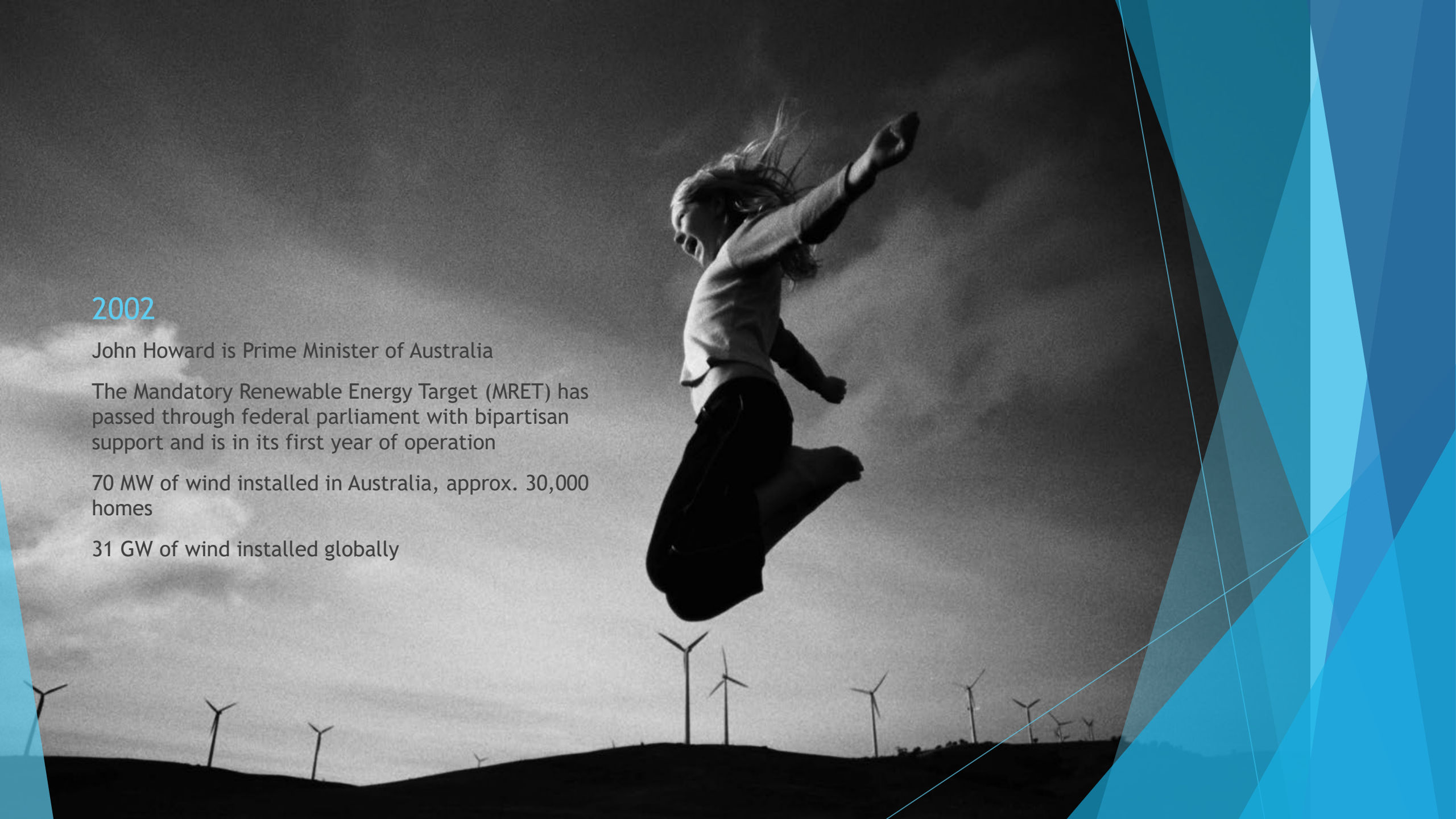
Rise of renewables

On 6 November 2019 Australia was powered by 50% renewables for the first time

Wind & solar are unquestionably the lowest-cost new energy sources in Australia

Low cost renewable energy & storage are reshaping out energy systems


18449
24,322
31,592
39,725
47,932
59,463
74,166
94,476
121,326
159,801
23,371
198,863
40,871
239,498
72,683
284,528
102,871
320,551
139,602
372,226
177,496
435,859
225,820
490,501
297,293
542,993
391,063
594,293
485,826
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Global installed wind capacity, source GWEC
Global installed solar capacity, source IRENA



2002

John Howard is Prime Minister of Australia

The Mandatory Renewable Energy Target (MRET) has passed through federal parliament with bipartisan support and is in its first year of operation

70 MW of wind installed in Australia, approx. 30,000 homes

31 GW of wind installed globally

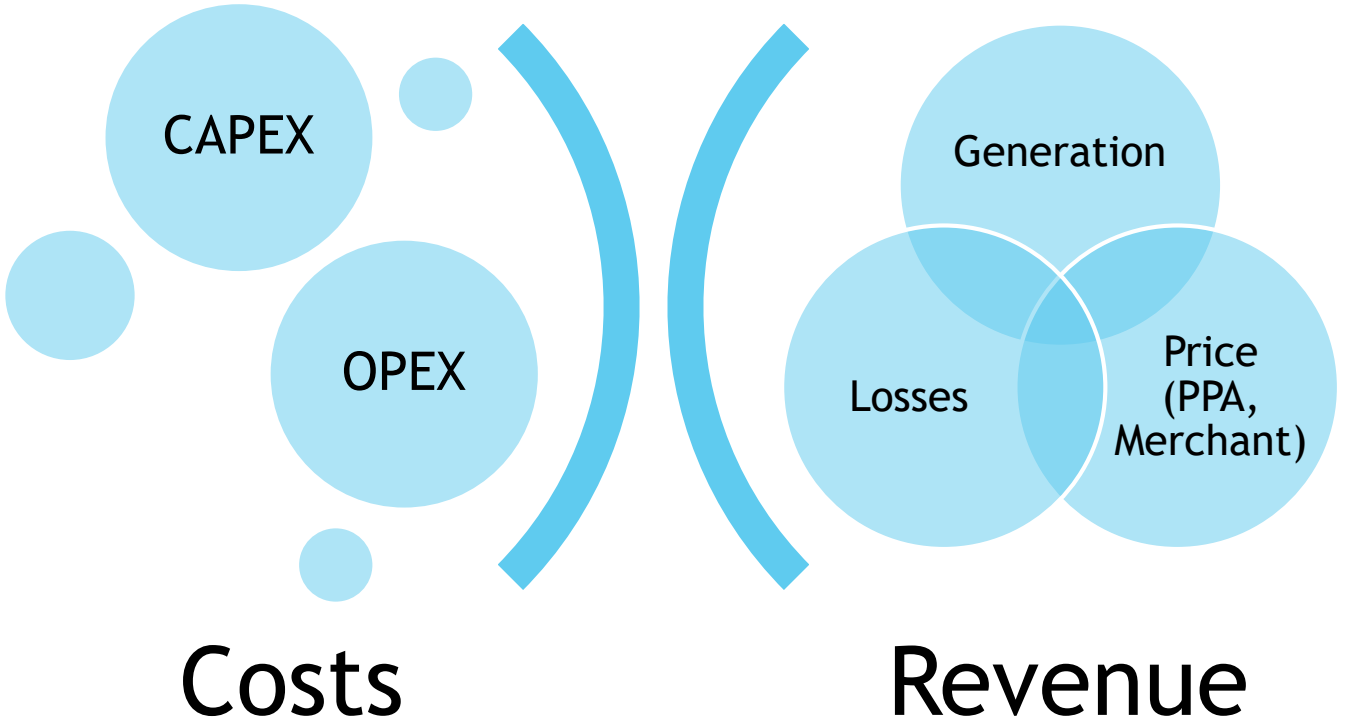
Challicum Hills Wind Farm

- Largest wind farm in the southern hemisphere
- First non-recourse project financed wind farm in Australia
- 52.5MW - 35 x NM64/1500 @ 68m hub height
- Pioneered construction techniques & grid connection
- Possible due to support of MRET – penalty $40 in 2003 (PPA with Origin)

Support / Auctions

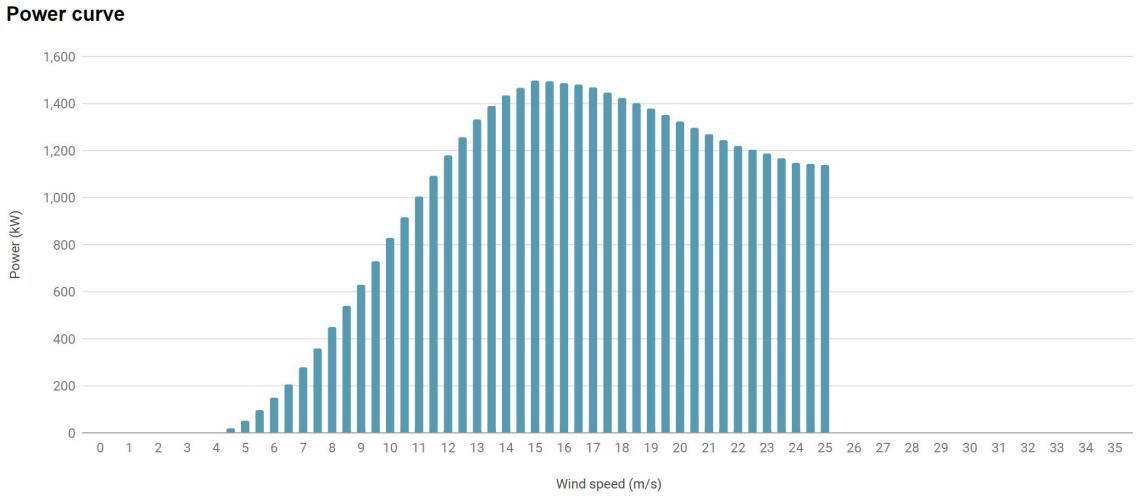
- Federal MRET - Required electricity retailers to source specific proportions of total electricity sales from renewable energy
  - 2001 - 2% - 2010 MRET
  - 2009 - 20% - 2020 MRET
  - 2012 – split LRET and SRET
  - 2019 – full
- Many state based schemes
  - 2004 & 2006 South Australia & Victoria an additional top up on MRET
  - Soft targets
- Auctions
  - ACT, Queensland, Victoria
- CEFC & ARENA

Key inputs to non-recourse finance



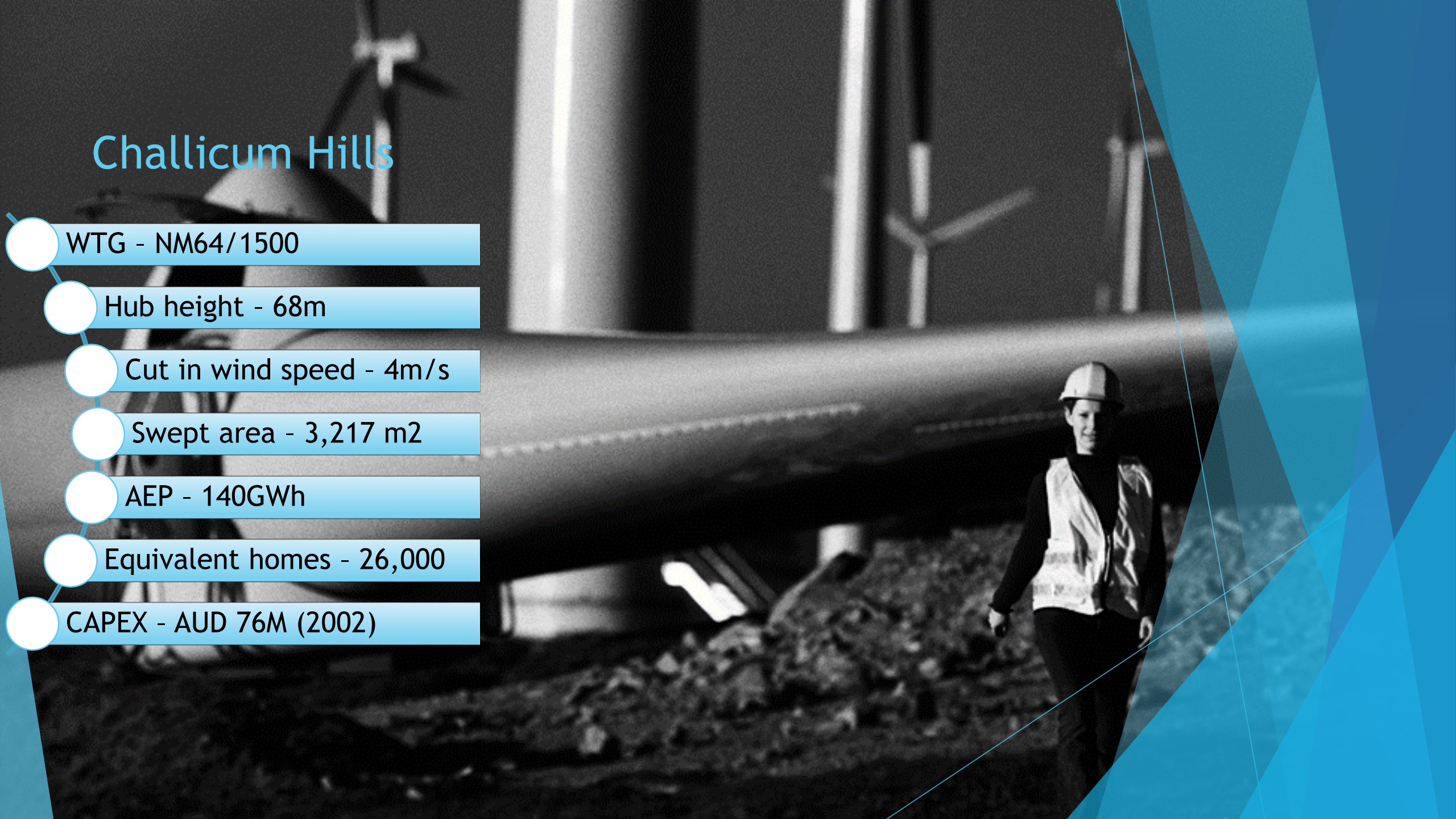
Challicum Hills NM64/1500

- $Power = \frac{1}{2}\,\rho\, A v^3 C_p$
- $Power = \frac{1}{2}\,\rho \pi r^2 v^3 C_p$
- where
  - $\rho =$ air density kg/m^3
  - $r =$ blade radius
  - $v =$ wind velocity
  - $C_p =$ Power coefficient

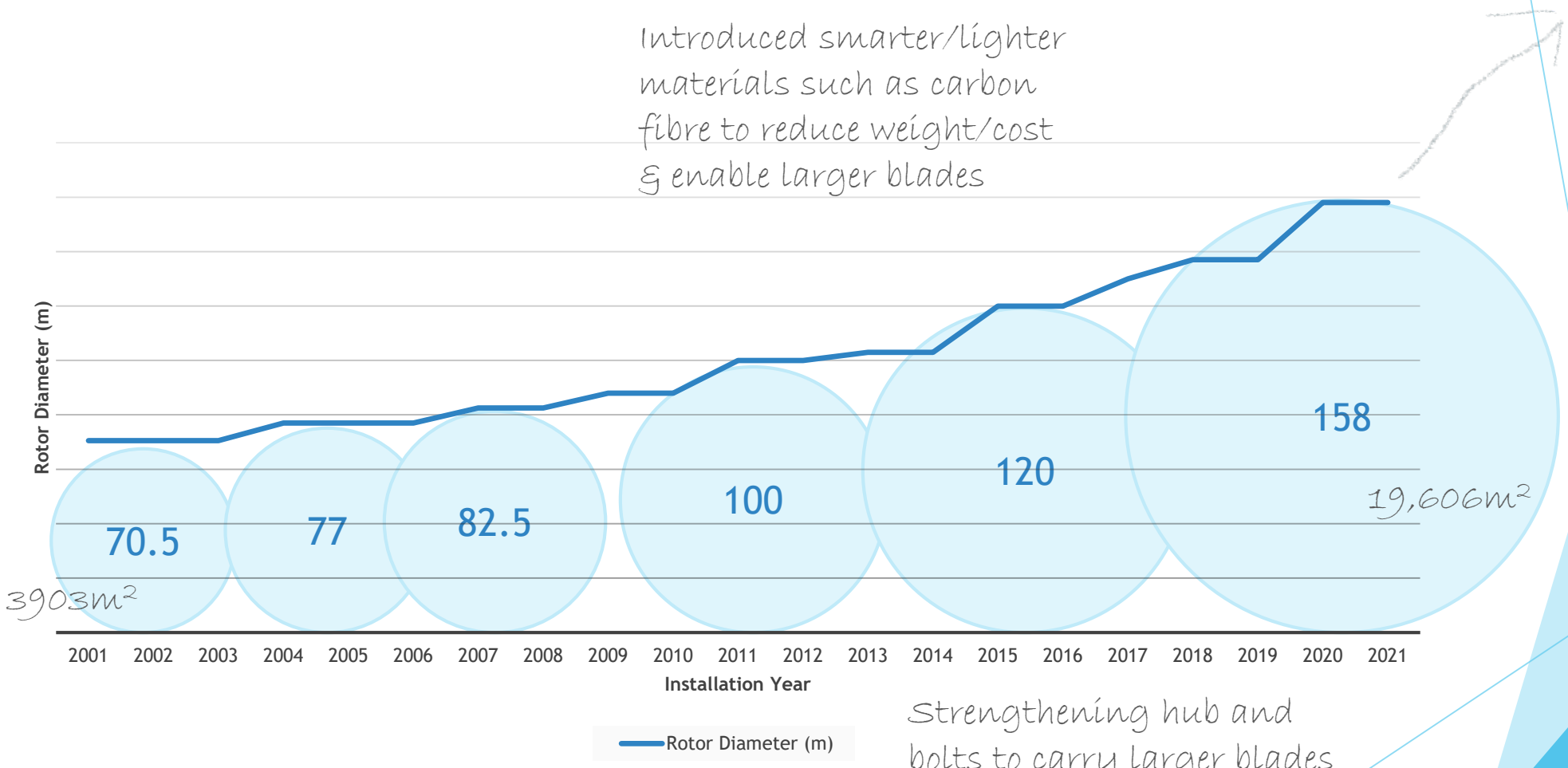


Challicum Hills

- WTG – NM64/1500
- Hub height – 68m
- Cut in wind speed – 4m/s
- Swept area – 3,217 m2
- AEP – 140GWh
- Equivalent homes – 26,000
- CAPEX – AUD 76M (2002)



Rotor Diameter 2x larger

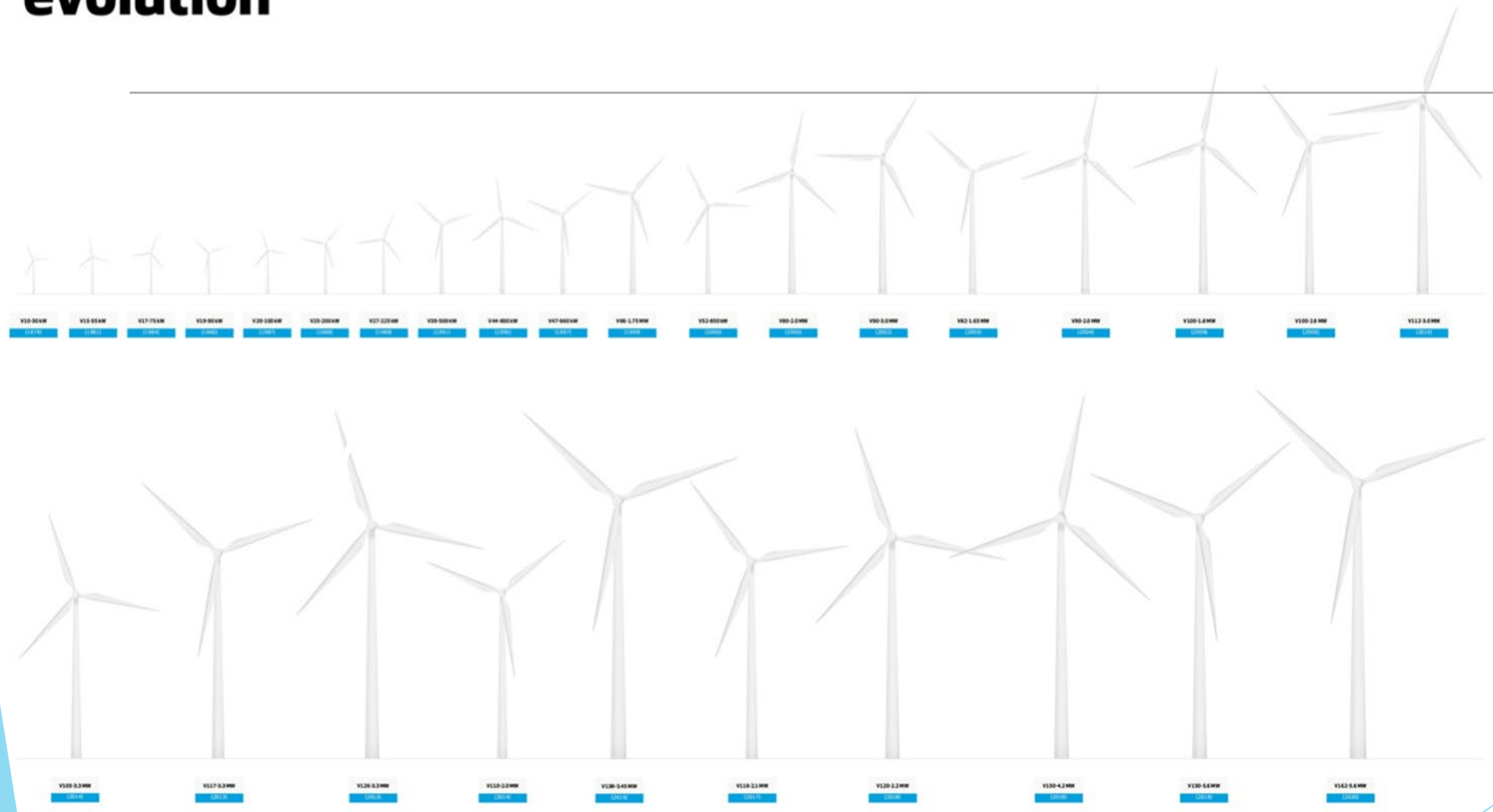


Onshore rotor diameters have tended to follow offshore GE Haliade - X 220m. However commercially limited given tip height constraints

pace of rotor growth in the last 10yrs ('11 to '21) has been ~40% greater than the preceding 10 yrs ('01-'11)

GE platforms in the Australian market, data curtesy of GE

Our turbine **evolution**



Vestas

Wind. It means the world to us.™

Incremental changes in platforms

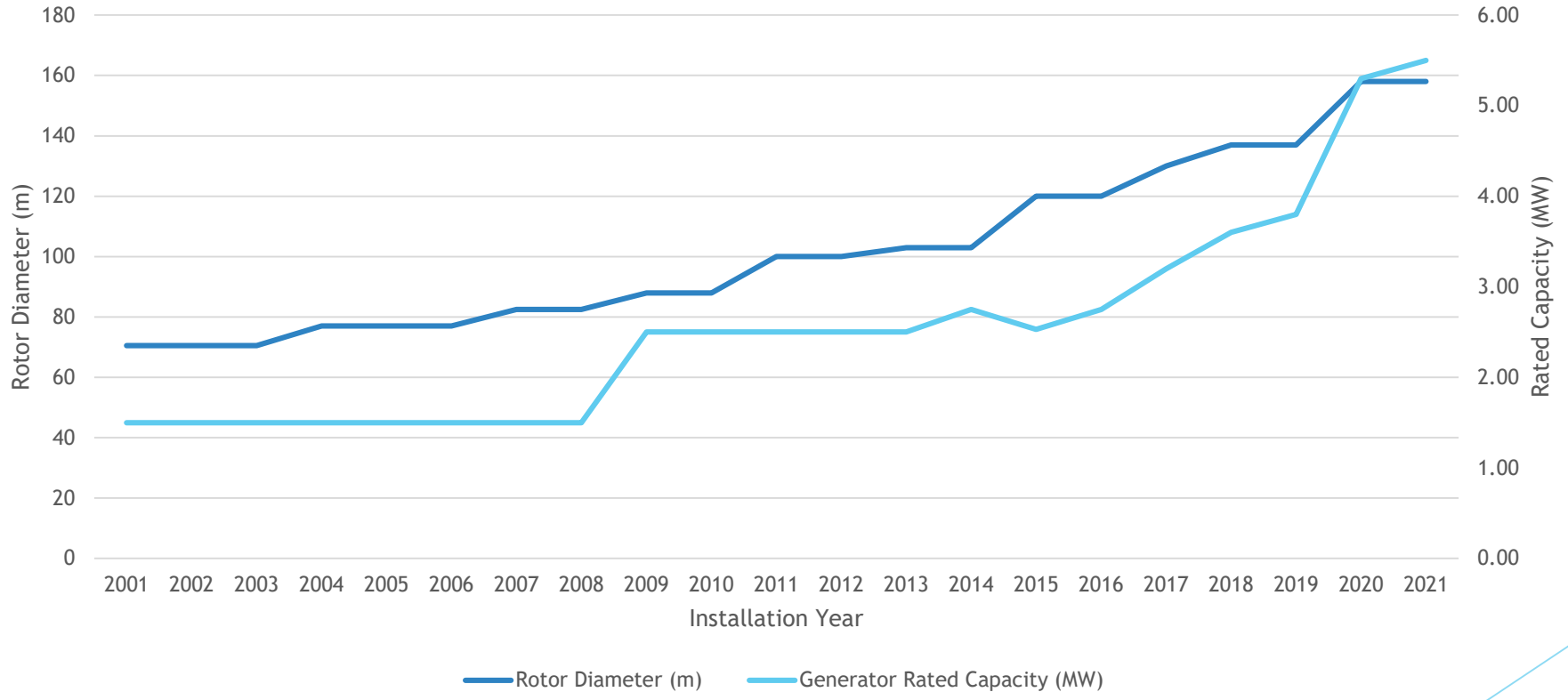
Changing

- Blades
- Gearbox rations
- Towers
- Hubs

Held relatively constant

- Generator
- Converter
- Controller
- Pitch system
- Transformer
- Main-shaft
- Main bearings
- Gearbox design,
- Bedplate,
- Yaw-system

Change in Rotor Diameter & Capacity

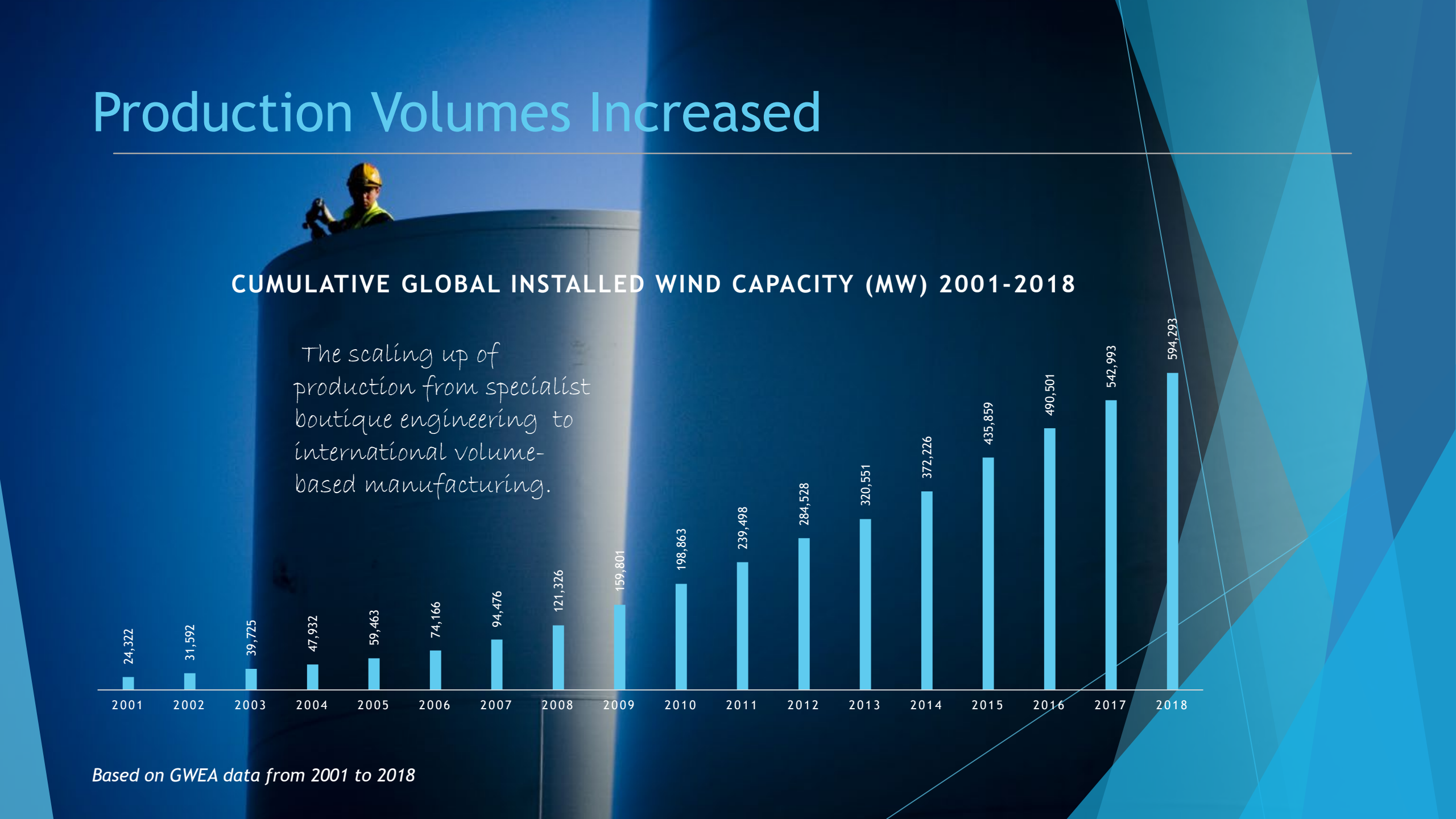


Pace of rotor growth in the last 10yrs ('11 to '21) has been ~40% greater than the preceding 10 yrs

pace of nameplate growth in the last 10yrs has been ~80% greater than the preceding 10 yrs ...so almost double.
On avg 13% nameplate growth / yr over last 20 yrs.

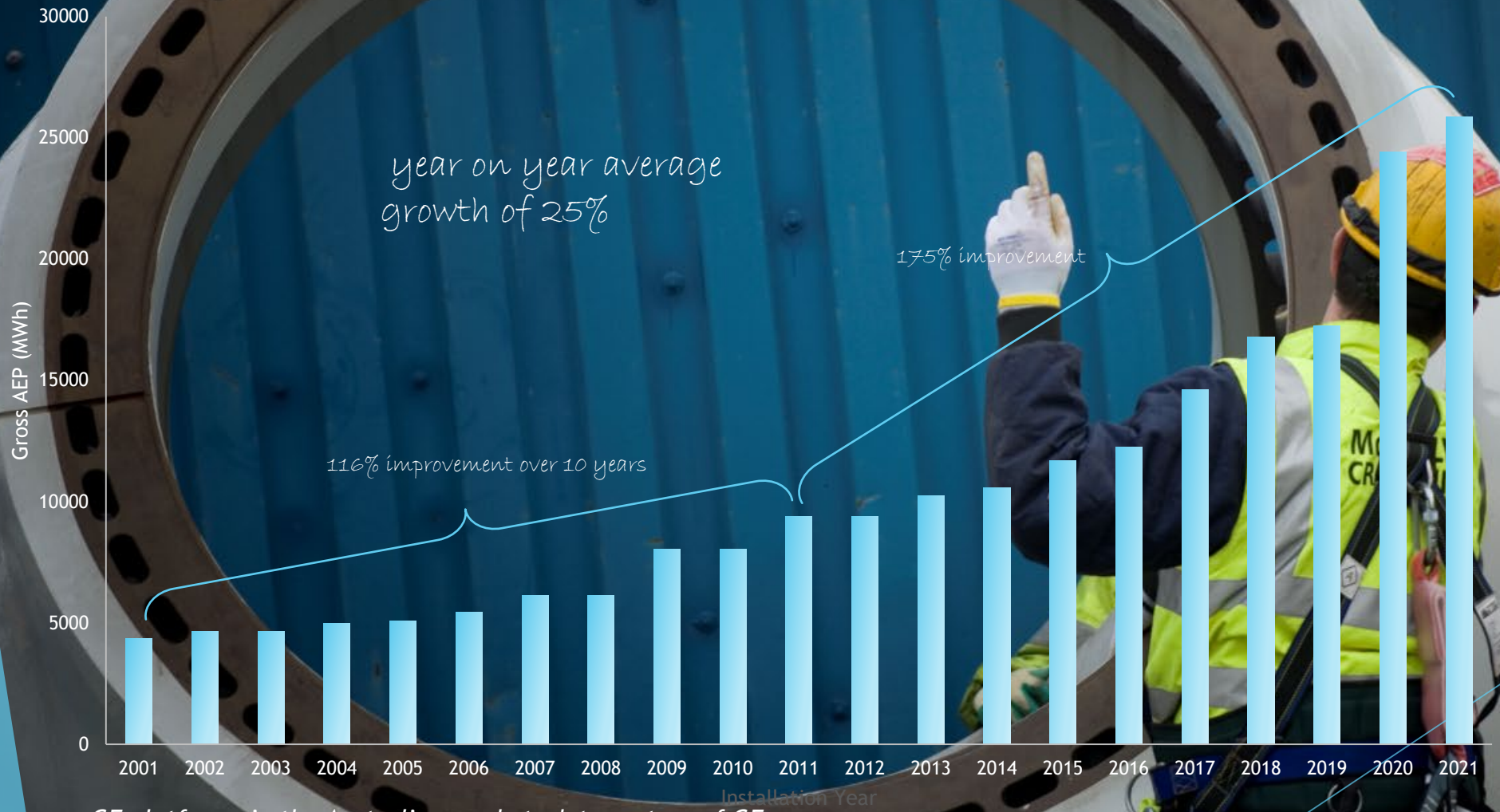
GE platforms in the Australian market, data curtesy of GE

Production Volumes Increased



Based on GWEA data from 2001 to 2018

495% increase in generation 2001-2021



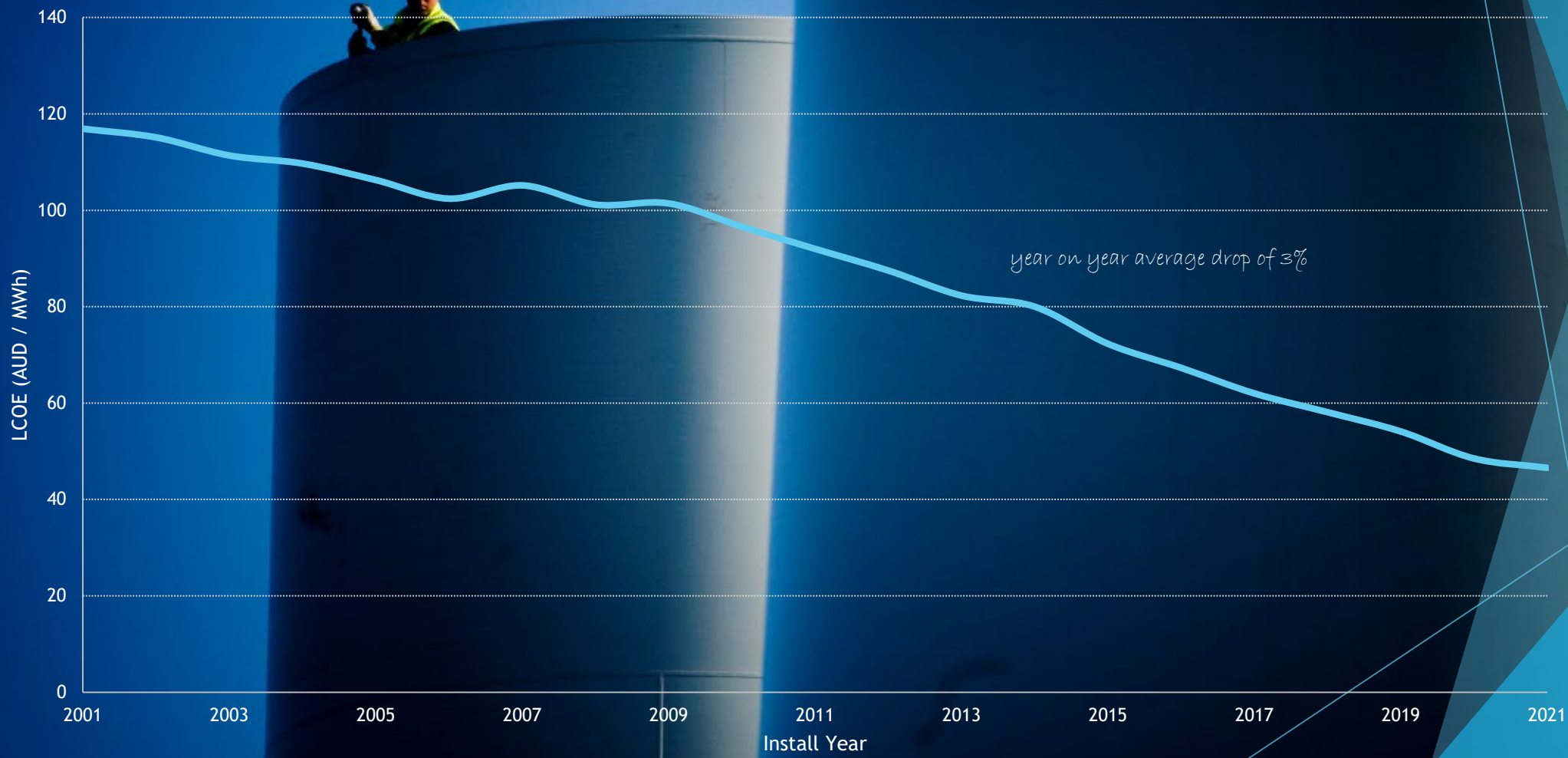
GE platforms in the Australian market, data curtesy of GE

Energy produced per wind turbine assuming constant wind of 8m/s at 100m.

Key changes

- Using smarter/lighter materials to improve the weight/cost curve (e.g. carbon fiber in the blades)
- better understanding of the mechanical loads, enabling over design to be reduced (not just build a big 'tank' of a turbine that is overly robust & expensive)
- better monitoring of loads using condition based monitoring and turbine SCADA, helps to improve turbine availability & prevent faults
- smarter sensors and faster control logic which allows the blades to be more responsive (pitch faster) which boosts the power curve (particularly in the knee region)
- The scaling up of the industry from boutique/niche/small projects to GW scale projects. Through scale/ deployment the industry has achieve major cost reductions.

60% drop in LCOE 2001 - 2021



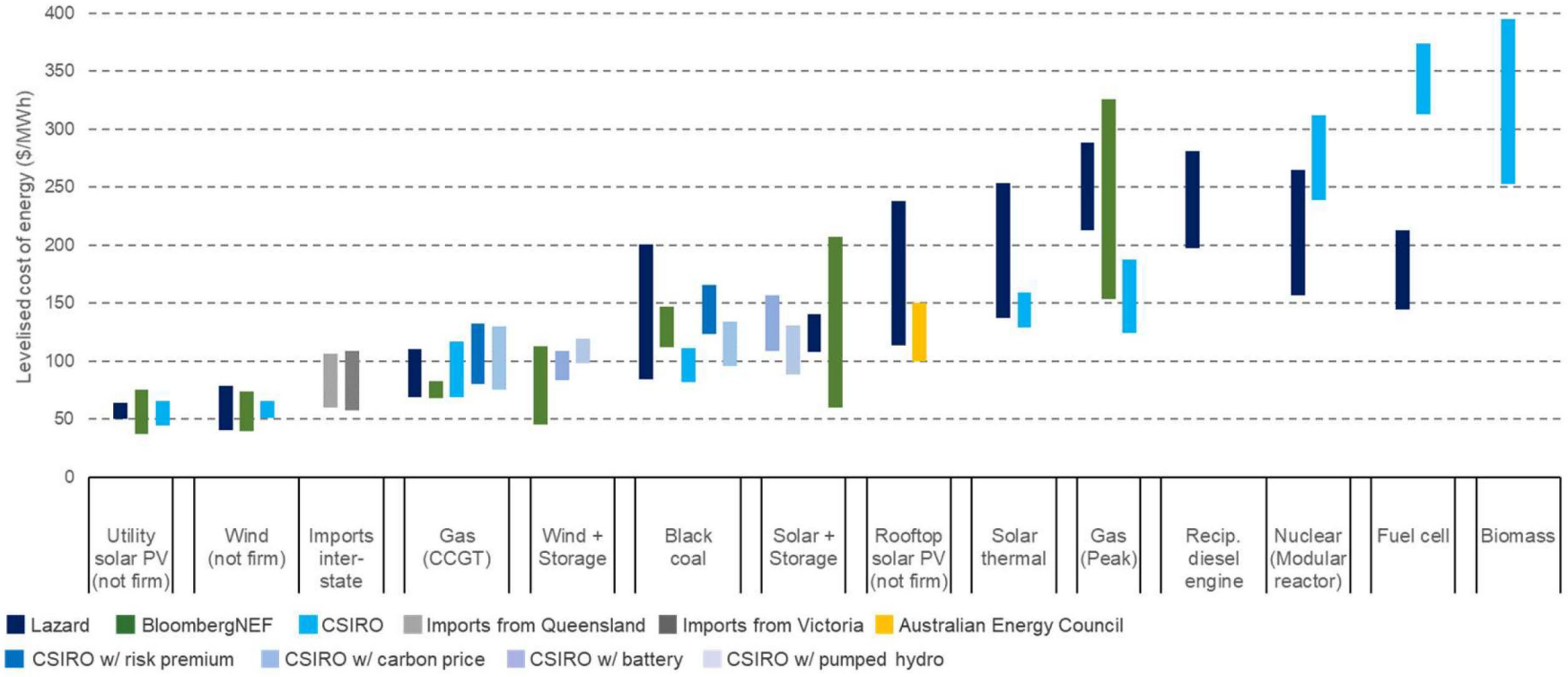
GE platforms in the Australian market, data curtesy of GE

Change in levelized cost of energy of GE's platforms over time created by advances in wind technology, assuming wind & financing costs held constant.

Challicum Hills today

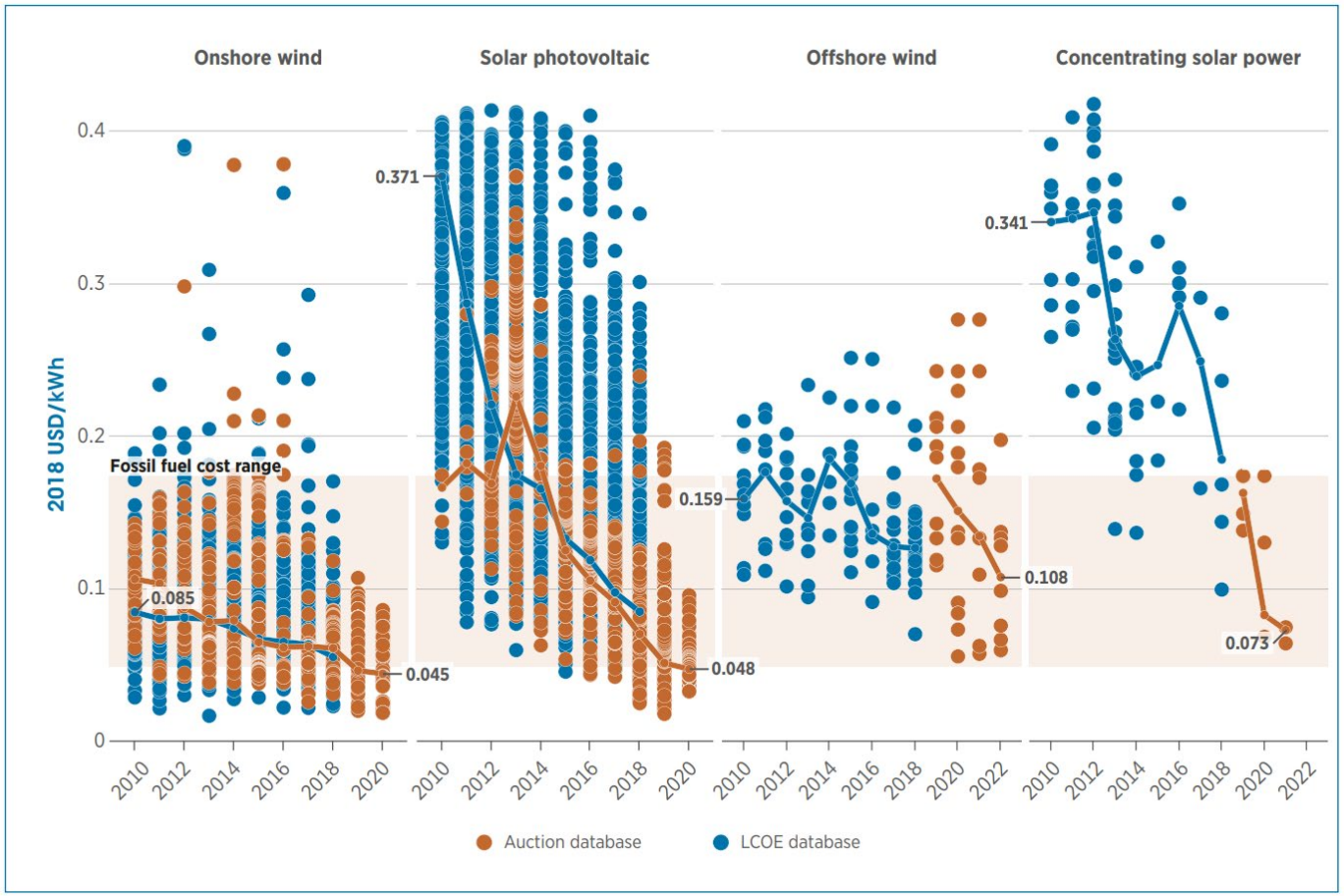
	2002	now
Turbine	NM 64/1500	GE 5.5-158
Hub heights	68m – 80m	101m – 161m
Rated power	1,500kW	5,500kW
Cut-in wind speed	4 m/s	3 m/s
Rotor diameter	64m	158m
Swept area	3,217 m^2	19,607 m^2
AEP for 35 WTGs	Approx. 140GWh	Approx. 860GWh
Equivalent homes	26,000	160,000
Or …	35 WTGs	7 WTGs

Cost of new energy in Australia



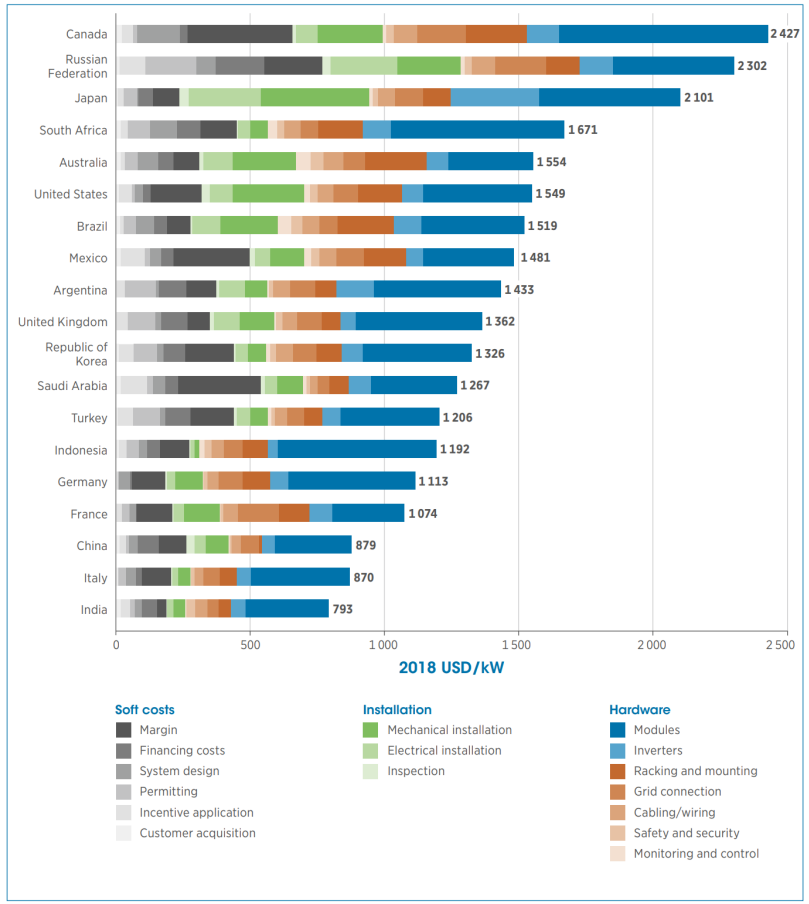
Source NSW DPIE – Inquiry into sustainable energy supply & resources NSW
Based on collation of various reports Lazards 2018, BloombergNEF 2019, CSIRO 2018, Australian Energy Council 2019, DPIE own analysis

Global LCOE



Source IRENA (2019), Renewable Power Generation Costs in 2018

PV Solar



- Average module prices in Australia dropped 60% 2013-2018
- Total installed costs in Australia declined by 20% between 2017 and 2018, but remained relatively high on a global basis due to higher labour & balance of plant costs
- High “learning rate” ie price decrease with volume installed
- LCOE reductions in 2018 were supported by module price declines of around 30%

Source IRENA (2019), Renewable Power Generation Costs in 2018

Massive uptake of solar

6 solar panels were installed every minute in Australia in 2018

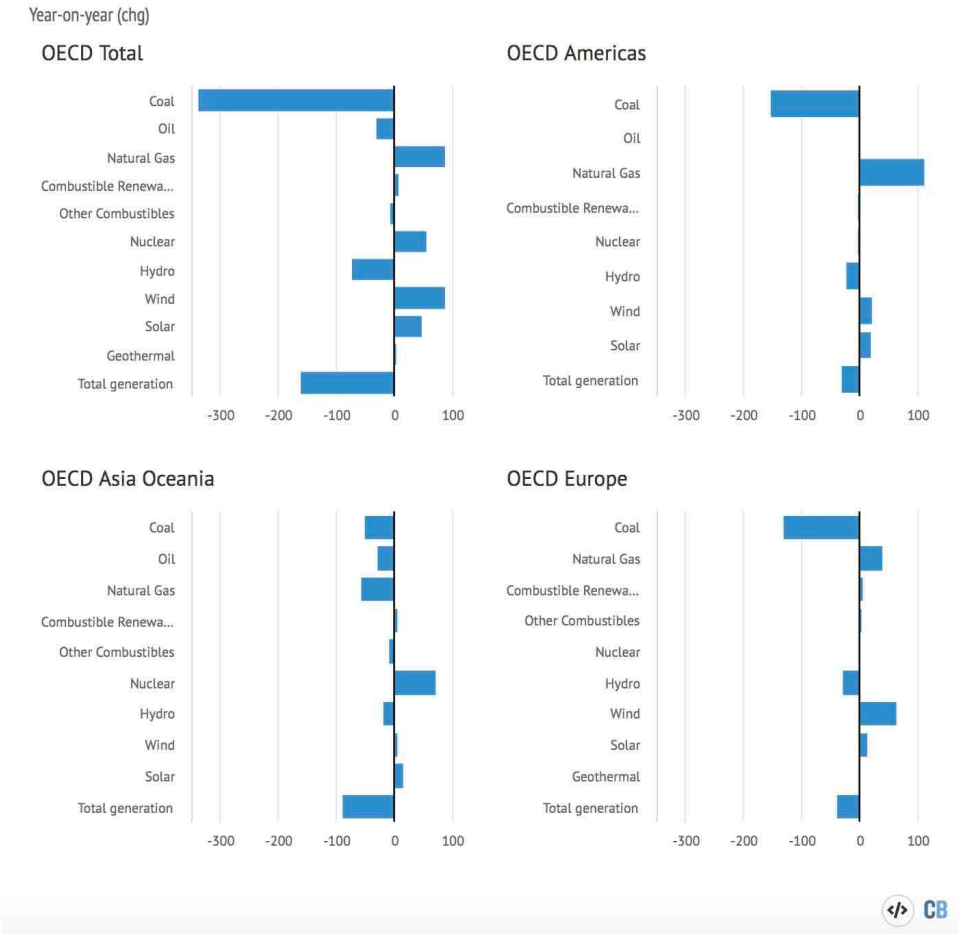
45% growth in commercial solar installations

1 in 5 Australian households have rooftop solar

Renewables displace coal

- Onshore wind and solar have reached a junction where they cheaper than the marginal operating cost of coal.
- IRENA report that in 2020:
  - the weighted average PPA, or auction price, for solar PV is expected to be less than the marginal operating costs of around 700 GW of the coal-fired capacity operational at that time based on analysis from Carbon Tracker on marginal operating costs for coal plants
  - the weighted average PPA or auction price for onshore wind – is less than the marginal operating costs of almost 900GW of the operational coal-fired capacity potentially online in 2020

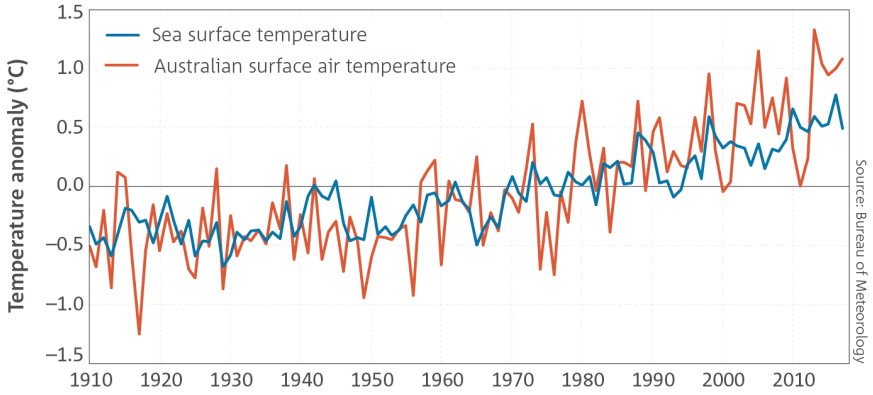
Demand down & Renewables Up

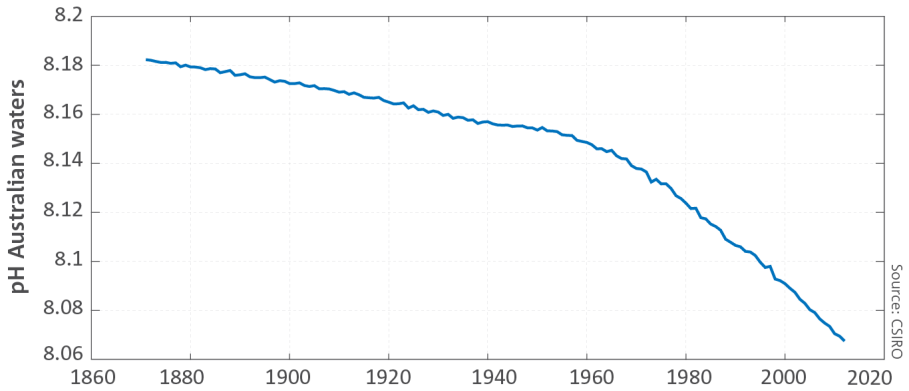


- Generation & Coal down
- Global electricity production from coal is on track to fall by around 3% in 2019, the largest drop on record.
- Reduction of around 300 terawatt hours (TWh), more than the combined total output from coal in Germany, Spain and the UK in 2018.

Change in electricity generation by source in OECD, first 7 months of 2019 compared with same period in 2018.
Source: International Energy Agency. Chart by Carbon Brief using Highcharts.

None of this is happening too soon



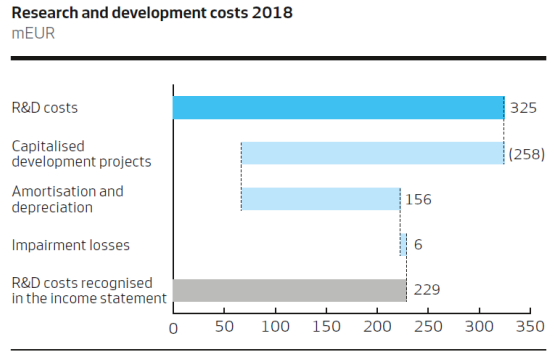


- Australia's climate & oceans have warmed over 1 °C since 1910 leading to an increase in the frequency of extreme heat events.
- There has been a decline of around 11 % in April–October rainfall in the southeast of Australia since the late 1990s.
- There has been a long-term increase in extreme fire weather, and in the length of the fire season, across large parts of Australia.

What’s next

Wind OEM Research & Development

- 2.6B AUD invested in R&D by the world's top 10 wind turbine manufactures in 2018. Their R&D expenditure more than doubling over the past four years.
- R&D investment expected to continue to rise with IntelStor forecasting 54.4B AUD investment over next 10 years, or 5.3% of revenue up from 2.7% in 2013.
  - OEMs accelerate R&D investment as they strive to further reduce wind energy's LCOE. Focus on next-generation platforms with lower LCOE to mitigate generator risk re exposer to increasingly merchant market.



Source: Vestas 2018 Consolidated financial statement

What's next

Product innovations

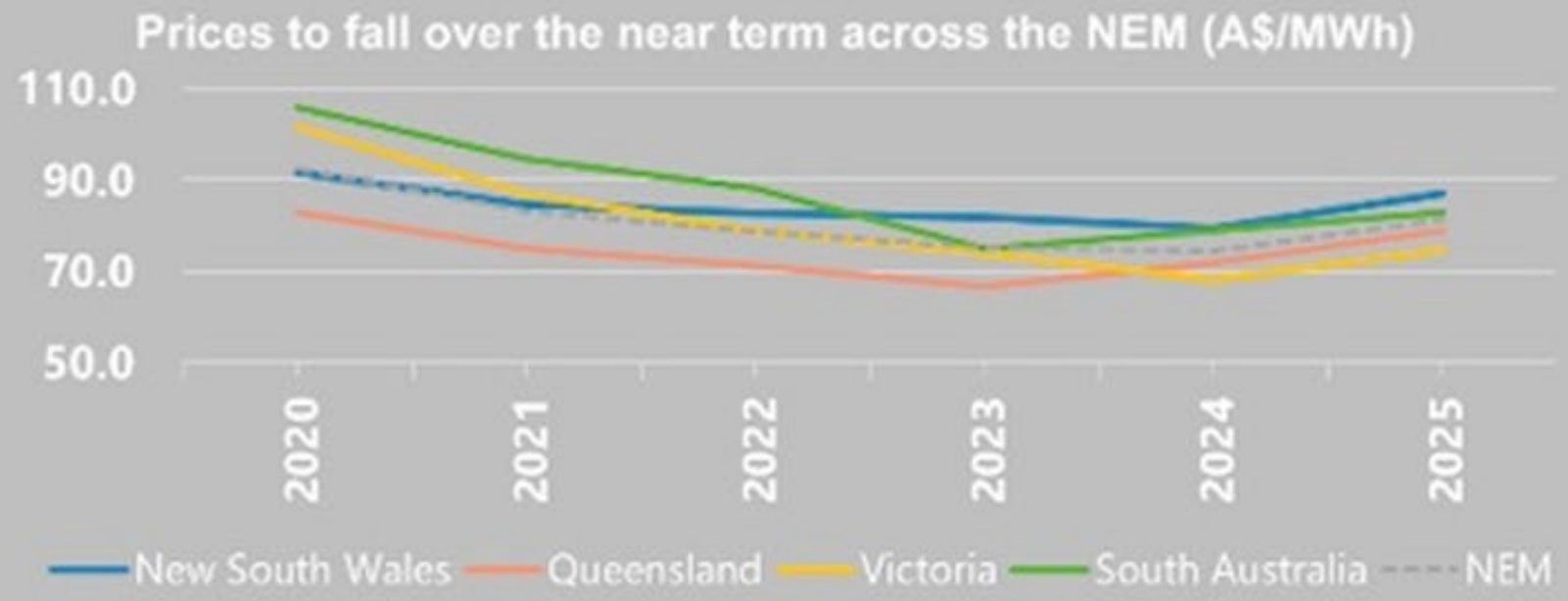
- OEMs continue pursue technology improvement. This year Vestas V162-5.6 followed by SGRE's SG 5.8-170
- OEMs seek to balance cost and performance curves
- Expect 7-8MW onshore WTGs with 200m+ rotors by 2025. Big rotors playing into the new Mega Projects
- Rotor to remain central product differentiator.
- Knock on impact requires continual innovation on rotor, tower & drive chain

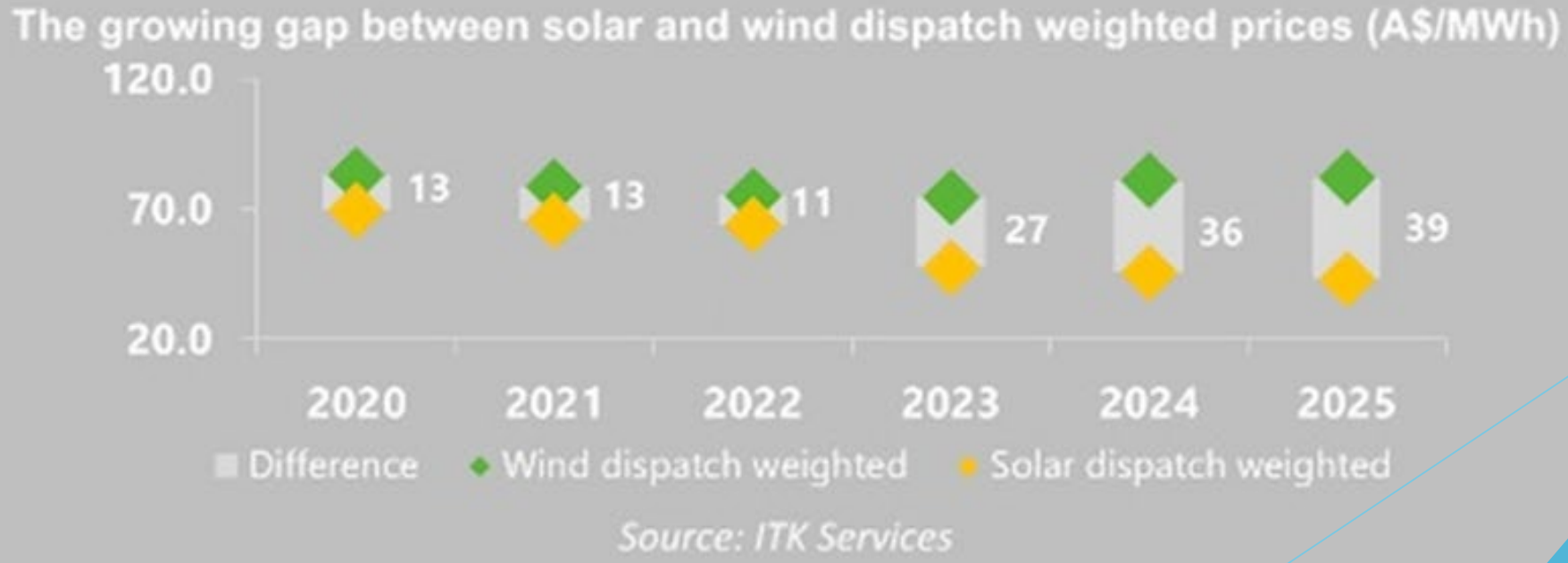
Mass production

- OEMs moving to product platform development approach to drive costs down & provide flexibility.
- Interchangeable parts enabling:
  - optimised WTGs for site specific conditions
  - flexibility in component sourcing
  - increased economies of scale

Market drivers

- Competition will see OEMs continue to seek LCOE improvement (solar, US post-PSC era etc)
- Power sales strategies and storage will drive different product solutions
  - Owners who are pessimistic about future power price or grid congestion will seek high net capacity factor machines to run hard, seeing less value in later years. “Make hay whilst the sun shines”
  - Owners who are optimistic about future prices and solutions to grid congestion will seek big rotor machines and long design lives out to 40 years
- Remote Mega Projects will drive big rotor onshore machines with high AEP
- Continued growth in corporate PPAs and auctions will drive new technology and firming solutions





Source: ITK Services

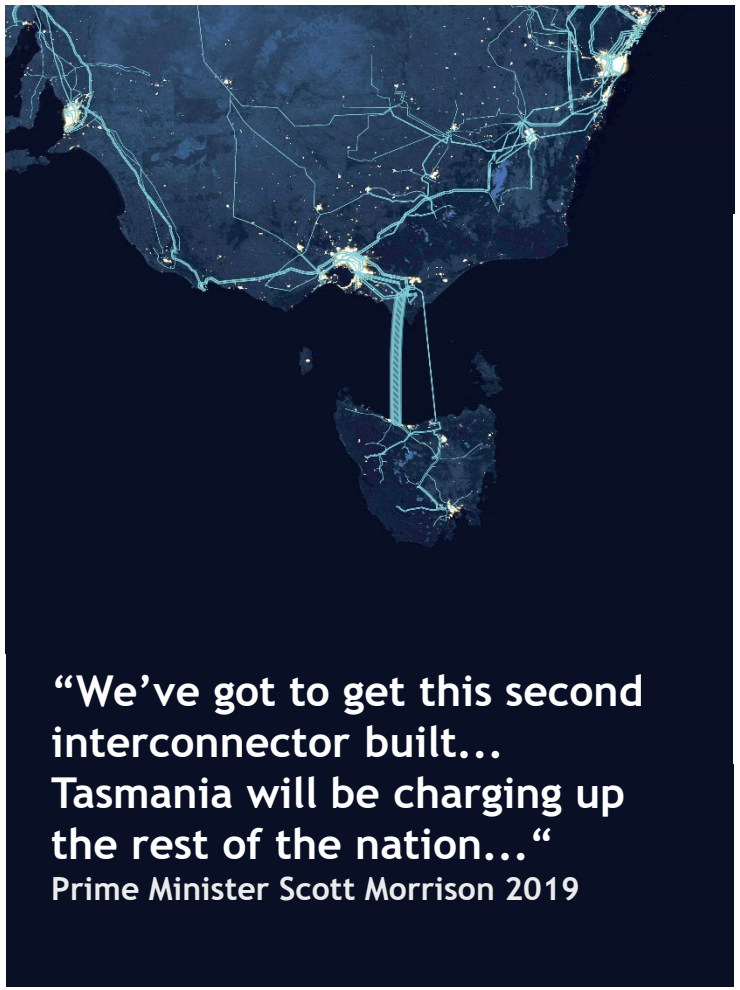
Transition to high penetration renewables, the challenge is transmission

- The NEM is a stringy system set up for thermal plant
- Enhancing grid penetration of renewables – removing the need for non renewable generation
- Problem wind and solar are asynchronous and subject to variability
  - Require inertia / system strength / reliability
- Solutions being pursued
  - project level fixes – suboptimal & problematic
  - grid level synchronous condensers to provide inertia
  - cleaver battery storage
  - pumped hydro
  - interconnection
  - Rule changes – do they make sense?

MARINUS LINK

DELIVERING LOW COST, RELIABLE AND CLEAN ENERGY

Marinus Link and supporting transmission is national infrastructure



"We've got to get this second interconnector built... Tasmania will be charging up the rest of the nation..."
Prime Minister Scott Morrison 2019

By 2035, in the NEM there will be:

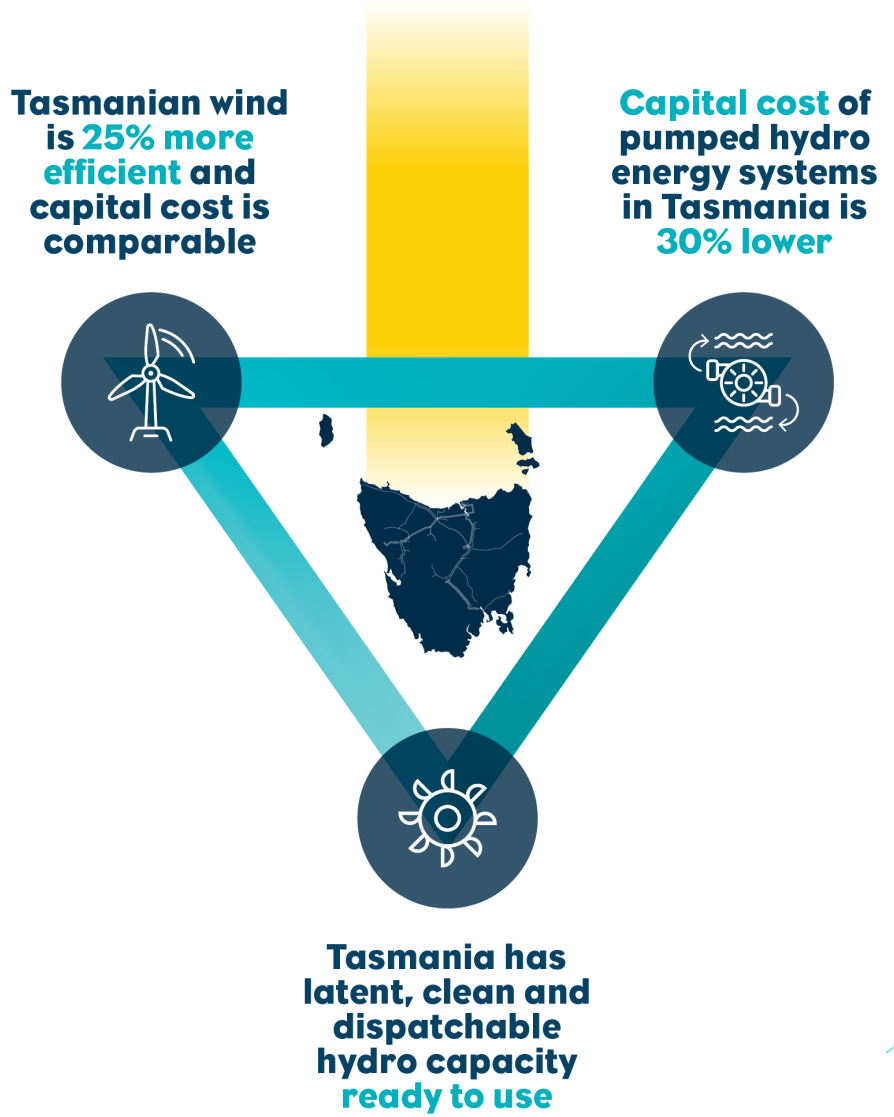
12,000 MW OF **COAL RETIRING** = **40,000 MW** OF VARIABLE **RENEWABLE CAPACITY REQUIRED** TO REPLACE IT + **8,000 MW** OF **DISPATCHABLE CAPACITY REQUIRED** TO FIRM THE RENEWABLES

TasNetworks Delivering your power

MARINUS LINK

DELIVERING LOW COST, RELIABLE AND CLEAN ENERGY

Tasmania has what the NEM needs



TasNetworks Delivering your power

What is Marinus Link?

- **1500 MW of increased transmission capacity** between Tasmania and Victoria
- Infrastructure Australia **high priority initiative**
- Australian Energy Market Operator's **(AEMO's) Insights paper** (July 2019) **calls for Marinus to be progressed through feasibility, business case and approvals phases as a matter of priority**
- **$20M feasibility and business case assessment** being finalised – supported by ARENA by end-2019
- **$56M Commonwealth funding** now in action to fast track the **Design and Approvals phase**

ASIAN RENEWABLE ENERGY HUB

15,000+ MW of wind and solar generation on a 6,598 km^2 site in the Pilbara region in Western Australia, to be delivered in phases over 9 years.

The Asian Renewable Energy Hub
Nyangumartamili wangal pa janyja

Green hydrogen and renewable electricity for local and export customers

InterContinental Energy

cwp Renewables

MACQUARIE

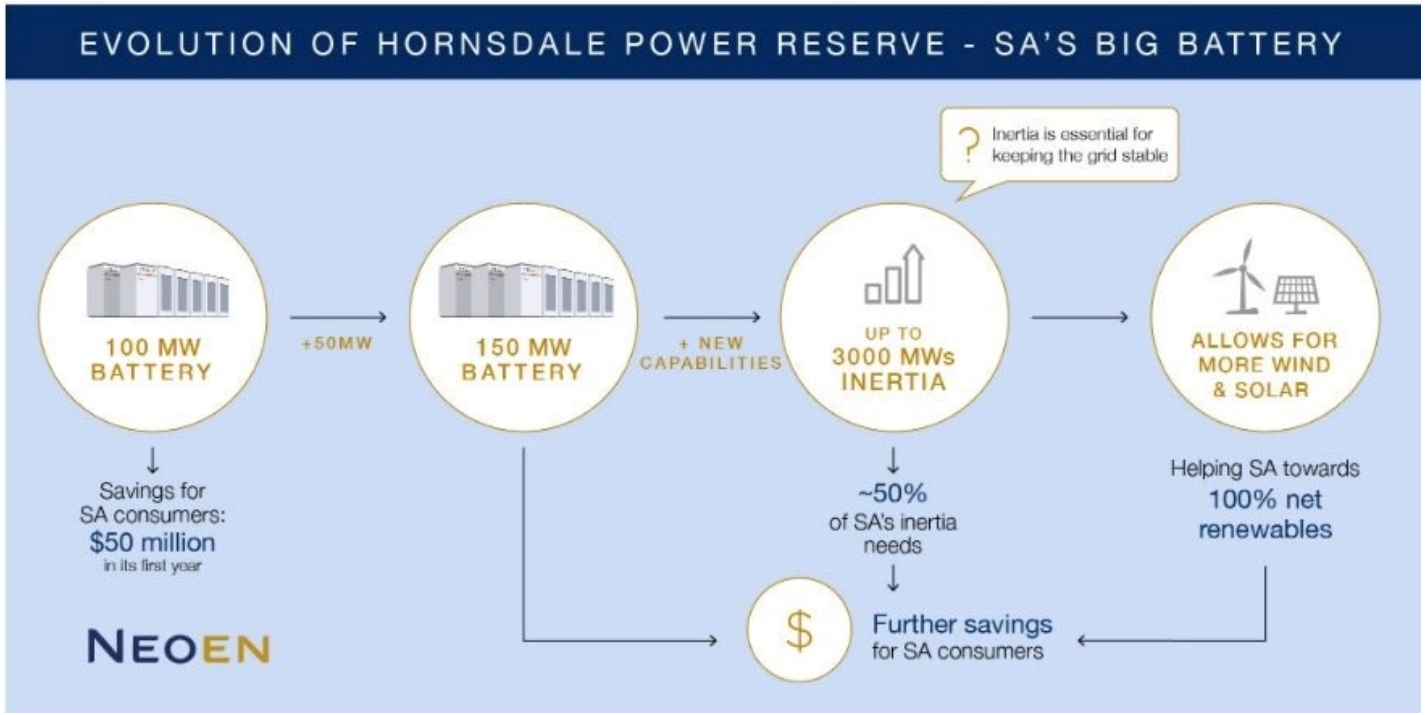
Vestas

NYANGUMARTA WARRARN • DESERT TO THE SEA •

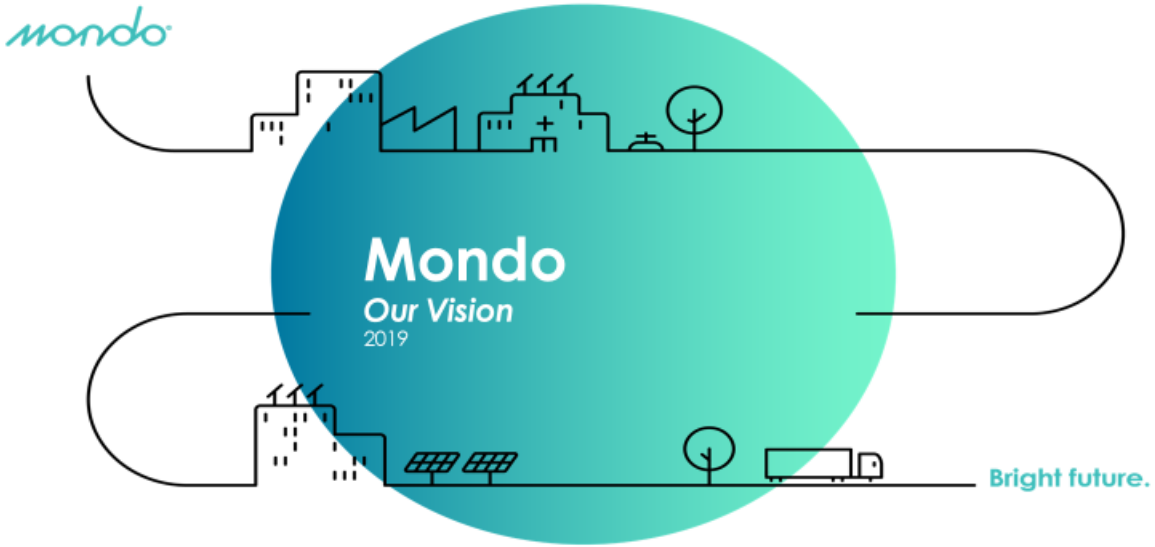
Grid Support Service

Area	Grid Services	Coal	Gas Peaker	Synchronous Condenser	Pumped Storage – Variable-Speed Turbine	BESS
Peaker Services	Peak Power/ Energy Arbitrage	Low ramp rate (100% of capacity in multiple hours)	Medium ramp rate (100% of capacity in 8 minutes); high variable cost (max 38% efficiency)	Only provides reactive power	Medium ramp rate (3 minutes idle to full)	Fastest ramp rate (100% of capacity in <1sec)
	Frequency Response	Low accuracy	Medium accuracy; Regulation from 23% to 89% of max. capacity	Only provides reactive power	Available when charging. Discharge AGC available from 60 to 100% of nameplate	High accuracy; Regulation from 0% to 100% of capacity
	Inertia	Provides inertia	Provides inertia	Provides inertia	Provides inertia	Provides inertia
T&D Services	Reducing network congestion	Cannot charge	Cannot charge	Cannot charge	Can charge	Can charge
	Reducing line losses	Cannot charge	Cannot charge	Can optimize voltage but cannot charge	Can charge (siting limitations)	Can charge; modular/flexible siting
	Deferring transmission or distribution investment	Slow construction (years)	Slow construction (years)	Fast construction	Slow construction (years)	Fastest construction
Renewable Integration	Renewable integration	Cannot charge	Cannot charge	Cannot charge	Can charge, 6 – 10 min. from max. charging to max. discharging	Can charge and deal with rapid fluctuations

“The Big Banana”



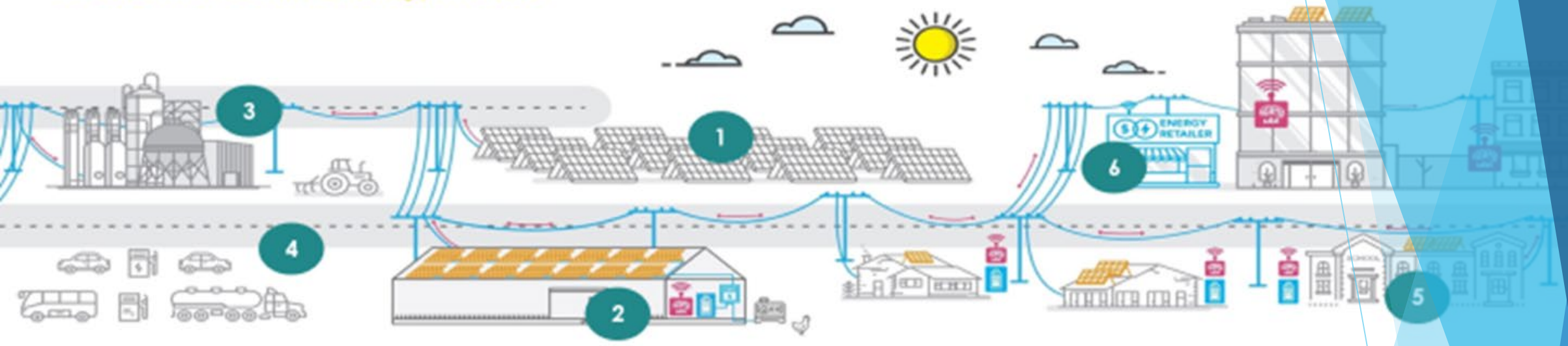
- biggest lithium ion battery in the world
- 3,000 megawatt seconds of inertia / 50% of South Australis requirements
- Support from ARENA / SA Gov / CEFC
- Key example of State Target in action – net 100 % renewables by 2030
- $22M profit in first year of operation
- 2 other similar sized projects for SA alone



Dhammika Adihetty – GM Emerging Markets & Policy at Mondo
“transition to a 100% renewable energy system with 40-50% locally produced energy”

OUR VISION FOR THE ROLE OF ENERGY IN AUSTRALIA

A customer-centric energy market



Thriving new economies

New industries
- Renewables and storage
- Information
- Telecommunications
- Transport fuels

Established economies
Agriculture, transport, tourism, manufacturing, food processing, water, mining

Education and employment

Empowered

Consumer imperative & choice
- Information and market signals
- Optimised and coordinated energy scheduling and use
- Consumer trading peer to peer
- Earning revenue

Confidence

Emergency power
- Community relief centres
- Emergency services

1. Renewable energy generation
Medium and large-scale solar PV systems installed across various locations.

2. Battery Storage
Selected solar sites fitted with battery storage.

3. Hydrogen fuel production
Pilot program to convert excess renewable energy and recycled water to hydrogen fuel for freight transport.

4. Electric Vehicle (EV) charging
Community charging point powered by renewable energy.

5. Excess energy provided to community
Unutilised, locally produced solar energy supplies the community.

6. Community able to "buy" portions of solar farms
Homes and businesses able to invest in solar farms.

Net-Zero Carbon Cities

25 cities (135 million citizens) committed to a Net Zero Carbon Building Declaration
All new buildings operate at net zero carbon by 2030
All buildings (old or new) will meet zero ne carbon standards by 2050

- Cape Town
- Copenhagen
- Durban
- Heidelberg
- Johannesburg
- London
- Los Angeles
- Medellin
- Montreal
- New York City
- Newburyport
- Oslow
- Paris
- Portland
- San Francisco
- San Jose
- Santa Monica
- Seattle
- Stockholm
- Sydney
- Tokyo
- Toronto
- Tshwane
- Vancouver
- Washington D.C.

Urban buildings are typically the largest source of greenhouse gas emissions

In London, Los Angeles and Paris building account for over 70% of the cities emissions

Source C40 Cities

Masterplanning Australia's first zero net energy city at Springfield

115,000 residents
BY 2036

2.6 million sqm
MIXED USE SPACE

22,850
APARTMENTS

We develop and enable innovative and smart city solutions to lead the zero-carbon future

- 50-year partnership between ENGIE and the City of Greater Springfield to make the city zero net energy within 20 years
- Energy security exclusively provided by ENGIE: powered by green energy, with hydrogen as part of its energy mix
- Delivery of full range of ENGIE capabilities: infrastructure, services, retail, planning, digital solutions, green mobility, renewables, storage
- Co-creating the design and development of an intelligent city that is resilient, connected and productive
- ENGIE is a world leader in innovative and better city solutions. Springfield is a leading regional demonstration of the implementation of ENGIE's Better Cities TODAY activities

Where we need to improve

- Marketing, public relations taking people on the journey
  - Not good enough to be doing the right thing
  - Sophisticated anti-renewables pro-thermal campaigns based on lessons learn't from gun lobby & tobacco industry
  - Those with the money have the ear of politicians – not great when you need to change
  - Over the last 15 years we have lost the PR war – its time to reverse that & make it easier to support our industry
  - Australian's support renewable energy, climate change is a key concern.
- Cooperation

Transition to a low carbon future

- Abundance of good onshore wind & solar in Australia
- Cost of energy is now sufficiently low to support transition to low carbon future
- Grid is now limiting the transition – this is our new challenge
- Achieving this by:
  - Mega projects – support high fixed cost of connection
  - Creating a stronger expanded transmission network
    - Integrating BESS, pumped hydro
    - Interconnection of the grid
  - Transitioning to hydrogen

Thank you

Thank you to GE Renewable Energy, Pacific Hydro, Mondo, Engie, CEC, Neoen, Tesla, CWP, TasNetworks, Eddie Safarik Images, Goldwind Australia, Vestas & Siemens Gamesa Renewable Energy for supplying information and images.

Further reading:

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