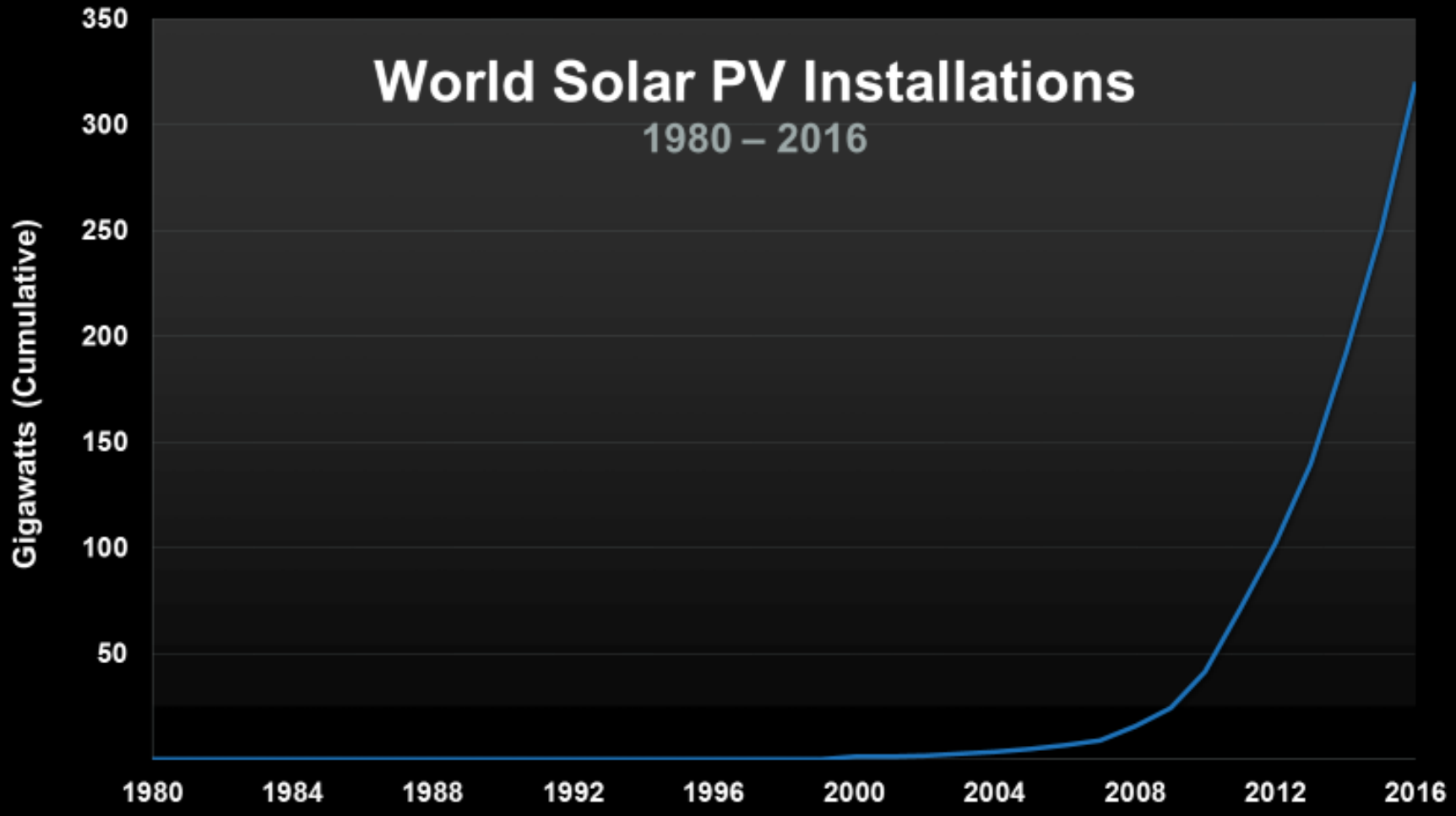
nationalgrid | nationalgrid.com/uk/

Source: National Grid

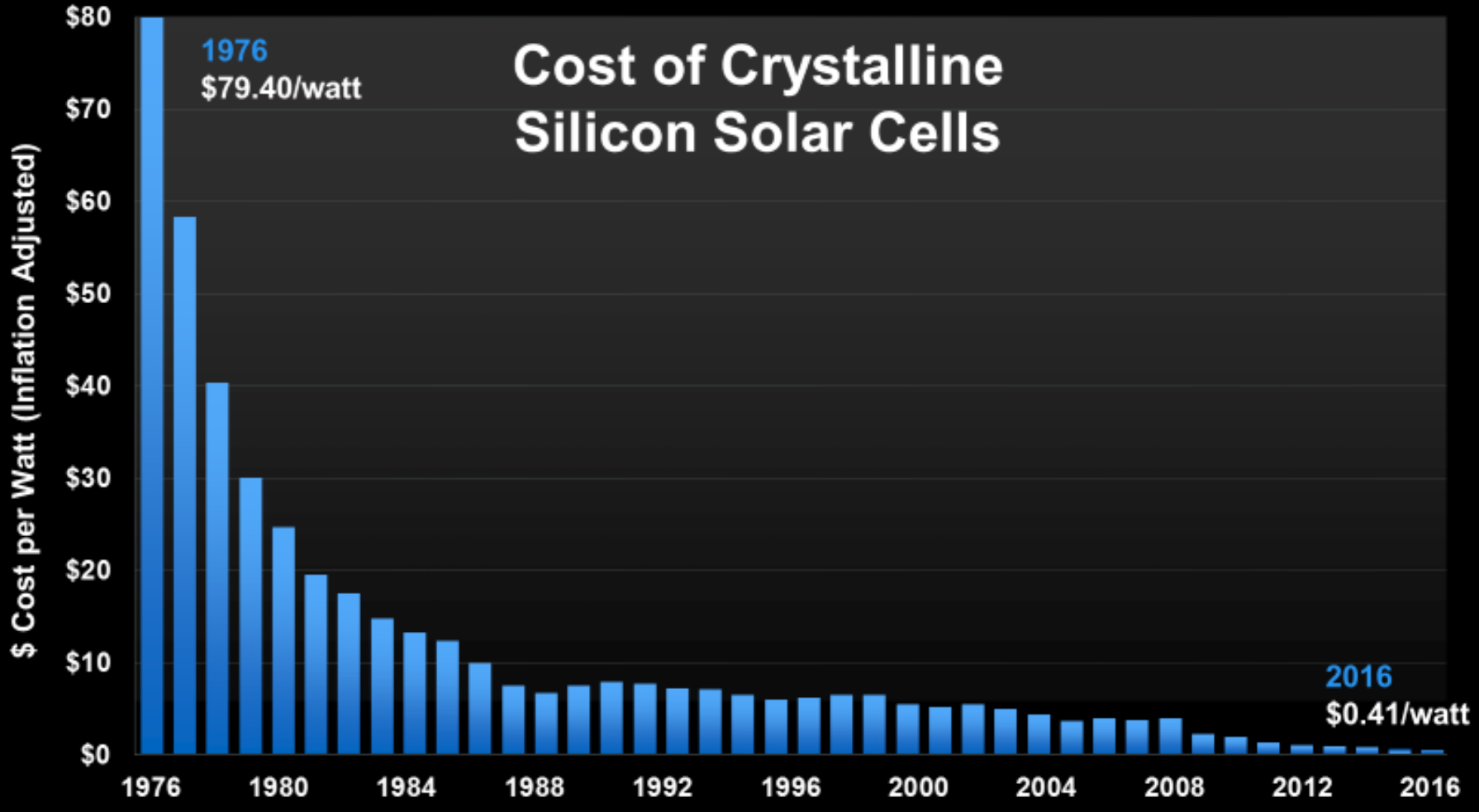
EU energy companies pledge no new coal fired power stations from 2020

Enough solar energy reaches Earth every hour to fill all the world's energy needs for a full year



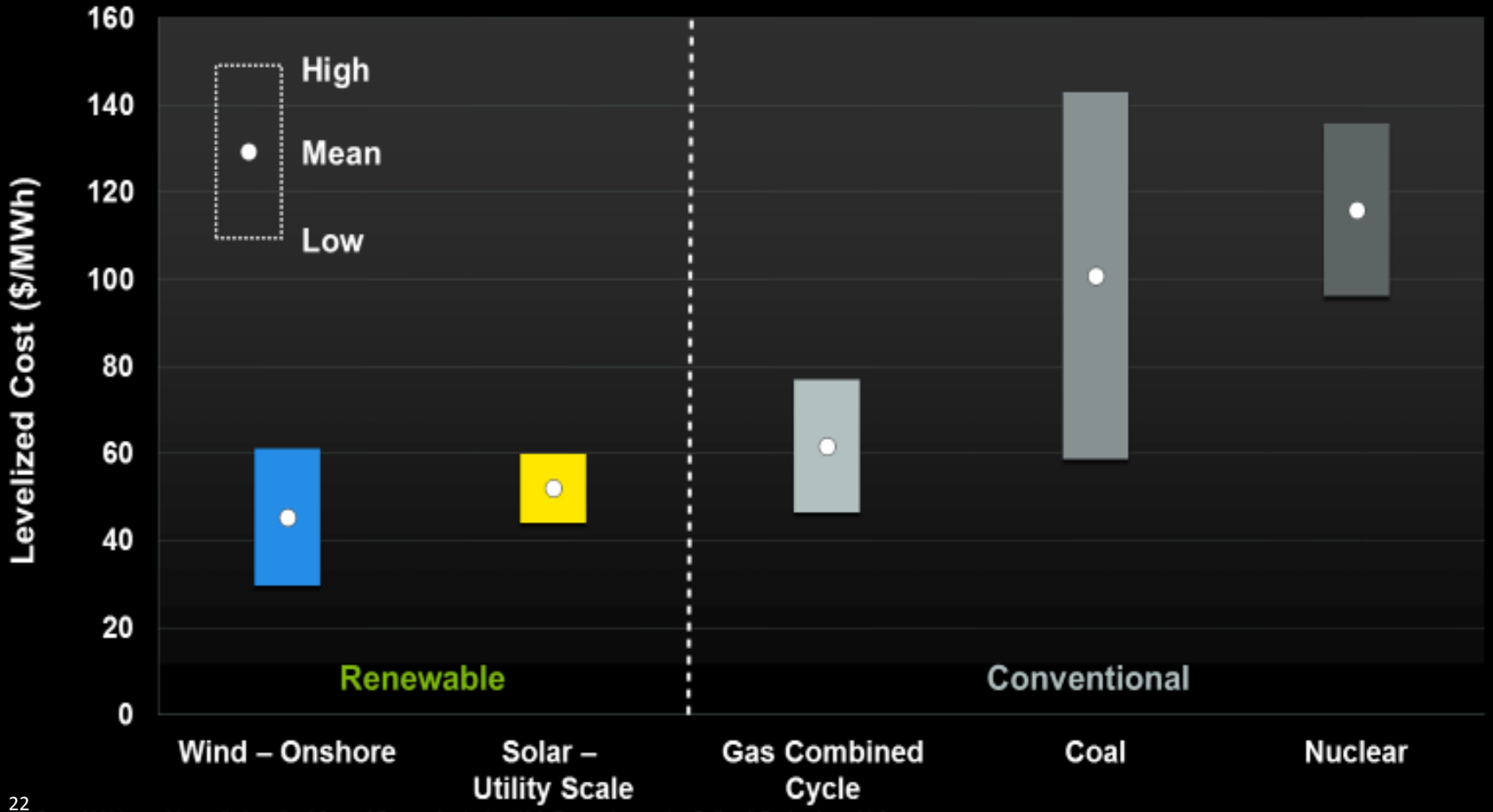


Data: Earth Policy Institute/BP, *Statistical Review of World Energy* June 2014 (London: 2014).



Data: Bloomberg New Energy Finance

Levelized Cost of Energy in the U.S.



Data: 2016 Lazard *Lazard's Levelized Cost of Energy Analysis v.10.0*; Energy Innovation Policy & Technology, LLC

levelized costs (LCOE)

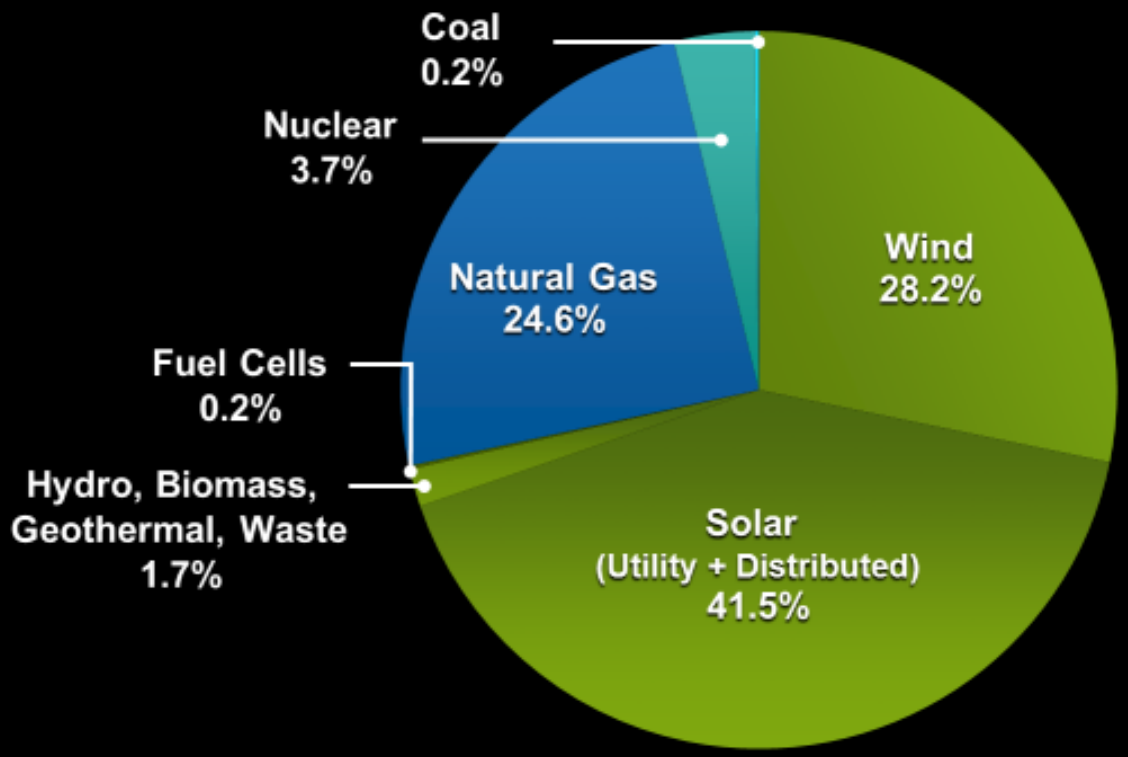
LCOE Is the average cost of producing electricity from a particular technology over its entire life, given assumptions about how the power station will operate.

It is the cost of power as delivered to the plant boundary. i.e does not include connection to grid or grid management costs

As defined in: Australian Power Generation Technology Report , 2015

New Electric Generation Capacity in the U.S.

2016



Data: Bloomberg Finance L.P. and the Business Council for Sustainable Energy: *2017 Sustainable Energy in America Factbook*

January 8, 2015

"…we believe the trend is clear:
grid parity
without subsidies
is already here,
increasing parity will occur, and
solar penetration rates
are set to ramp worldwide."

Deutsche Bank

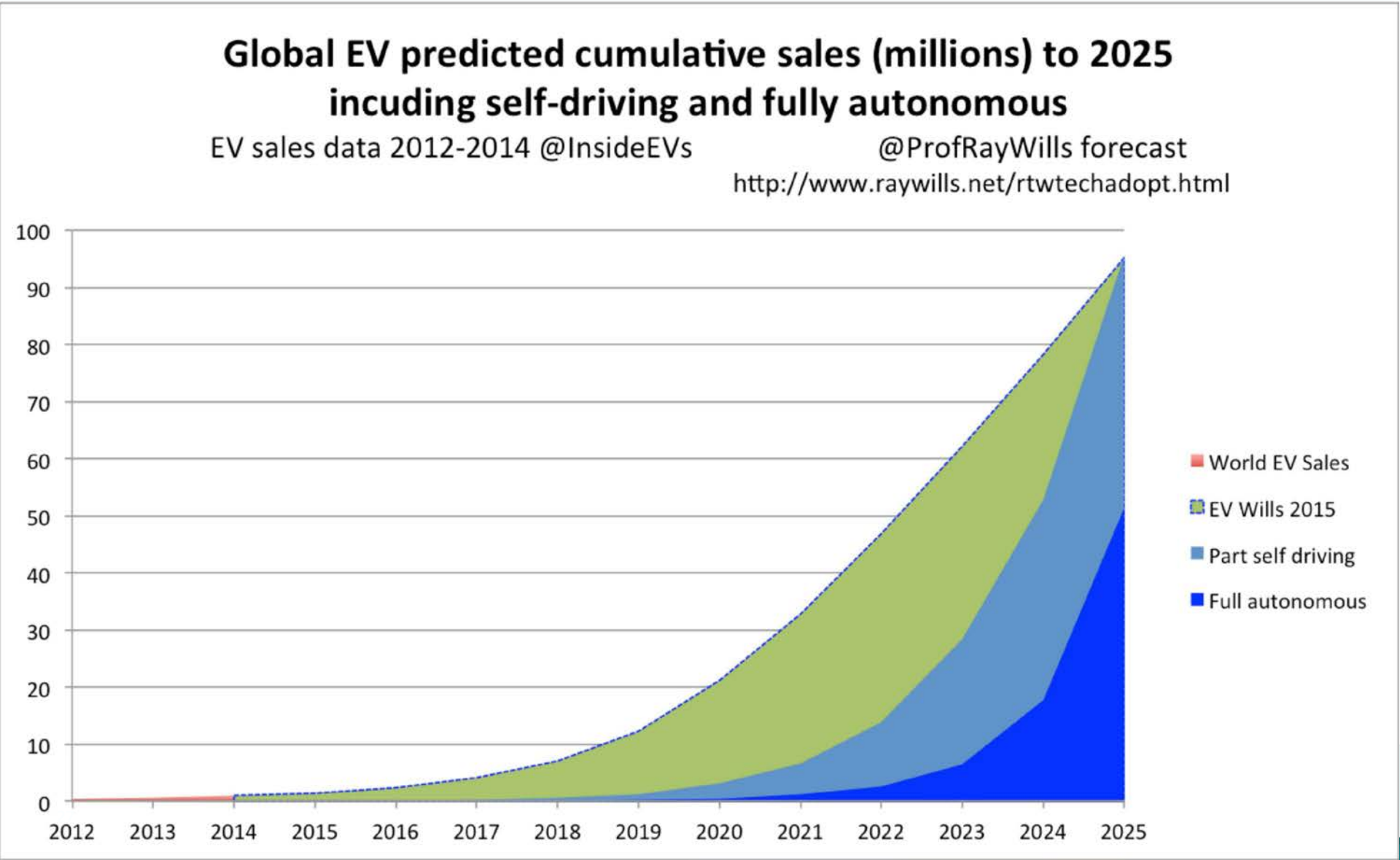
Increased use of electric vehicles

Why electric vehicles ?

There are a number of compelling benefits for electric cars over conventional petrol/diesel vehicles:

- *Vast improvement in air quality in our cities.*
- *Reduction in health costs caused by air pollution.*
- *Less noise pollution.*
- *Less CO2 into the atmosphere. Less poisonous and cancer causing emissions in our cities.*
- *Electric cars are much cheaper to run and require minimal servicing.*
- *The batteries are recyclable and not considered hazardous to the environment.*

Projected global sales of electric vehicles



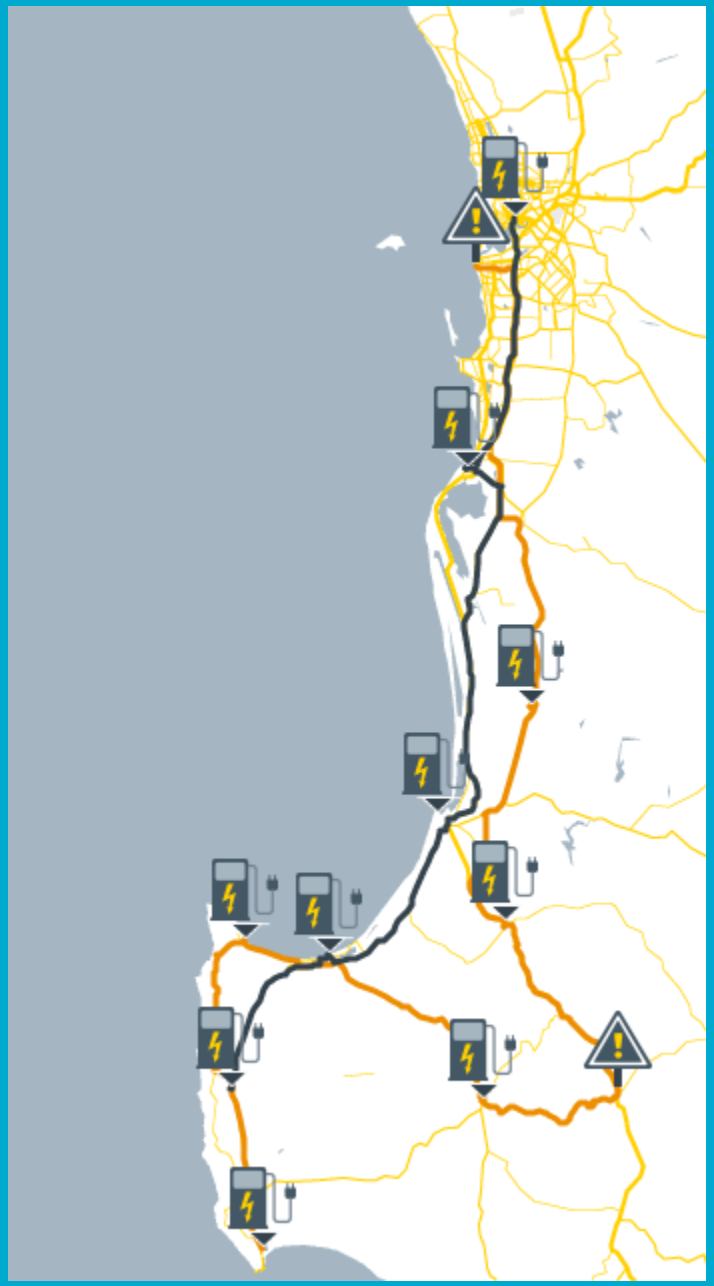
Tesla P850 electric car

Range approx. 500 km.
Supercharging stations add 100 km range in 10 minutes

Tesla 3 electric vehicle now in production

BMW i3 electric vehicle
Awarded World Car Design of the Year 2014 and World Green Car 2014

Max output	125kW (170hp)
Power consumption	12.9kWh/100km
Overall range in everyday use	130-160km
Torque	250Nm from a standing start
Charging	30 mins – at a suitable location, e.g. along the RAC Electric Highway®; or 3-6hrs – with a BMW i Wallbox for your home



EV charging stations in SW WA

Perth
Fremantle
Mandurah
Harvey
Bunbury
Bussleton
Dunsborough
Margaret River
Augusta

Donnybrook
Nannup
Bridgetown

Queensland to build one of the world's longest electric vehicle highways

The route, which will span 2,000km from Cairns to Coolangatta and west to Toowoomba, within six months will offer drivers 18 free recharging stations

Joshua Robertson

Thursday 27 July 2017 15.48 AEST

Queensland will have a 2,000km network of electric vehicle charging stations that make up one of the world's longest electric vehicle highways within six months.

The state government announced on Thursday it would build an 18-station network stretching along Queensland's east coast from Cairns to Coolangatta and west to Toowoomba.

The stations, which recharge a vehicle in 30 minutes, will offer free power for at least a year in what the environment minister, Steven Miles, said was a bid to boost the number of electric cars on Queensland roads, currently about 700.

From Guardian website 27 July 2017

Lithium reserves

- *The global reserves of lithium and recent studies suggest supplies of Lithium are more than adequate to power the global fleet till at least the end of this century - see Global Lithium availability –a constraint for electric vehicles (University of Michigan, 2010)*
- *The global resource estimates are more than 38 million tonnes.*
- *It is also estimated that seawater contains 230 billion tonnes. A South Korean company (POSCO) has developed technology to extract lithium from seawater.*
- *Lithium is also recyclable and EV manufacturers such as Tesla and Ford have already implemented recycling for their battery packs.*

Electric vehicles in Japan

Japan now has more electric charging points than petrol stations.
As at May 10, 2016, Japan had 6469 quick charging stations
vs 3028 in Europe and
1686 in USA.

ref: www.theguardian.com/world/2016/may/10/japan-electric-car-charge-points-petrol-stations

Australian examples of increasing use of renewable energy

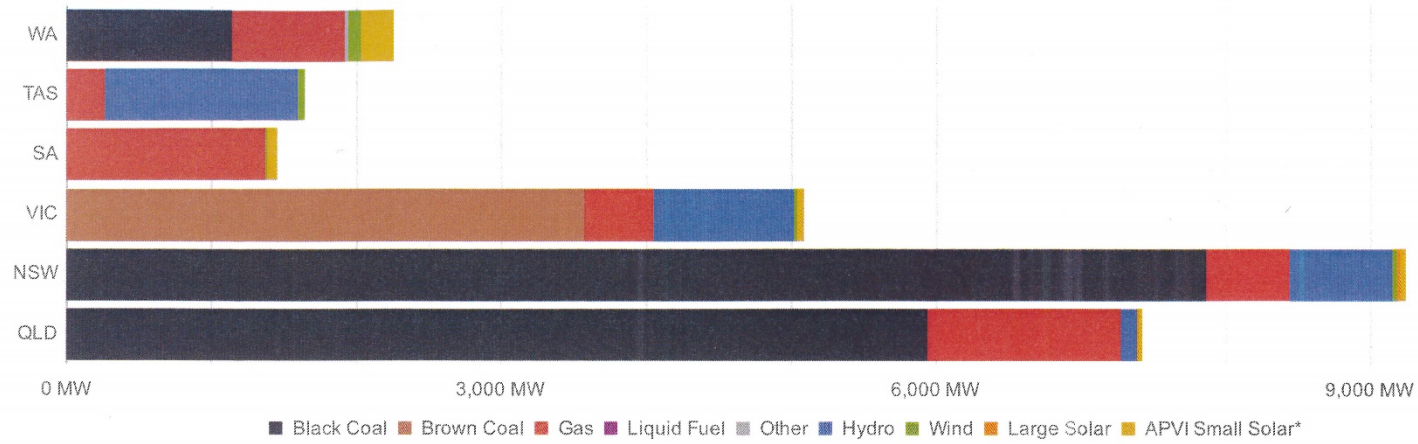
Opportunities

- *Energy network transformation – milestones following release of the roadmap 28 April 2017*
- *Solar pv*
- *Concentrated solar thermal*
- *Improved batteries*
- *Electricity grid stabilisation*
- *Increased use of wave power*
- *Hydrogen from Ammonia – export potential*
- *Increased use of electric vehicles – need longer range and lower price*
- *Many new jobs in renewables. Germany aims to have as many as in German car industry.*
- *Mining sector to increase exploration for minerals required for renewable energies*
- *Chief Scientist Alan Finkel review mid 2017*

Live generation for Australian States at 1705 aest 10 May 2017

5/10/2017

Nem Watch : RenewEconomy

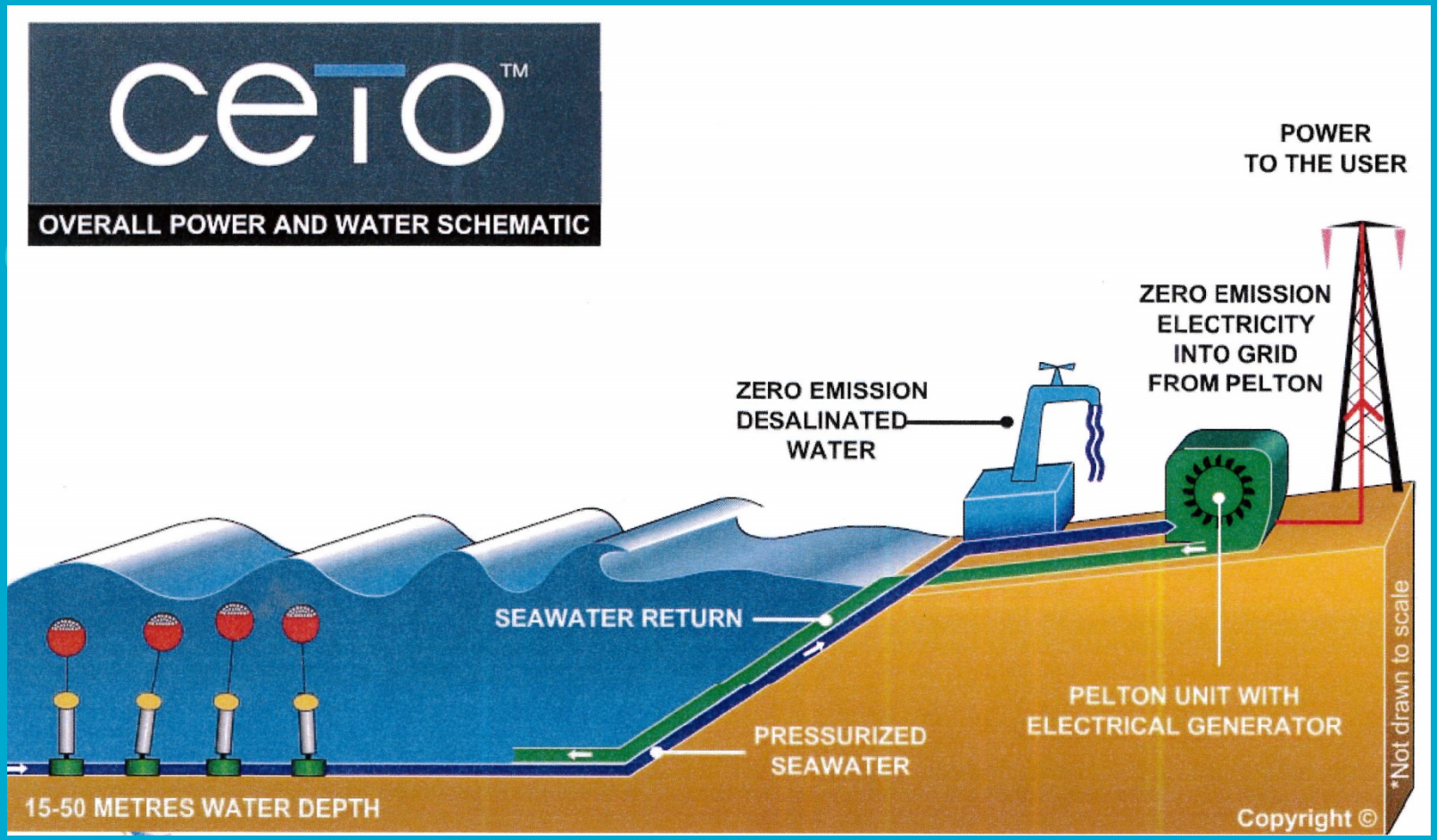


Region	Black Coal (MW)	Brown Coal (MW)	Gas (MW)	Liquid Fuel (MW)	Other (MW)	Hydro (MW)	Wind (MW)	Large Solar (MW)	APVI Small Solar* (MW)	Region Total (MW)
WA	1,147	0	777	0	17	0	89	8	205	2,243
TAS	0	0	265	0	0	1,331	36	0	0	1,632
SA	0	0	1,381	0	0	0	5	0	62	1,448
VIC	0	3,578	479	0	0	967	26	0	33	5,083
NSW	7,866	0	579	0	0	721	33	12	23	9,234
QLD	5,943	0	1,344	0	0	104	0	8	12	7,411
Total	**14,956**	**3,578**	**4,825**	**0**	**17**	**3,123**	**189**	**28**	**335**	**27,051**

* APVI small solar data is delayed. Mouse over the solar in each region for the specific delay.

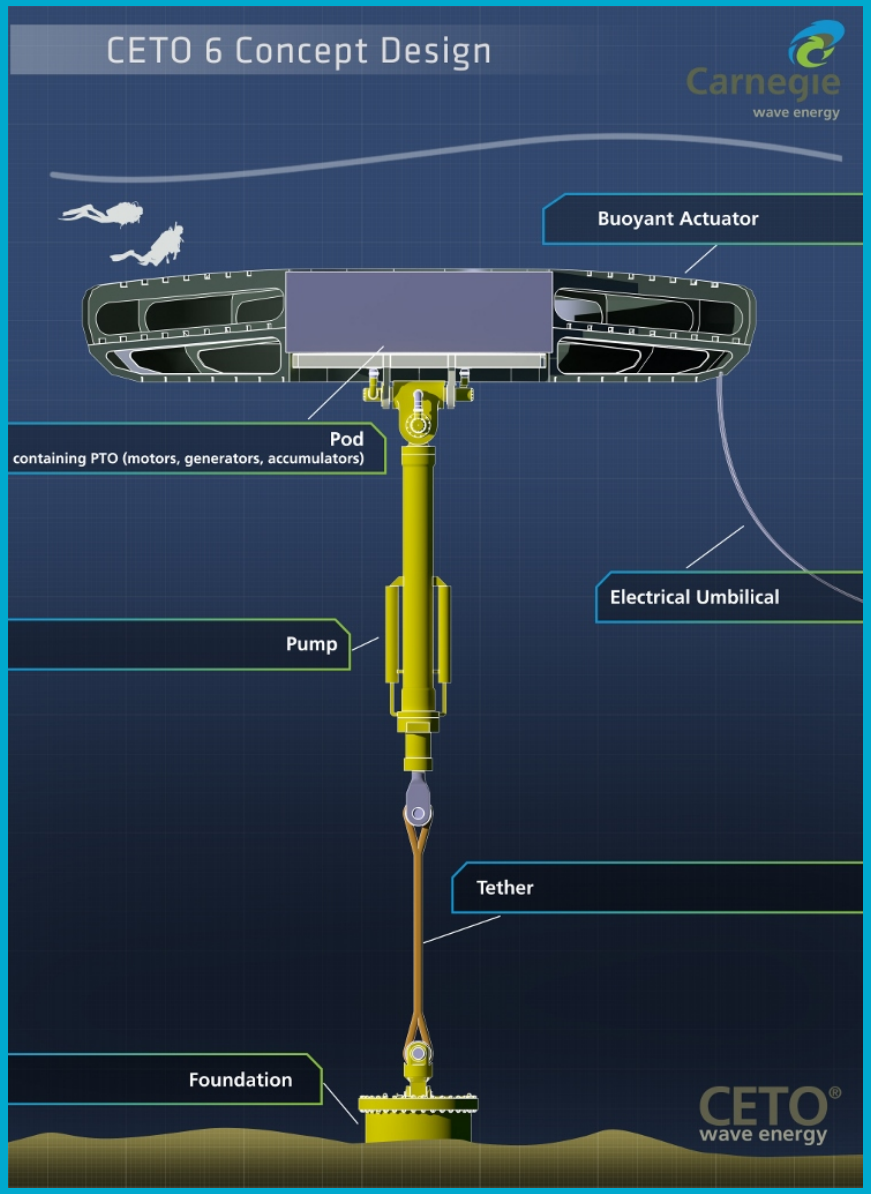
www.reneweconomy.com.au/nem-watch

widget by Global-Roam Pty Ltd


ceTO™
OVERALL POWER AND WATER SCHEMATIC
POWER
TO THE USER
ZERO EMISSION
ELECTRICITY
INTO GRID
FROM PELTON
ZERO EMISSION
DESALINATED
WATER
SEAWATER RETURN
PELTON UNIT WITH
ELECTRICAL GENERATOR
PRESSURIZED
SEAWATER
15-50 METRES WATER DEPTH
*Not drawn to scale
Copyright ©

Wavepower and desalination from Carnegie CETO system

- *Developed in Western Australia*
- *High pressure water at 1000 psi to generate electricity and run reverse osmosis desalination*
- ***Now being implemented at Garden Island naval base near Perth***
- *Will be tested soon at Cornish wave hub in UK*
- *Latest version CETO 6 produces electricity within the buoy and does not send high pressure water back to shore*
- ***CETO 6 proposed for Albany and has $ 20 m funding from WA government***
- *Carnegie advising Mauritius government on possible integrated system including wave, wind and solar*
- *CETO 6 can generate 1.5 MW per buoy*


CETO 6 Concept Design
Carnegie
wave energy
Buoyant Actuator
Pod
containing PTO (motors, generators, accumulators)
Electrical Umbilical
Pump
Tether
Foundation
CETO®
wave energy

CSIRO technology - hydrogen for fuel cell vehicles

CSIRO is developing technology to export Australia's supply of gas and renewable energy in a form that can power next generation hydrogen fuel cell transport.

CSIRO is developing technology that will solve the problem of transporting hydrogen to bowsers that will refuel cars. The technology will also make it commercially viable to export hydrogen overseas as ammonia (NH3) for use in fuel cells.

CSIRO's approach is to transport the hydrogen as ammonia (NH3) to bowsers, where it can be converted back to high-purity hydrogen for use in fuel cell vehicles. "CSIRO's membrane reactor technology will fill the gap between hydrogen production, distribution and delivery in the form a modular unit that can be used at, or near, a refuelling station,"

Ref: CSIRO media release 3 May 2017

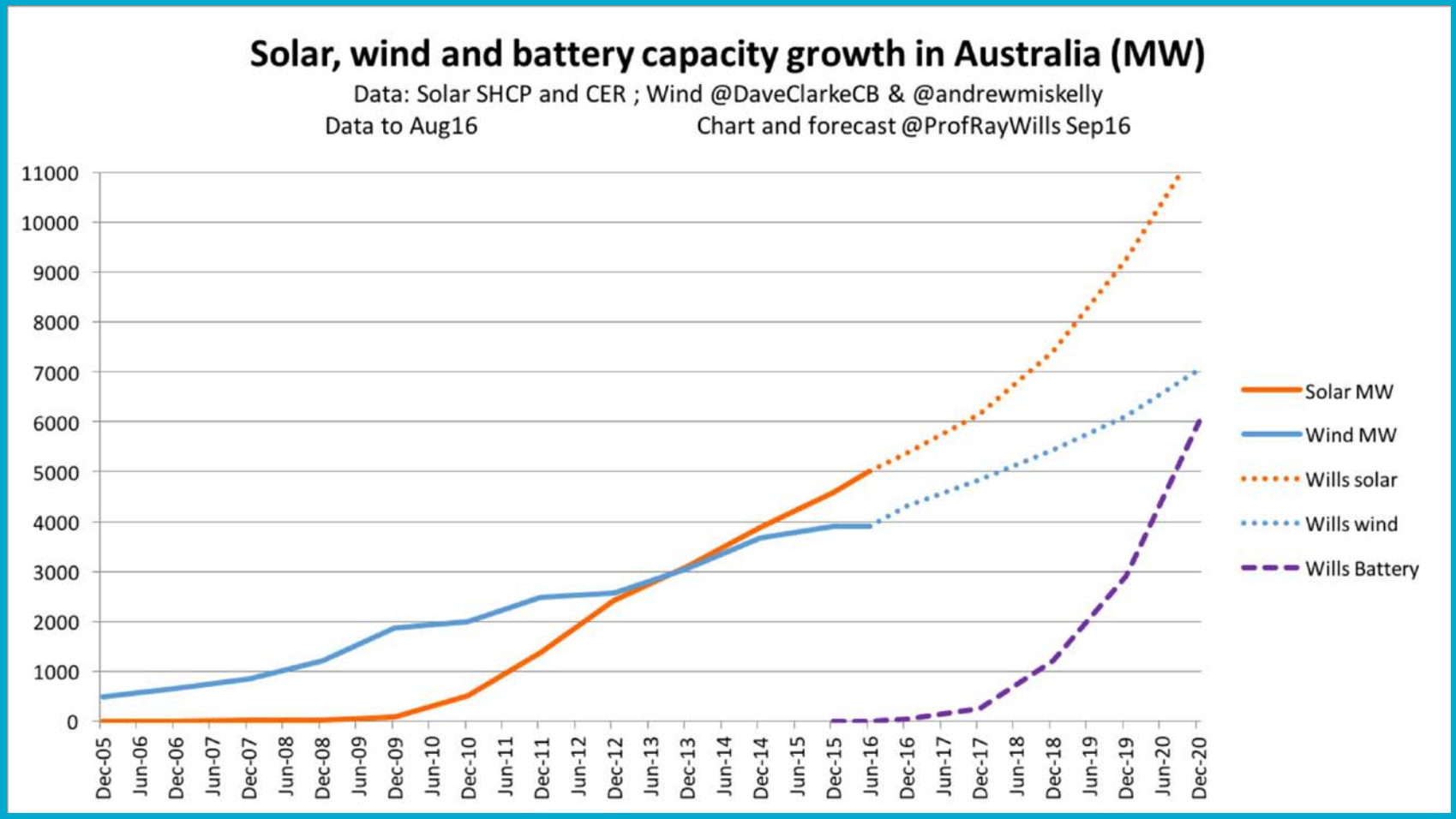
Toyota fuel cell vehicle

New solar farm to be built by private sector in South Australia

Lyon Group announces South Australia to get $1 bn solar farm (330 MW) and world's biggest battery (100 MW with 4 hours of storage)

System will include 3.4 m solar panels and 1.1 m batteries, with operations set to begin by end of 2017

Projections of solar pv, wind and battery growth in Australia



Australia had 4 GW of solar pv installed on 1.37 m homes as at Jan 2015

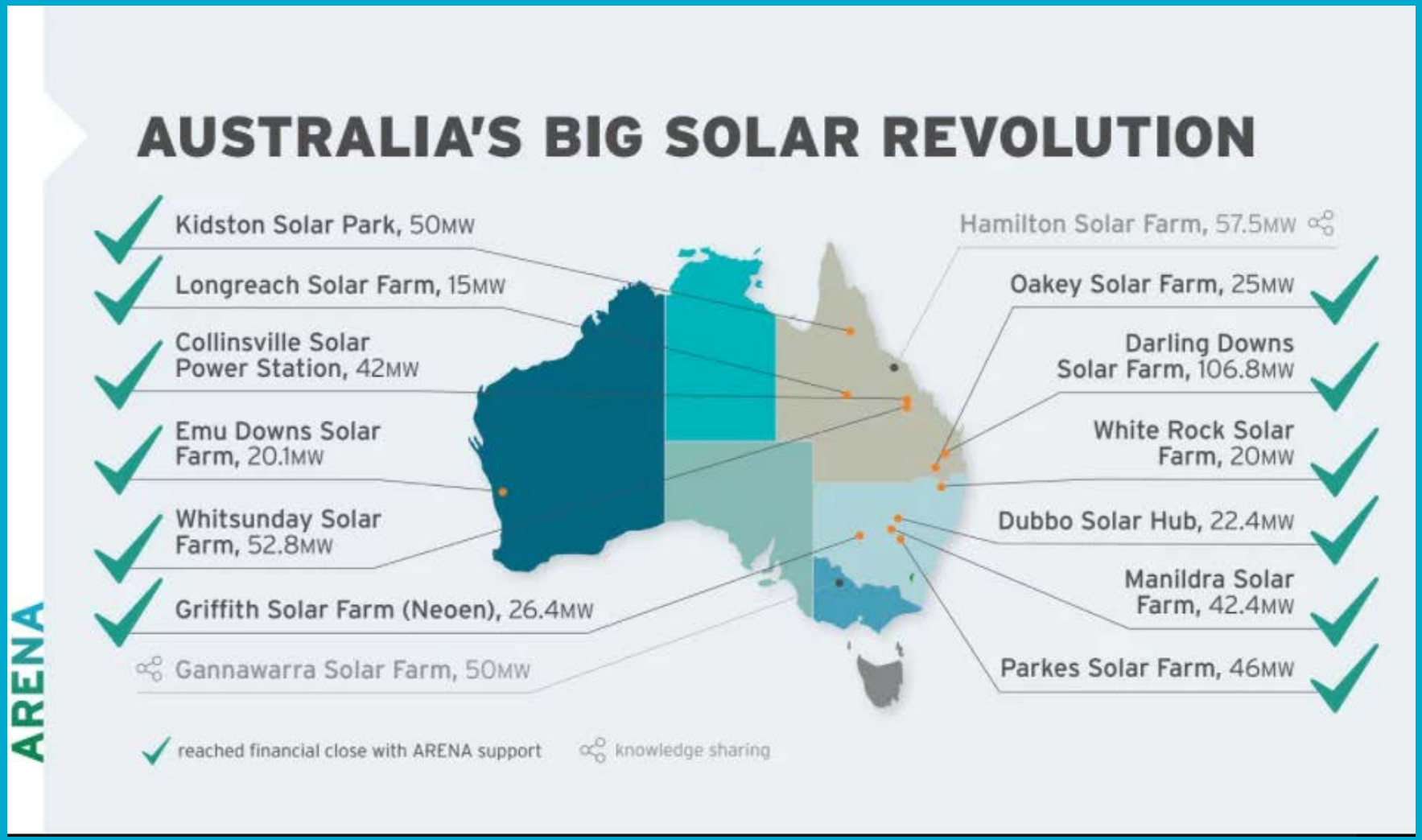
Lightweight 'printed solar' touted as a way to provide electricity in times of disaster

The creator of printed solar, Professor Paul Dastoor, at the trial site at the University of Newcastle. *www.abc.net.au/news/2017-05-15*

Large-scale solar industry takes off as 12 new plants secure finance (from ARENA)

Broken Hill solar farm.

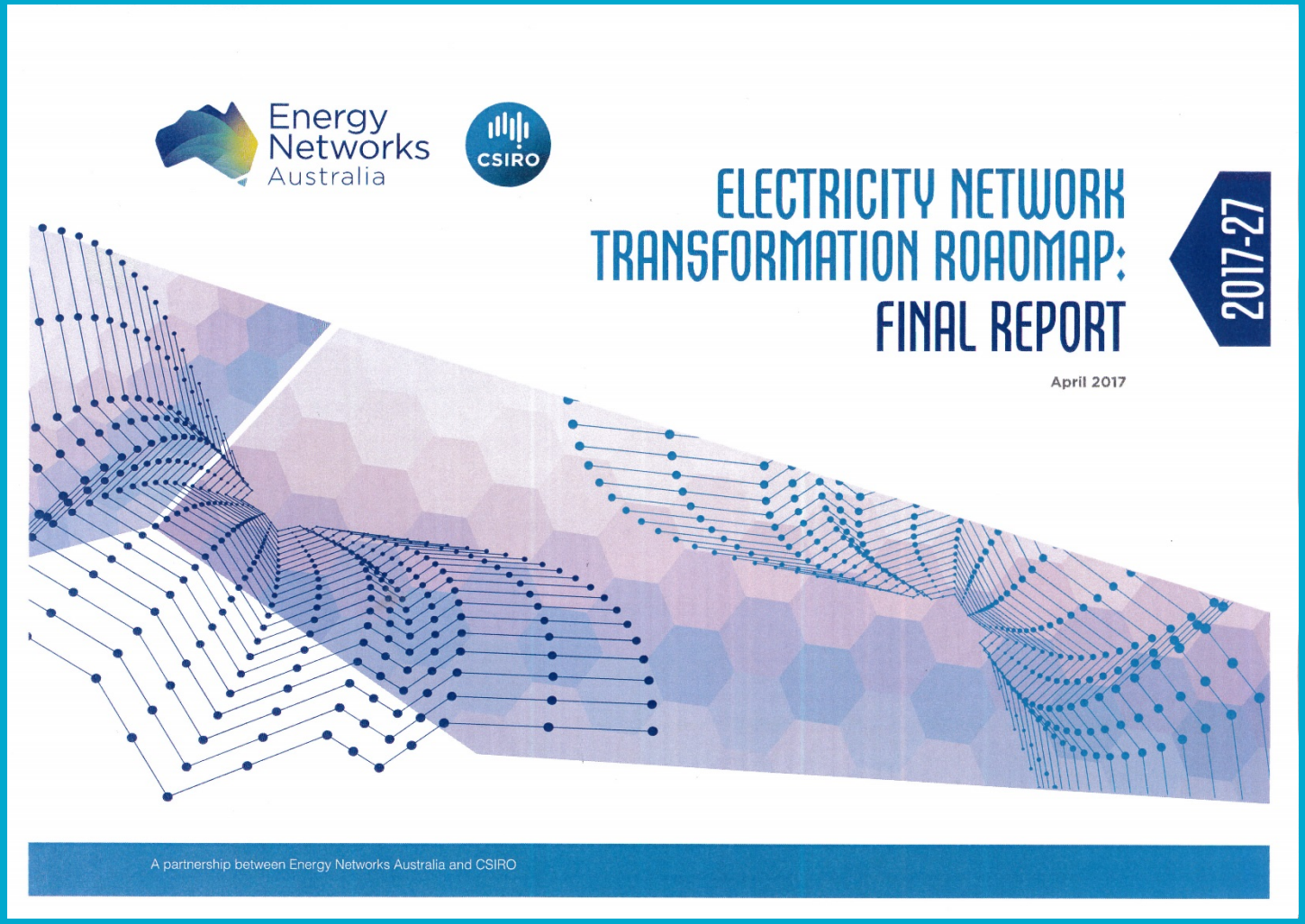
New solar developments with ARENA funding



CSIRO's solar thermal hub is a dynamic solar research facility.

Concentrated solar thermal with salt storage proposed for Port Augusta in South Australia

110 MW solar tower system proposed by US company SolarReserve. $ 110 m committed recently by Australian government.
ref: www.reneweconomy.com.au
31 March 2017



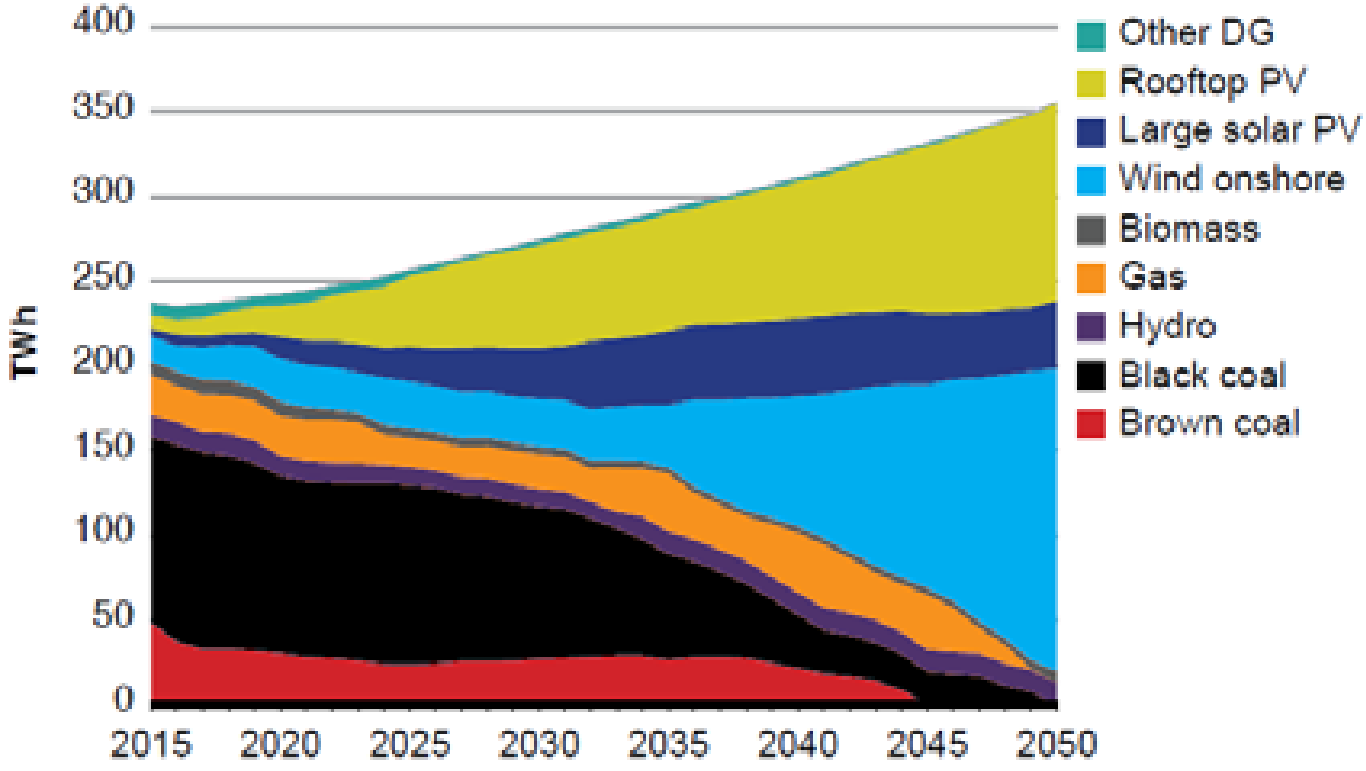
released 28 April 2017

The report finds that with a co-ordinated plan in 2050:

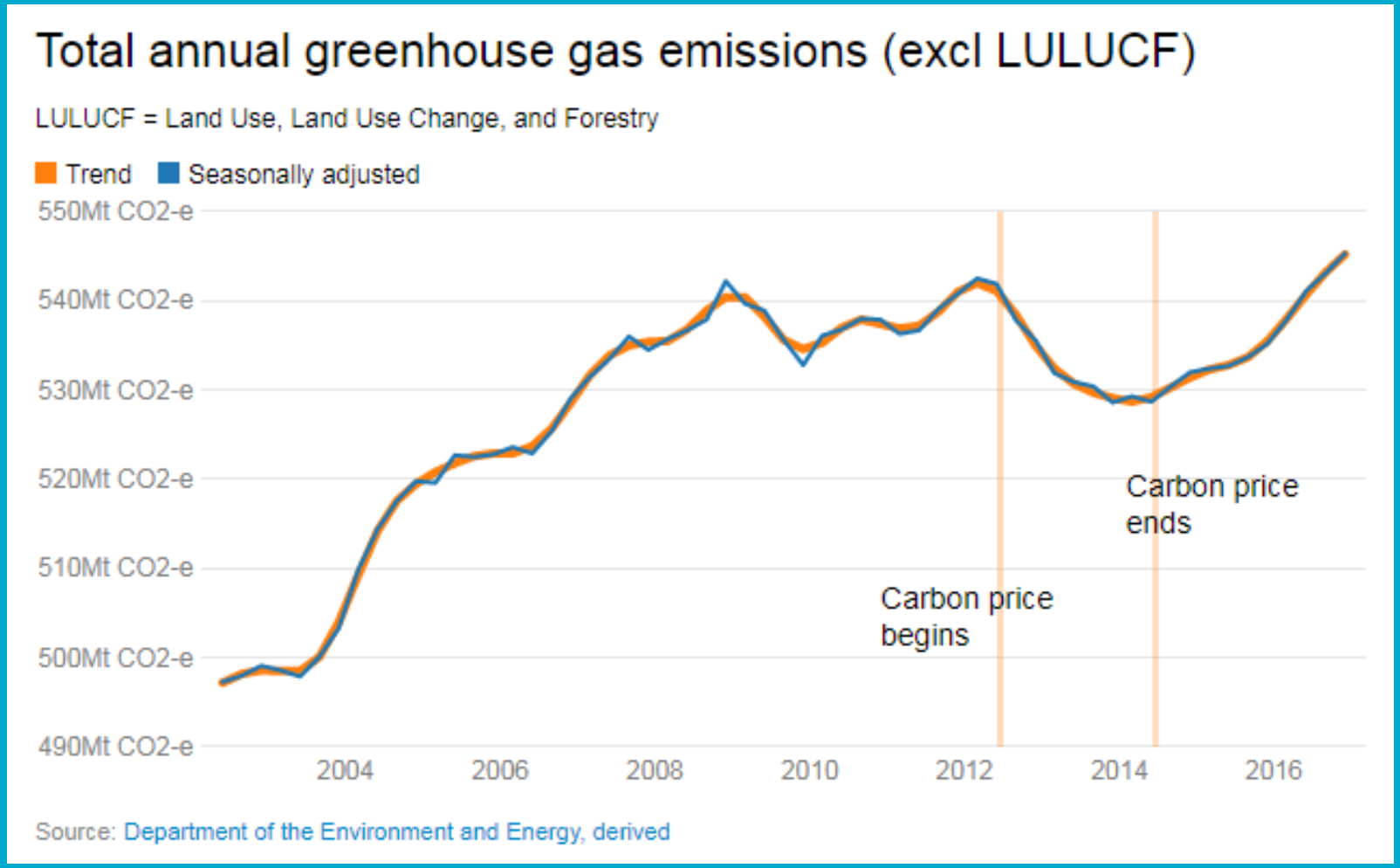
- **Customers retain security and reliability essential to lifestyle and employment**
- **Networks pay distributed energy resources customers $2.5 billion per annum for grid support services by 2050.**
- **Electricity sector achieves zero net emissions by 2050**
- **$16 billion in network infrastructure investment is avoided by management of distributed energy resources like solar and batteries**
- **Reduction in cumulative total electricity network expenditure of $101 billion by 2050**
- **Network charges 30% lower than 2016**
- **$414 annual saving in average household electricity bills (compared with roadmap counterfactual, business as usual, pathway)**
- **A medium family who cannot take up distributed energy resources is over $600 p.a. better off through removal of cross subsidies.**

Electricity generation mix

Projection of Australia's changing electricity generation mix to 2050

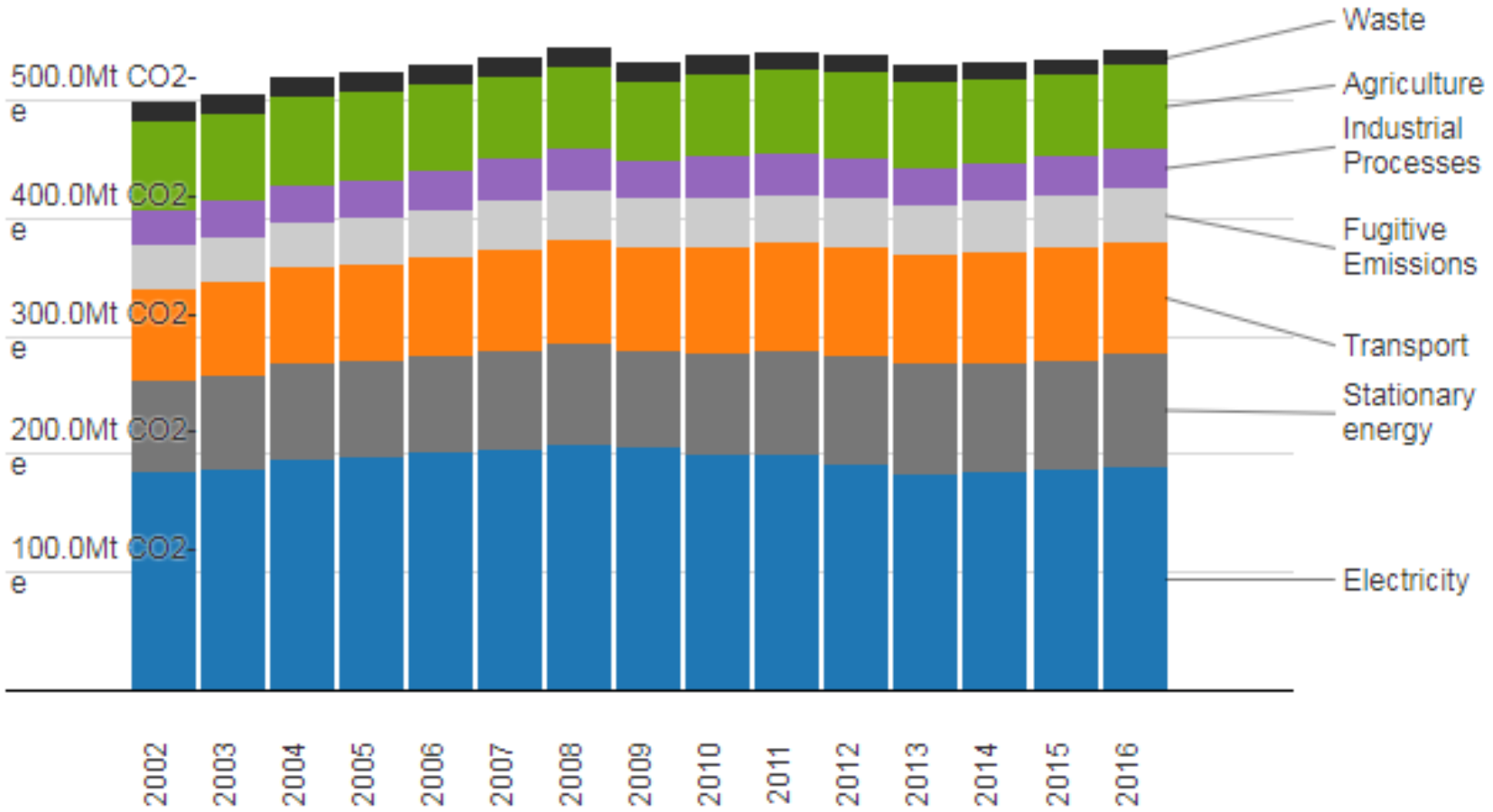


source: Electricity network transformation roadmap, April 2017



The biggest contributor to our emissions is the electricity sector – around 35% of all emissions:

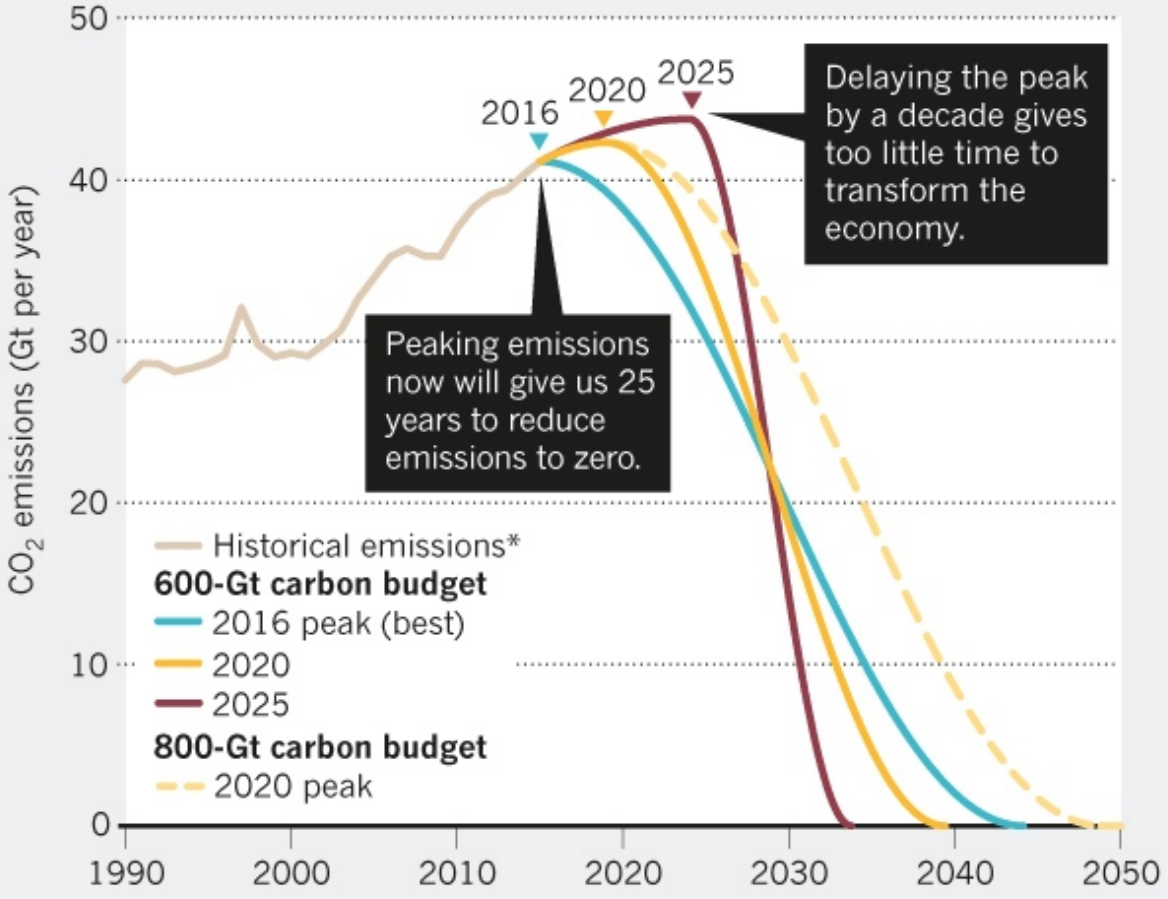
Australia's annual greenhouse gas emissions by sector



Source: Dept of Environmnet

CARBON CRUNCH

There is a mean budget of around 600 gigatonnes (Gt) of carbon dioxide left to emit before the planet warms dangerously, by more than 1.5–2°C. Stretching the budget to 800 Gt buys another 10 years, but at a greater risk of exceeding the temperature limit.



©nature

*Data from The Global Carbon Project.

from:
Three years to safeguard our climate, Figueres et al, Nature 28 June 2017

A panoramic view of fluorescing and bleaching corals in New Caledonia in the southwest Pacific, in March 2016.

THE OCEAN AGENCY/XL CATLIN SEAVIEW SURVEY

http://blogs.nature.com/aviewfromthebridge/2017/07/17/chasing-coral/

17 July 2017

A bleached reef.

CHASING CORAL, COURTESY OF NETFLIX

challenges

- *Rapid global decrease required of Greenhouse gas emissions. Zero emissions of CO2 by 2050*
- *Need to keep up and improve Paris commitments.*
- *Trump not helping ! But progressive individual US states and companies still going well with renewables*
- *Need for stable and agreed long range policies to enable further investments in renewable energies*
- *Managing the transition*

Some conclusions

- *Climate change is urgent global issue that we all need to address*
- *Some solutions are emerging which create jobs, economic benefits, research opportunities and healthier environments*
- *Increasing deployment of renewables and rapidly decreasing costs*
- *Batteries and other forms of storage key to more use of renewables*
- ***Economics and private sector investments will be key drivers***
- ***Need for stable long range, agreed policies and viable roadmaps***

WE NEED TO ACT ON CLIMATE CHANGE

SCIENTISTS AGREE

The overwhelming majority of the world's climate scientists agree: man-made climate change is a reality. Unless we act now, temperatures will rise beyond our control.

THERE ARE REAL DANGERS

We're looking at a future of seas climbing up our shores; devastating floods, droughts, and storms becoming more frequent facts of life; seasons changing beyond recognition; and dangerous consequences for our health we're only beginning to understand.

IT'S OUR DUTY

We have a moral responsibility to each other and to our children to address this crisis. This is our one beautiful and deeply precious home.

WE CAN SOLVE CLIMATE CHANGE

WE HAVE THE MEANS

We know how to stop climate change, and we have the tools to do it. We start by ditching the dirty fossil fuels devastating our climate and our health and switching to clean, reliable, and affordable renewable energies like wind and solar.

IT MAKES ECONOMIC SENSE

Changing technology means renewables keep getting cheaper, more accessible, and more widespread everywhere from rooftops to power plants. Renewable energy costs the same or less than energy from fossil fuels. In 2014, numerous countries' economies grew while their carbon emissions levels dropped.

WE'RE DOING IT TOGETHER

We're bringing together people from all walks of life and corners of the earth to support a strong climate agreement in Paris that puts us on the path to zero carbon emissions and the healthy and prosperous future we want. When the world speaks with one voice, our leaders have to listen.

Spare slides

Further, faster, together
If we delay, the conditions for human prosperity will be severely curtailed.

There are three pressing and practical steps:

1. *First use science to guide decisions and set targets. Policies must be based on robust evidence. Those in power must stand up for science. e.g President Macron in France.*

2. *Existing solutions must be scaled up rapidly. All countries should adopt 100 % renewable electricity production while ensuring that markets are designed to enable renewable energy.*

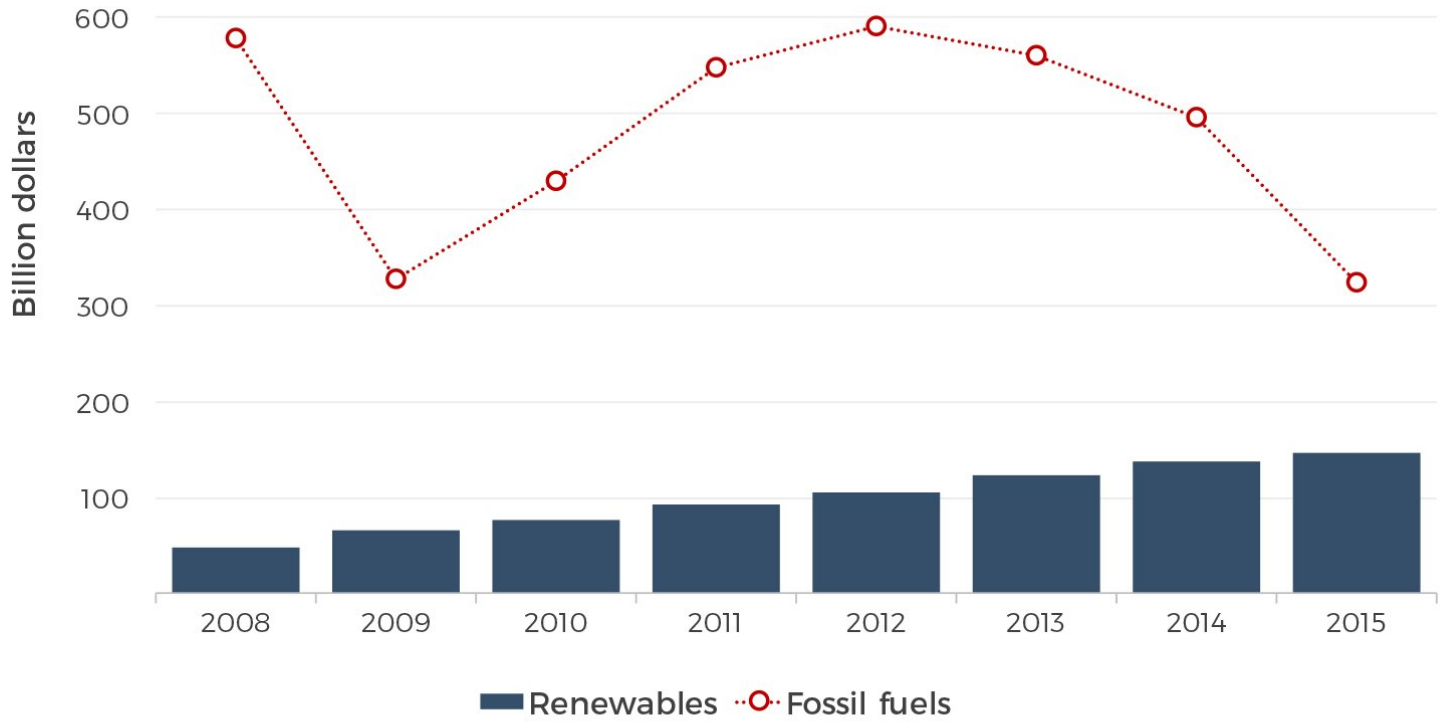
3. *Encourage optimism. Share success stories.*

Extract from "Three years to safeguard our climate". Figueres et al , Nature 28 June 2017

Initiatives such as We Are Still In , an open declaration of continued support of climate action to meet the Paris agreement. The letter has now been signed by 1,565 companies and investors, including giants such as Apple, Walmart, Microsoft, Adidas, Facebook and Google, as well as leaders from 208 cities and counties, nine US states and 309 colleges and u*niversities*

https://*www.theguardian.com/sustainable-business/2017/jun/30/no-more-business-as-usual-the-corporates-stepping-up-to-save-the-planet*

Estimates for global fossil-fuel consumption subsidies and subsidies for renewables



World Energy Outlook 2016

Thank you

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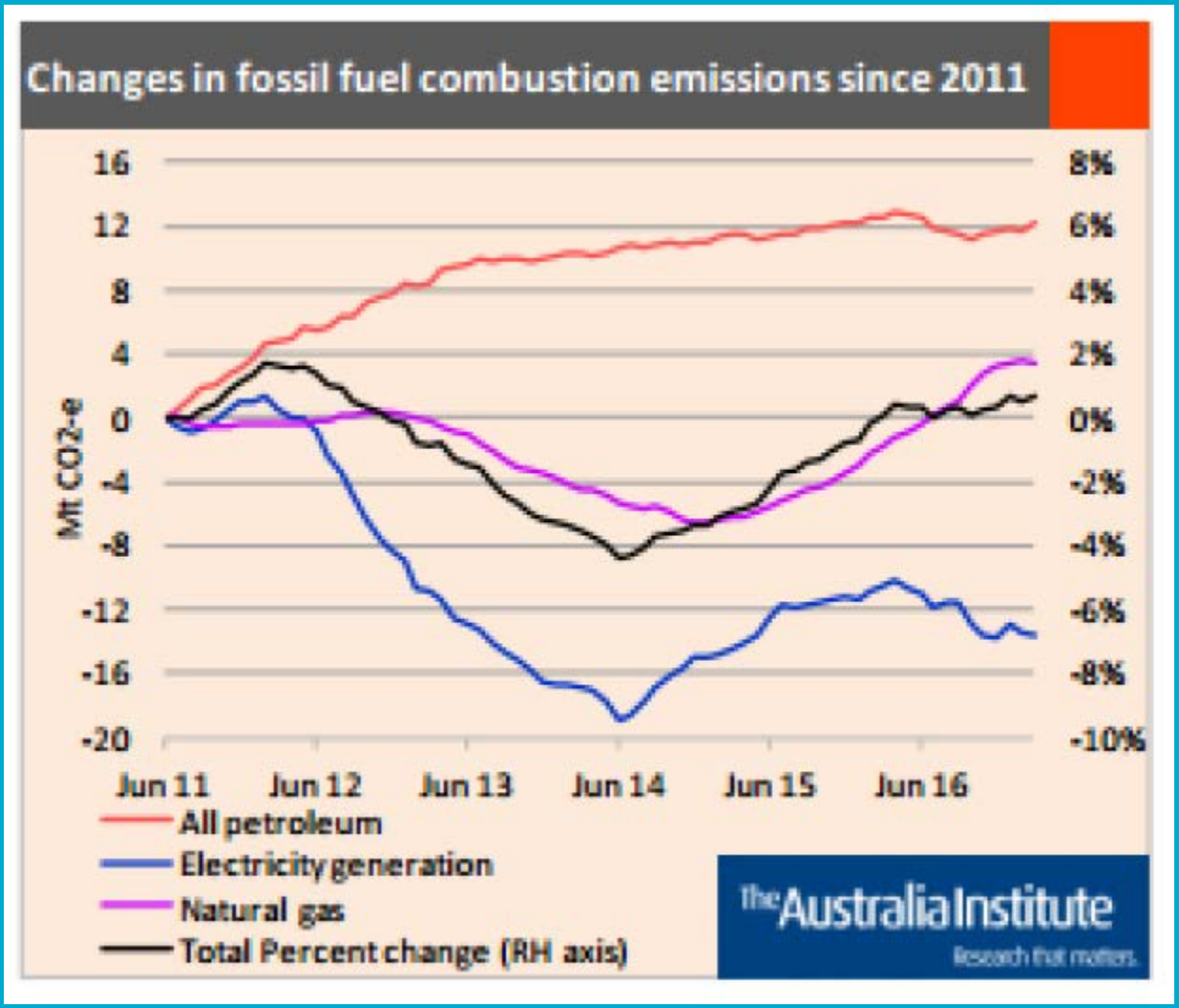
Andrew Vesey CEO of AGL Energy, opening address of Australian Energy Week in Melbourne 21 May 2017

In the opening address at Australian Energy Week in Melbourne on Wednesday, Vesey – who heads the country's biggest owner of coal-fired power station – said that technology was driving the new market direction, which was to large-scale renewables, firmed up by gas and soon battery storage.

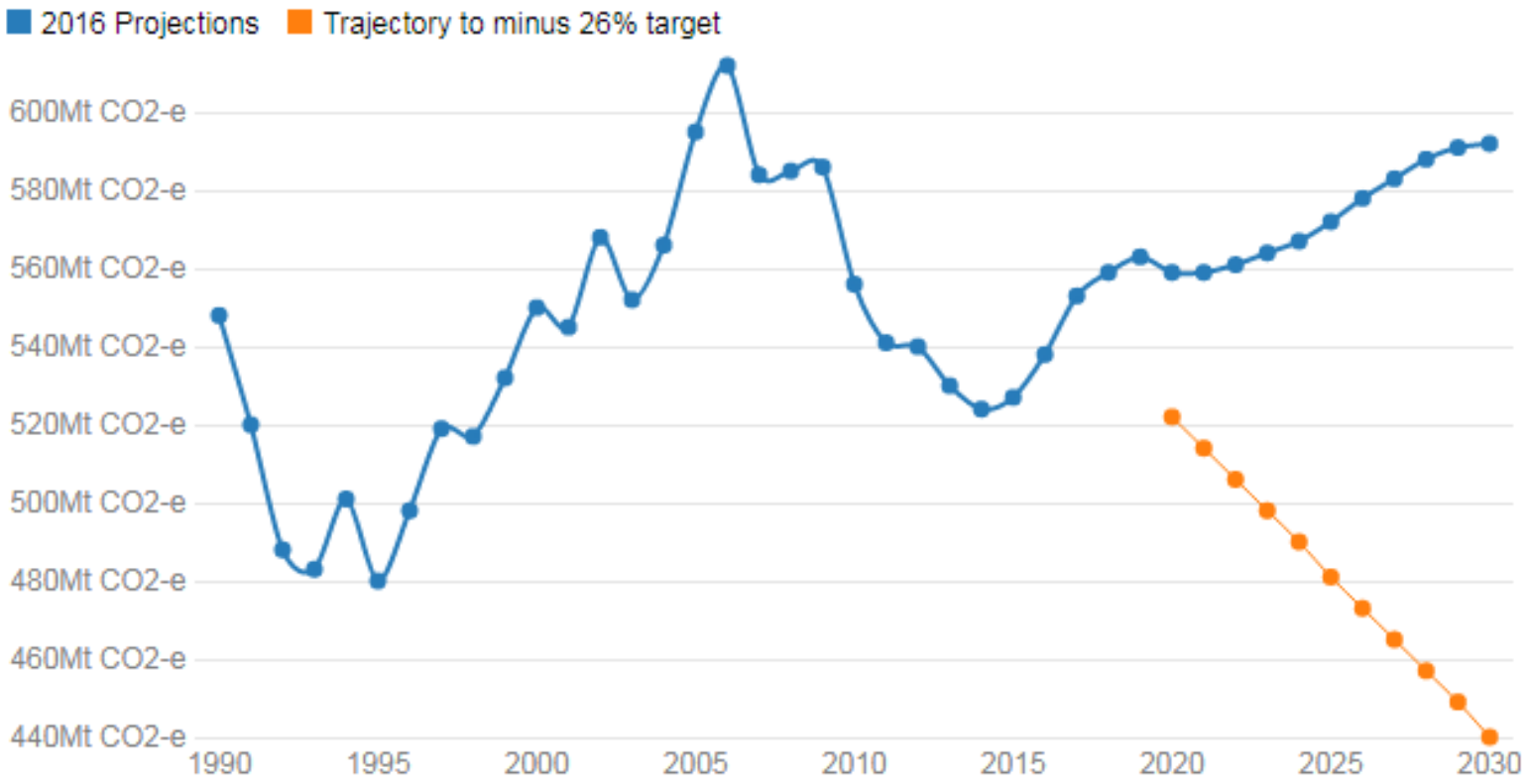

Changes in fossil fuel combustion emissions since 2011
16
12
8
4
0
-4
-8
-12
-16
-20
Mt CO2-e
8%
6%
4%
2%
0%
-2%
-4%
-6%
-8%
-10%
Jun 11
Jun 12
Jun 13
Jun 14
Jun 15
Jun 16
All petroleum
Electricity generation
Natural gas
Total Percent change (RH axis)
The Australia Institute
Research that matters

Al Gore, whose new film An Inconvenient Sequel: Truth to Power was released in July 2017, said

“There is now in our world a sustainability revolution and it’s best understood, in my view, by placing it in the context of other great global transformations – the agricultural revolution, the industrial revolution, the digital revolution,”

“This sustainability revolution has the breadth and magnitude of the industrial revolution but it has the speed of the digital revolution”

Australia's greenhouse gas emissions



Source: Dept of Environment and Energy

from:
Three years to safeguard our climate. Figueres et al , Nature 28 June 2017

Six milestones

To prioritize actions, we've identified milestones in six sectors. Developed with knowledge leaders, these were reviewed and refined in collaboration with analysts at Yale University, the Climate Action Tracker consortium, Carbon Tracker, the low-carbon coalition We Mean Business, the Partnership on Sustainable, Low Carbon Transport (SLoCaT), advisory firm SYSTEMIQ, the New Climate Economy project and Conservation International.

These goals may be idealistic at best, unrealistic at worst. However, we are in the age of exponential transformation and think that such a focus will unleash ingenuity. By 2020, here's where the world needs to be:

by 2020 here is where the world needs to be

Land. Land-use policies are enacted that reduce forest destruction and shift to reforestation and afforestation efforts. Current net emissions from deforestation and land-use changes form about 12% of the global total. If these can be cut to zero next decade, and afforestation and reforestation can instead be used to create a carbon sink by 2030, it will help to push total net global emissions to zero, while supporting water supplies and other benefits. Sustainable agricultural practices can reduce emissions and increase CO_2 sequestration in healthy, well-managed soils.

Industry. Heavy industry is developing and publishing plans for increasing efficiencies and cutting emissions, with a goal of halving emissions well before 2050. Carbon-intensive industries — such as iron and steel, cement, chemicals, and oil and gas — currently emit more than one-fifth of the world's CO_2, excluding their electricity and heat demands.

Finance. The financial sector has rethought how it deploys capital and is mobilizing at least $1 trillion a year for climate action. Most will come from the private sector. Governments, private banks and lenders such as the World Bank need to issue many more 'green bonds' to finance climate-mitigation efforts. This would create an annual market that, by 2020, processes more than 10 times the $81 billion of bonds issued in 2016.

by 2020 here is where the world needs to be

Energy. Renewables make up at least 30% of the world's electricity supply — up from 23.7% in 2015 (ref. 8). No coal-fired power plants are approved beyond 2020, and all existing ones are being retired.

Infrastructure. Cities and states have initiated action plans to fully decarbonize buildings and infrastructures by 2050, with funding of $300 billion annually. Cities are upgrading at least 3% of their building stock to zero- or near-zero emissions structures each year[9].

Transport. Electric vehicles make up at least 15% of new car sales globally, a major increase from the almost 1% market share that battery-powered and plug-in hybrid vehicles now claim. Also required are commitments for a doubling of mass-transit utilization in cities, a 20% increase in fuel efficiencies for heavy-duty vehicles and a 20% decrease in greenhouse-gas emissions from aviation per kilometre travelled.

Further, faster, together

If we delay, the conditions for human prosperity will be severely curtailed. There are three pressing and practical steps to avoid this.

First, use science to guide decisions and set targets. Policies and actions must be based on robust evidence. Uncensored and transparent communication of peer-reviewed science to global decision-makers is crucial. Academic journal articles are not easily read or digested by non-experts, so we need a new kind of communication in which *Nature* meets *Harvard Business Review*. Science associations should provide more media training to young scientists and hold communication boot camps on how to make climate science relevant to corporate boards and investors.

Those in power must also stand up for science. French President Emmanuel Macron's Make Our Planet Great Again campaign is a compelling example. He has spoken out to a global audience in support of climate scientists, and invited researchers to move to France to help accelerate action and deliver on the Paris agreement. To encourage others to speak, scientists should forge connections with leaders from policy, business and civil society. The Arctic Basecamp at Davos in January, for instance, brought scientists into high-level discussions on global risk at the World Economic Forum's annual meeting in Switzerland.

"The fossil-free economy is already profitable."

Second, existing solutions must be scaled up rapidly. With no time to wait, all countries should adopt plans for achieving 100% renewable electricity production, while ensuring that markets can be designed to enable renewable-energy expansion.

Third, encourage optimism. Recent political events have thrown the future of our world into sharp focus. But as before Paris, we must remember that impossible is not a fact, it's an attitude. It is crucial that success stories are shared. Demonstrating where countries and businesses have over-achieved on their targets will raise the bar for others. More-ambitious targets become easier to set.