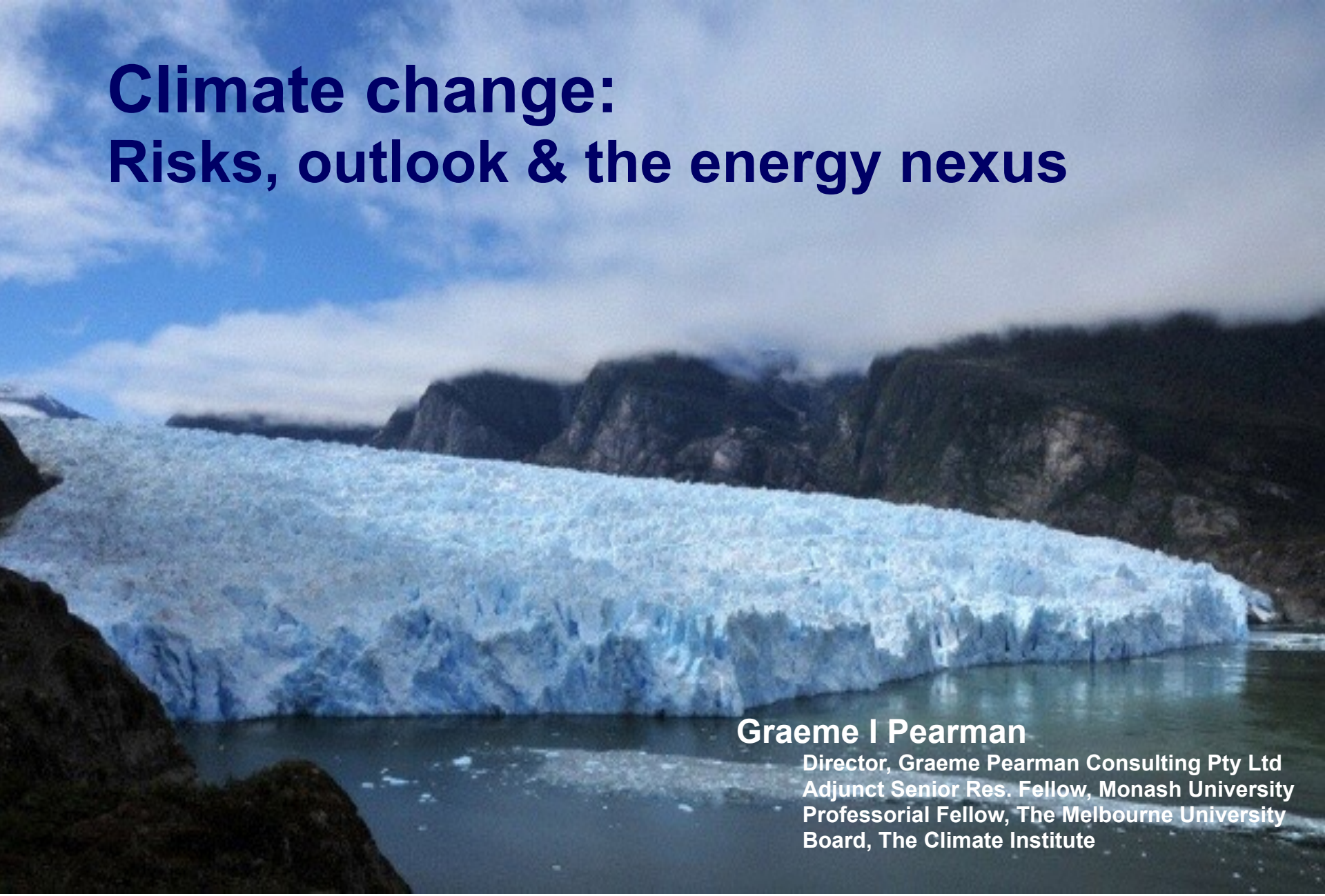
# Climate change:
## Risks, outlook & the energy nexus



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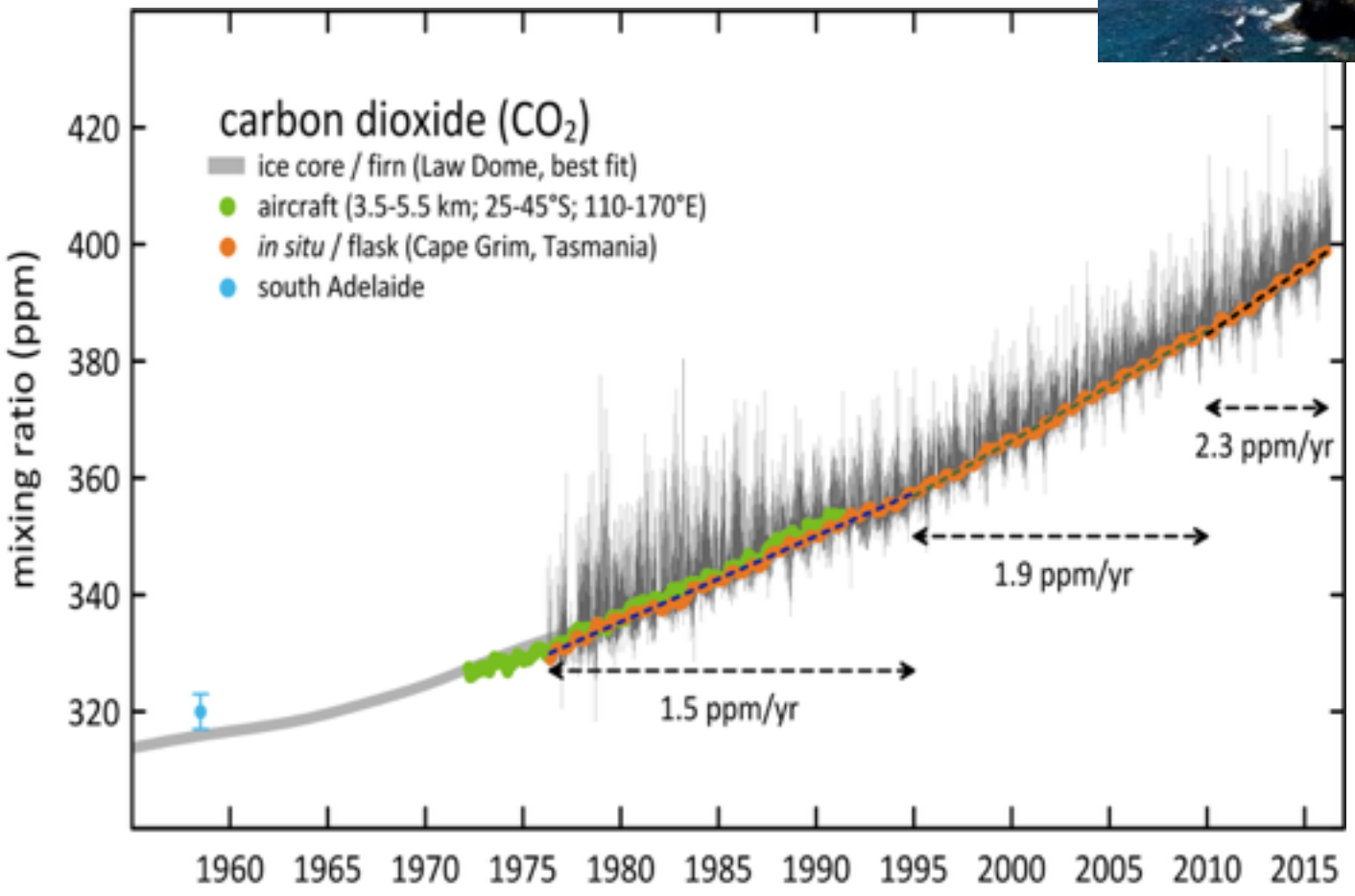
Board, The Climate Institute

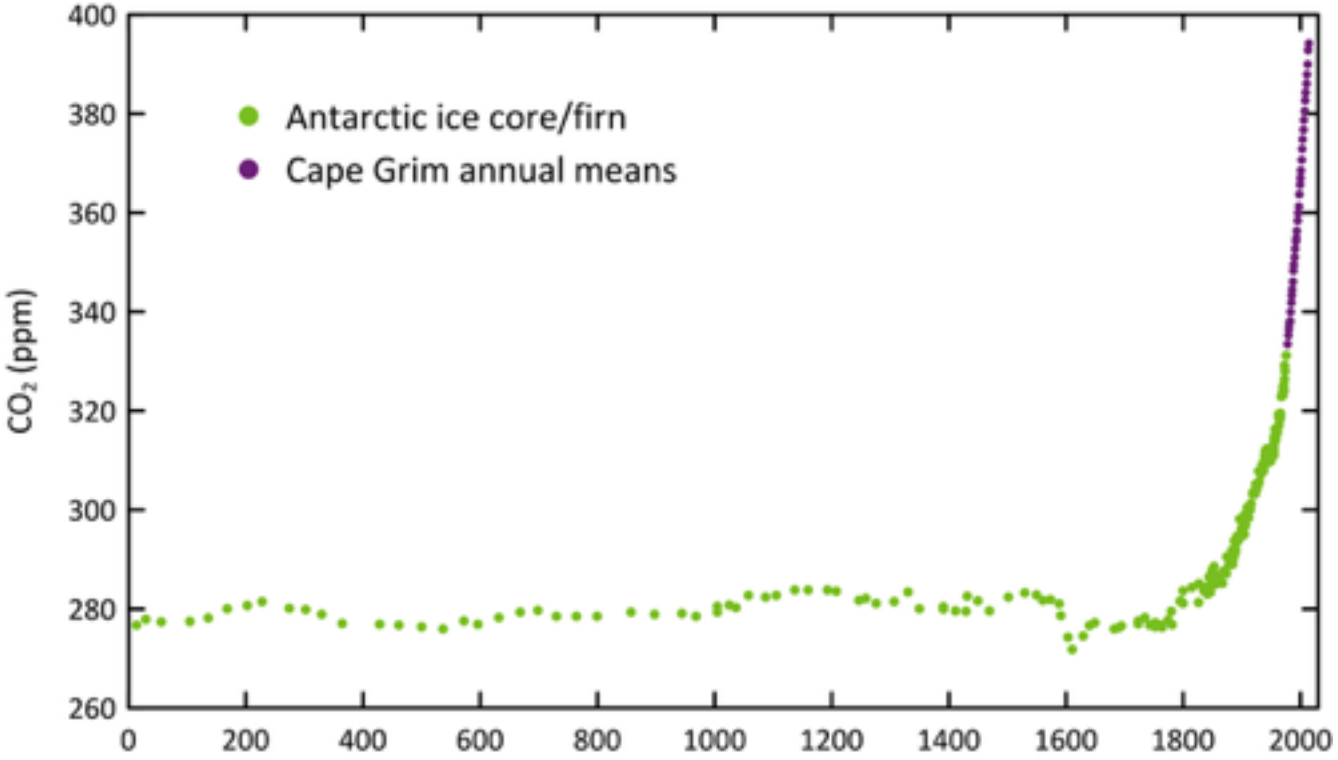
# Risks, outlook & the energy nexus

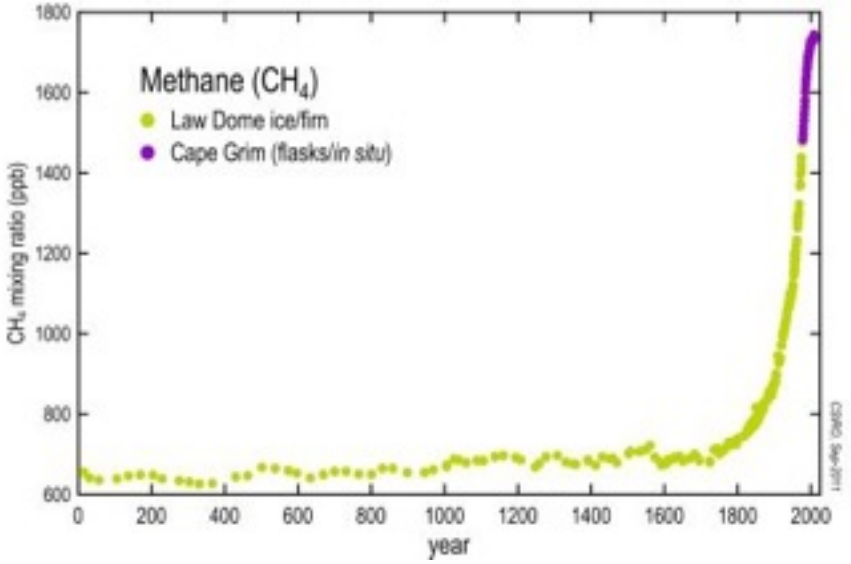
- Assessing climate-change risk to manage
- Anticipating change
- The climate–energy nexus
- Role of engineers

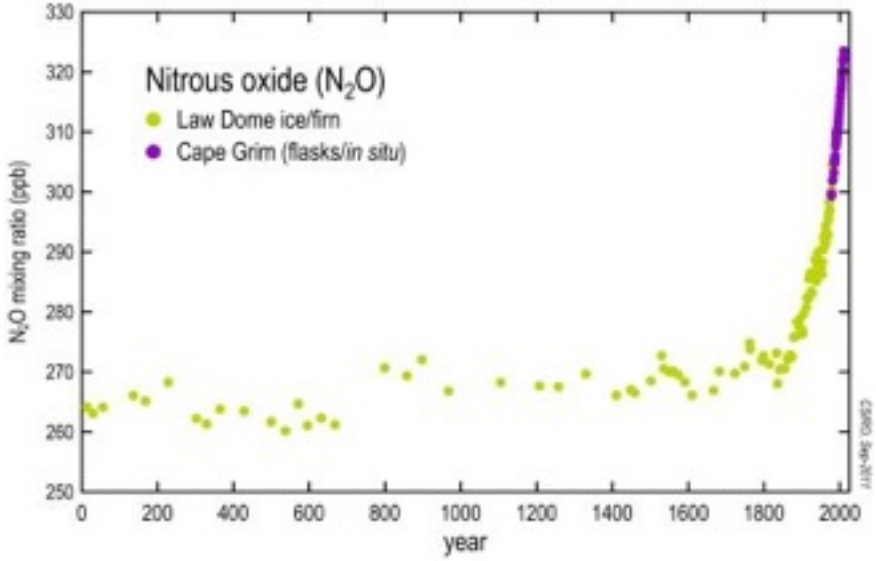
# Carbon dioxide concentration at Cape Grim, Tasmania



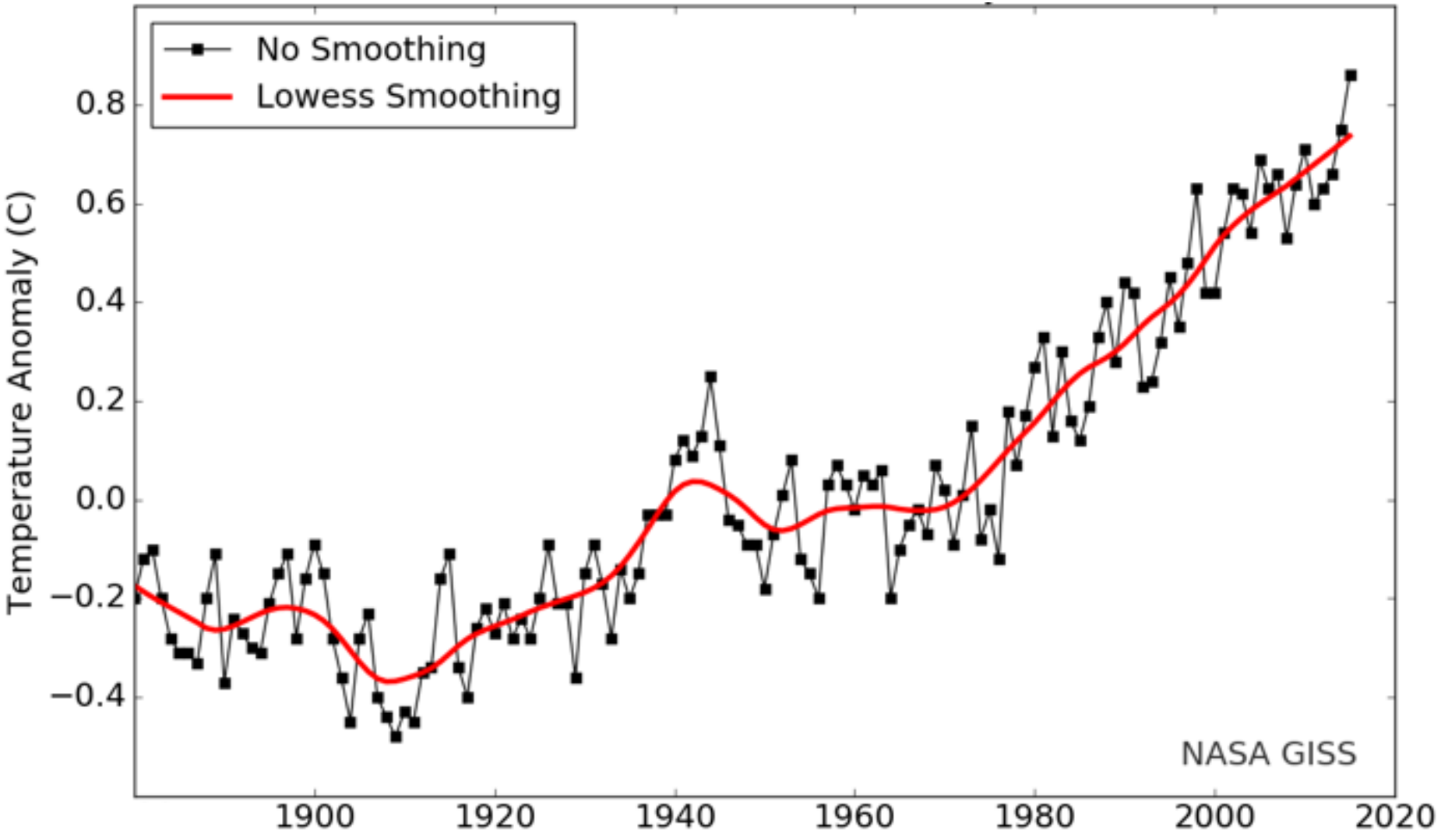
# Human influence on greenhouse gases as measured in Australia



# Global mean annual average surface temperature



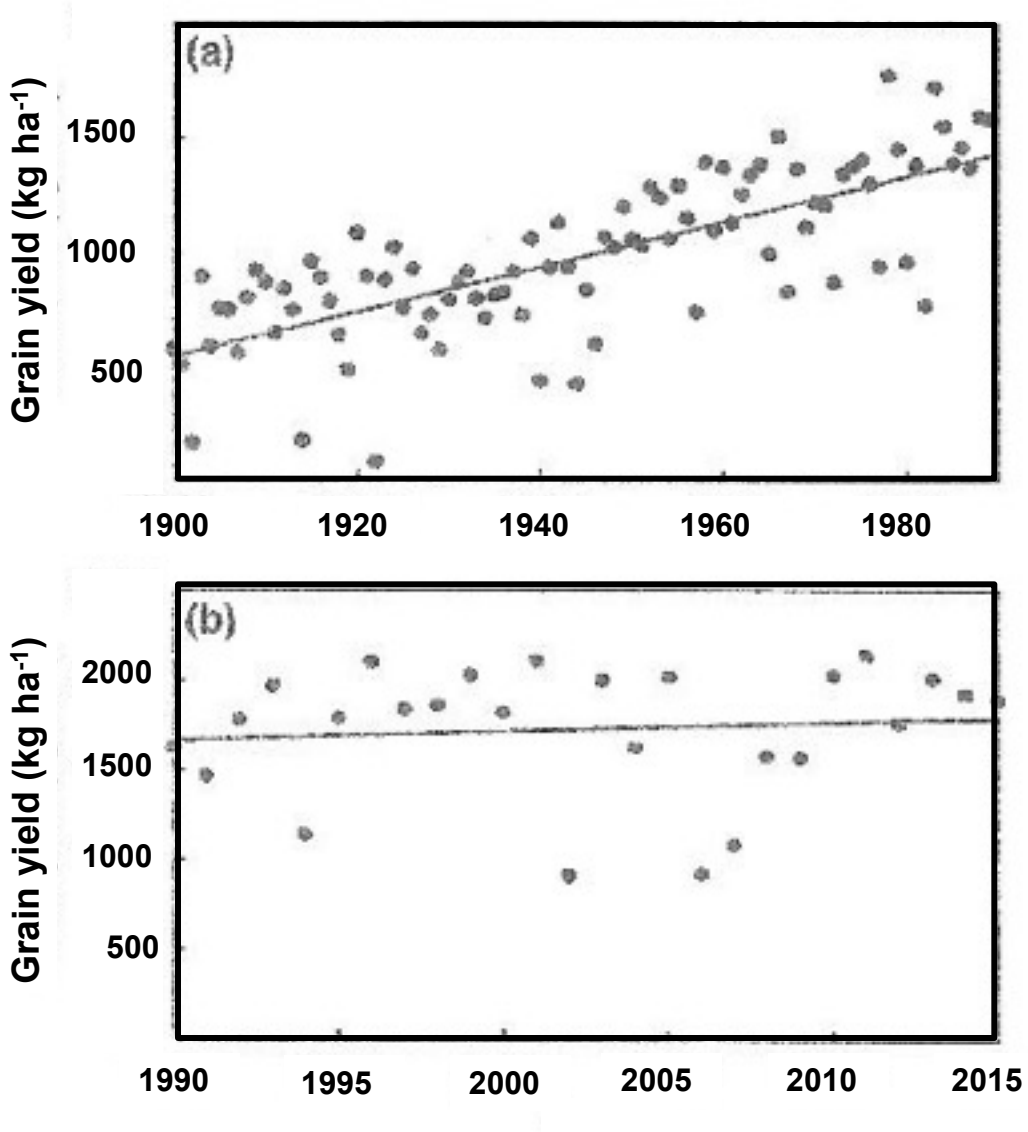
# Consequences

- The planet surface warmed by ~ 1$^{o}$C in last 100 yrs
  - Mostly in the last 2 decades; at higher latitudes
- Sea level rose by ~20 cm world wide
  - With regional differences; thermal expansion/melting
- Antarctica, Greenland ice & glaciers retreated
  - Geopolitical issues; ecosystem impacts
- Atmospheric & oceanic currents are changing
  - Changed frequency in weather statistics
- Impacts on natural & agricultural ecosystems
  - Insurance; fire risk; production systems

# Example observations of change in 2016

- **Record amount of Great Barrier Reef coral perished**
  - 93% of 2,900 individual reefs impacted by coral-bleaching
- **Polar sea ice the size of India disappeared**
  - Polar sea ice about 3.8 Mkm$^2$ below the 1981-2010 average
- **Biggest glacier in East Antarctica is melting**
  - Totten Glacier (E. Antarctica) melting from below; global sea level would rise by ~3.5 m if all melts
- **US coastal communities felt brunt of sea-level rise**
- **Global oceanic oxygen decline, past five decades**
  - Solubility & circulation, Schmidtko *et al.* Nature 542, 335–339 (16 Feb. 2017)

# Stalled wheat yields in Australia since 1990




**"83% due to reduced rainfall and 17% due to rising temperature"**

Hochman *et al.* Global Change Biology (2017), doi: 10.1111/gcb.13604

# Australian Prudential Regulation Authority
# Exec. Board member, Geoff Summerhayes speech:

## 'Australia's new horizon: Climate change challenges & prudential risk'
## 15 Feb. 2017

**"…while climate risks have been broadly recognised, they have often been seen as a future problem or a non-financial problem. ... APRA wants to be explicit .... this is no longer the case."**

**"a comprehensive understanding that will help to identify and avert potential vulnerabilities is not possible unless entities and regulators are systematically monitoring, disclosing and talking about these risks."**

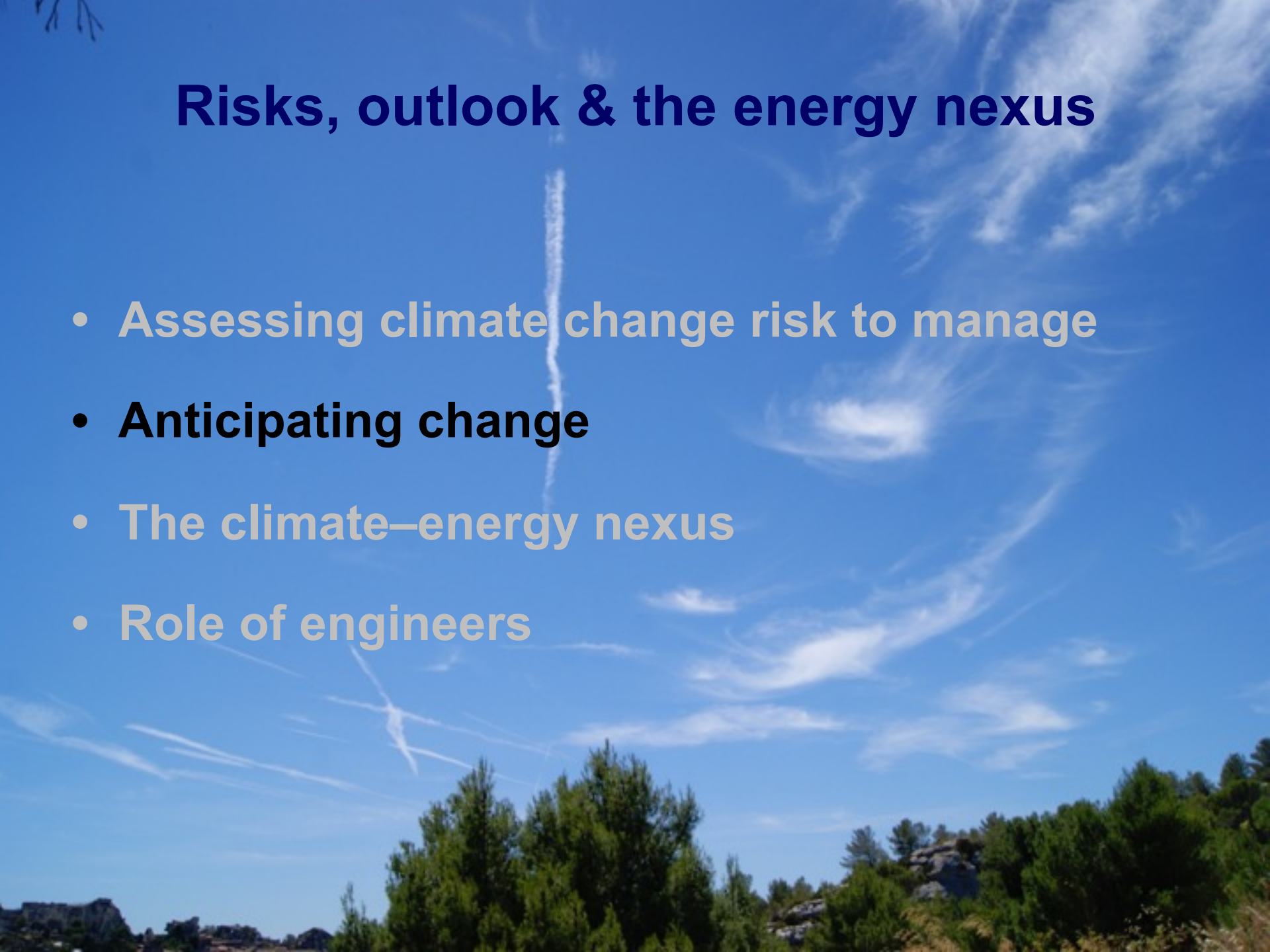
**"...it's unsafe for entities or regulators to ignore risks just because there is uncertainty, or even controversy, about the policy outlook."**

**"....expect to see from us...a greater emphasis on stress testing for organisational and systemic resilience in the face of adverse shocks."**

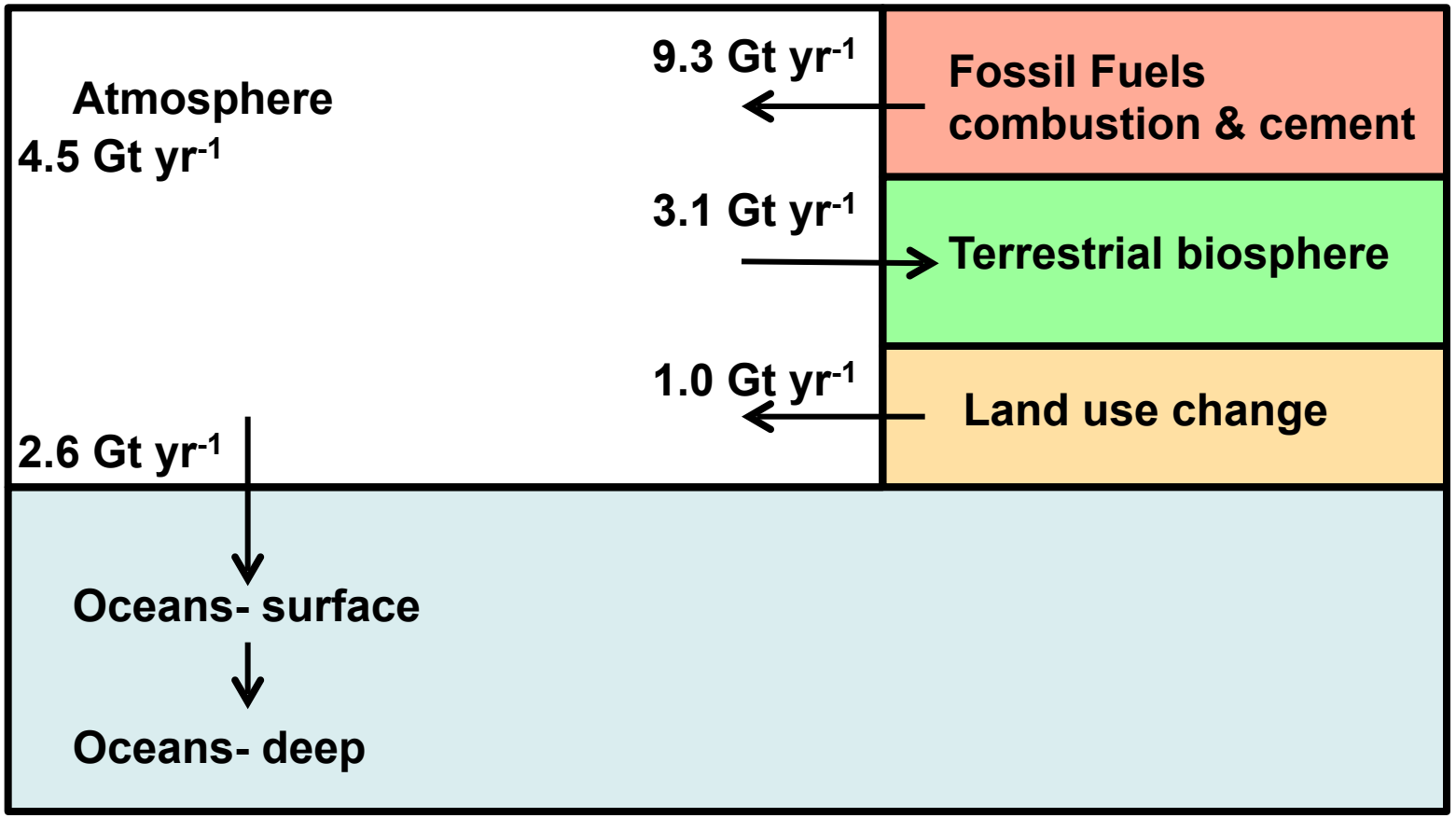
http://www.apra.gov.au/Speeches/Pages/Australias-new-horizon.aspx

# Risks, outlook & the energy nexus

- Assessing climate change risk to manage
- **Anticipating change**
- The climate–energy nexus
- Role of engineers



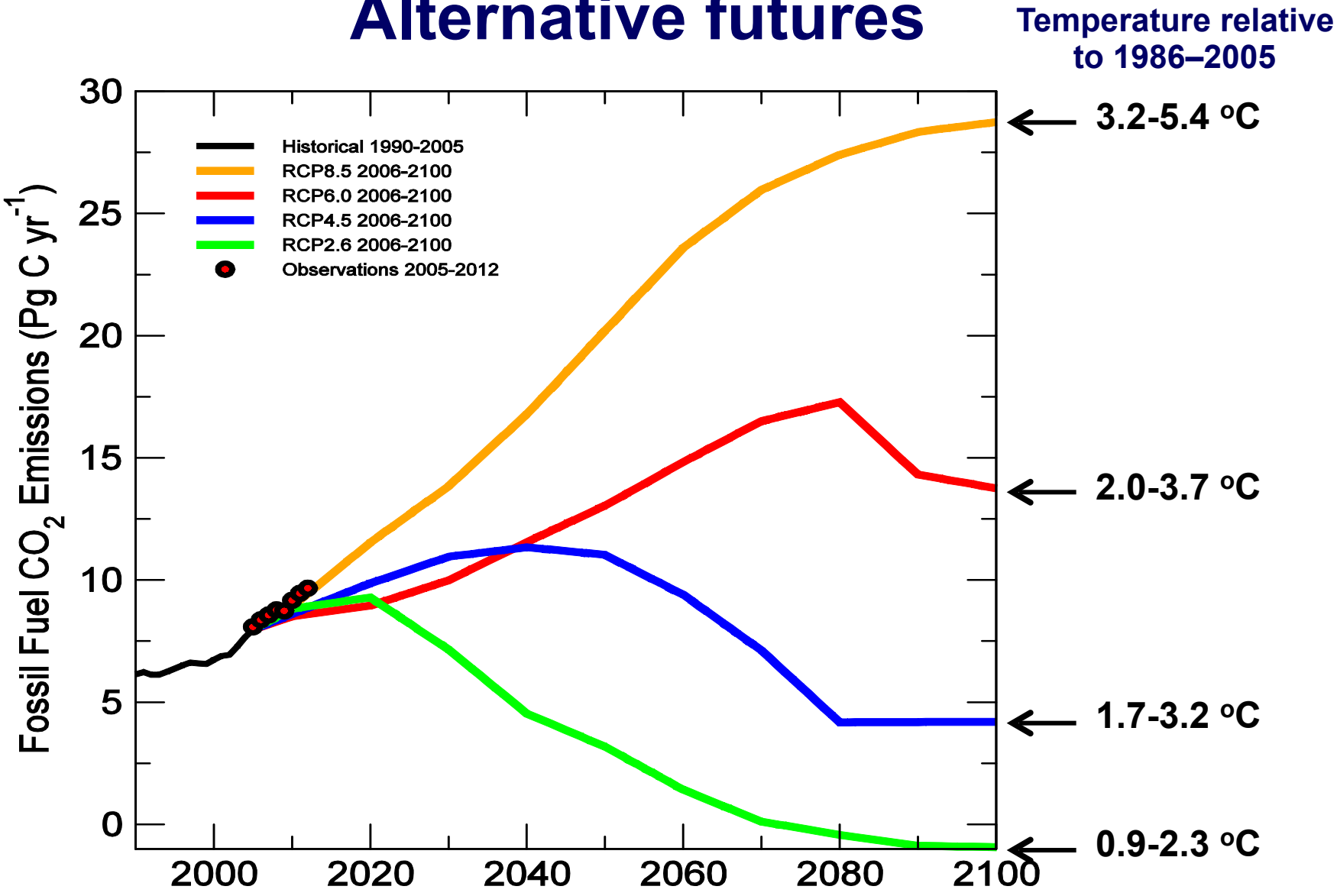
# State of the global carbon budget, 2006-2015



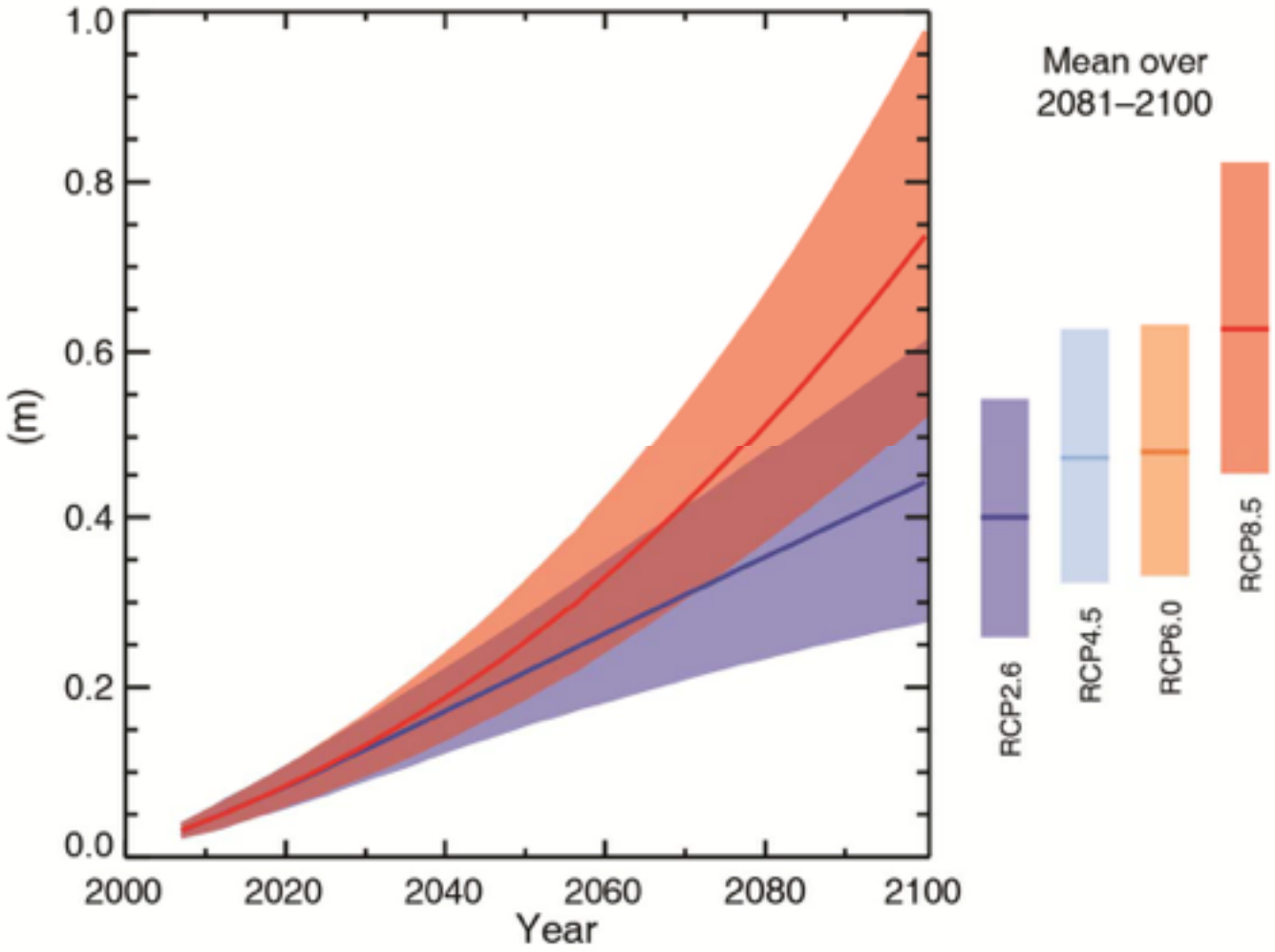

**FF + LUC = ATMOS + OCEANS + LAND SINK; all fluxes in units of carbon**

Le Quere *et al.,* Earth Systems Science Data 8, 605-649, 2016

# Alternative futures



# Global mean sea-level rise




From IPCC Fifth Assessment Report- Summary for Policy Makers, Figure SPM 9

# Key south east Australian findings

- Multiple lines of evidence indicate that tropical weather systems are expanding southward, considerably influencing SE Australia climate

- There is evidence that the southern storm tracks that historically brought reliable cool season rainfall to southern Australia have shifted southward

Results of the SEA Climate Initiative: http://www.seaci.org/

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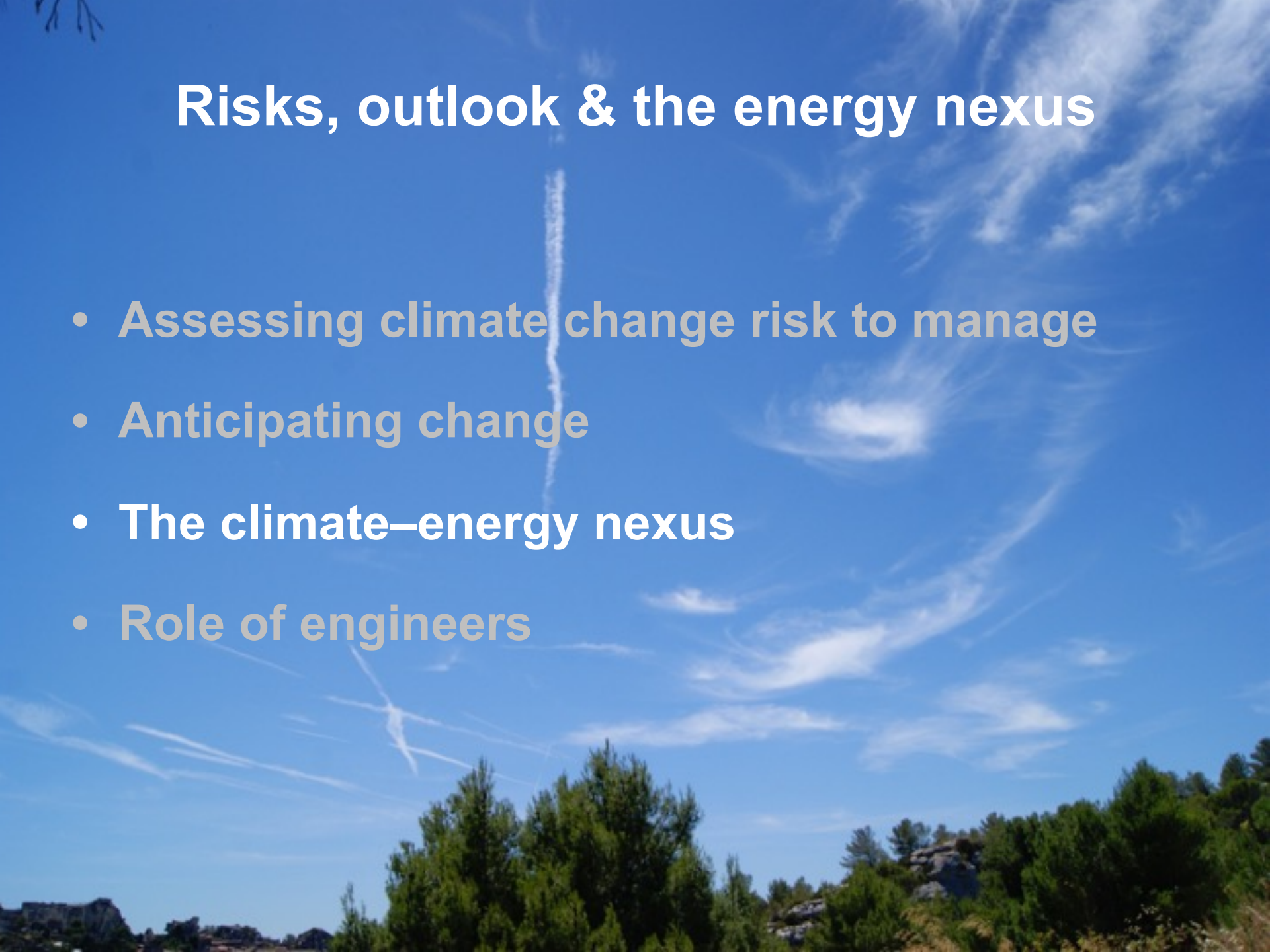


# Probability of exceeding 2°C

## Allowing for climate sensitivity & global cumulative greenhouse-gas emissions, 2000–2049

| $CO_2$ equivalent (Gt) | Probability of exceeding 2°C (%) |
|---|---|
| 1,356 | 8–37 |
| 1,500 | 10–43 |
| 1,678 | 15–51 |
| 2,000 | 29–70 |

Meinshausen et al. 2009, 458 1158-1163. doi:10.1038/nature08017

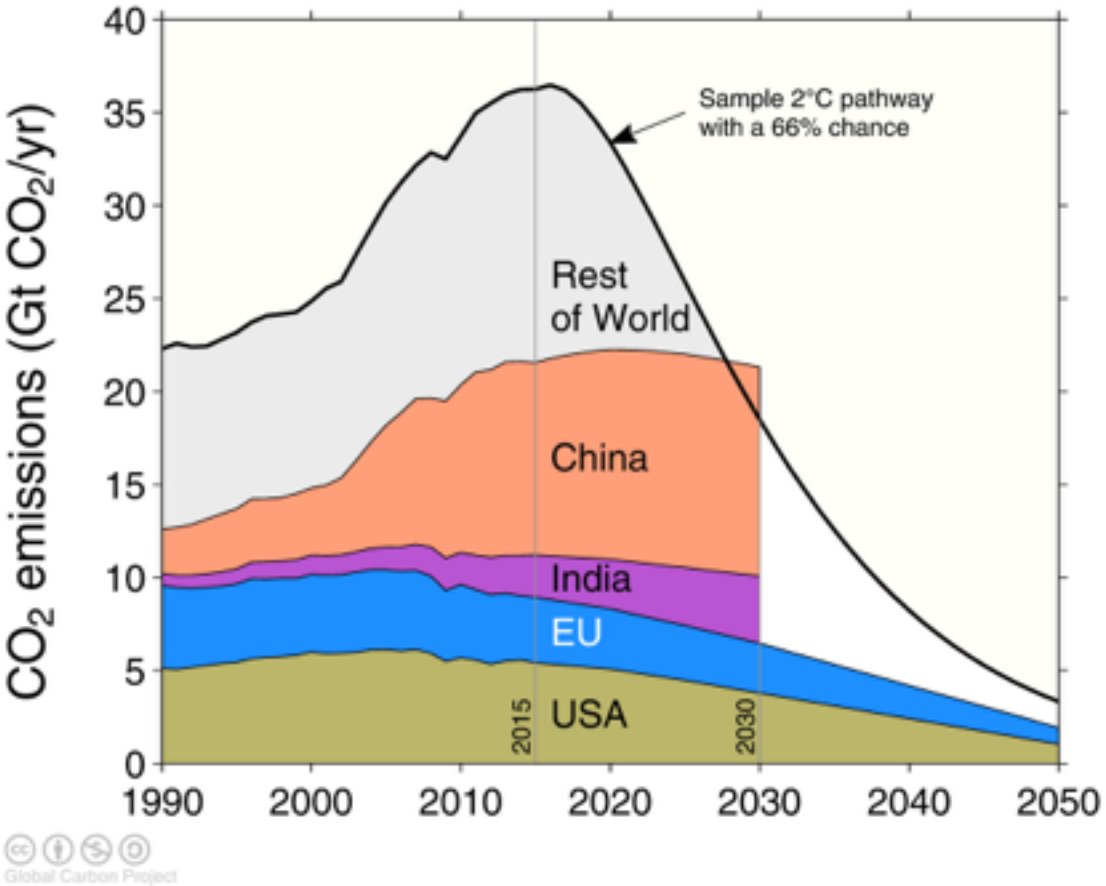
# Paris Agreement
## Conference of the Parties (CoP21) to the UN Framework Convention on Climate Change

- 122 Parties of 197 Parties to the Convention had ratified by January 11, 2016
- Threshold for Agreement to enter into force was achieved 5 October 2016 & entered into force 4 November 2016
- Nationally Determined Contributions
  - Australia will implement an economy-wide target to reduce greenhouse gas emissions by 26 to 28% below 2005 levels by 2030

# Yes- The good news

- **We have an international agreement (>190 states)**
  - **Paris 2015 Conference of the Parties to the UN Framework Convention on Climate Change**
  - **To keep warming to <2$^{o}$C; preferably to 1.5$^{o}$C**
- **Agreed "nationally determined contributions"**
  - **Australia, 26-28% below 2000 levels by 2030**
- **Support for developing countries**
  - **$100 billion a year by 2020 through 2025**
- **Regular 5-yearly reviews of progress**
- **Transformation of energy system**
  - **Photovoltaics, wind, retailing, energy storage, electric vehicles, etc.**
  - **Opportunities for new businesses**

# Emission pledges (INDCs) of top-4 emitters




Peters *et al.* 2015; Global Carbon Budget 2016

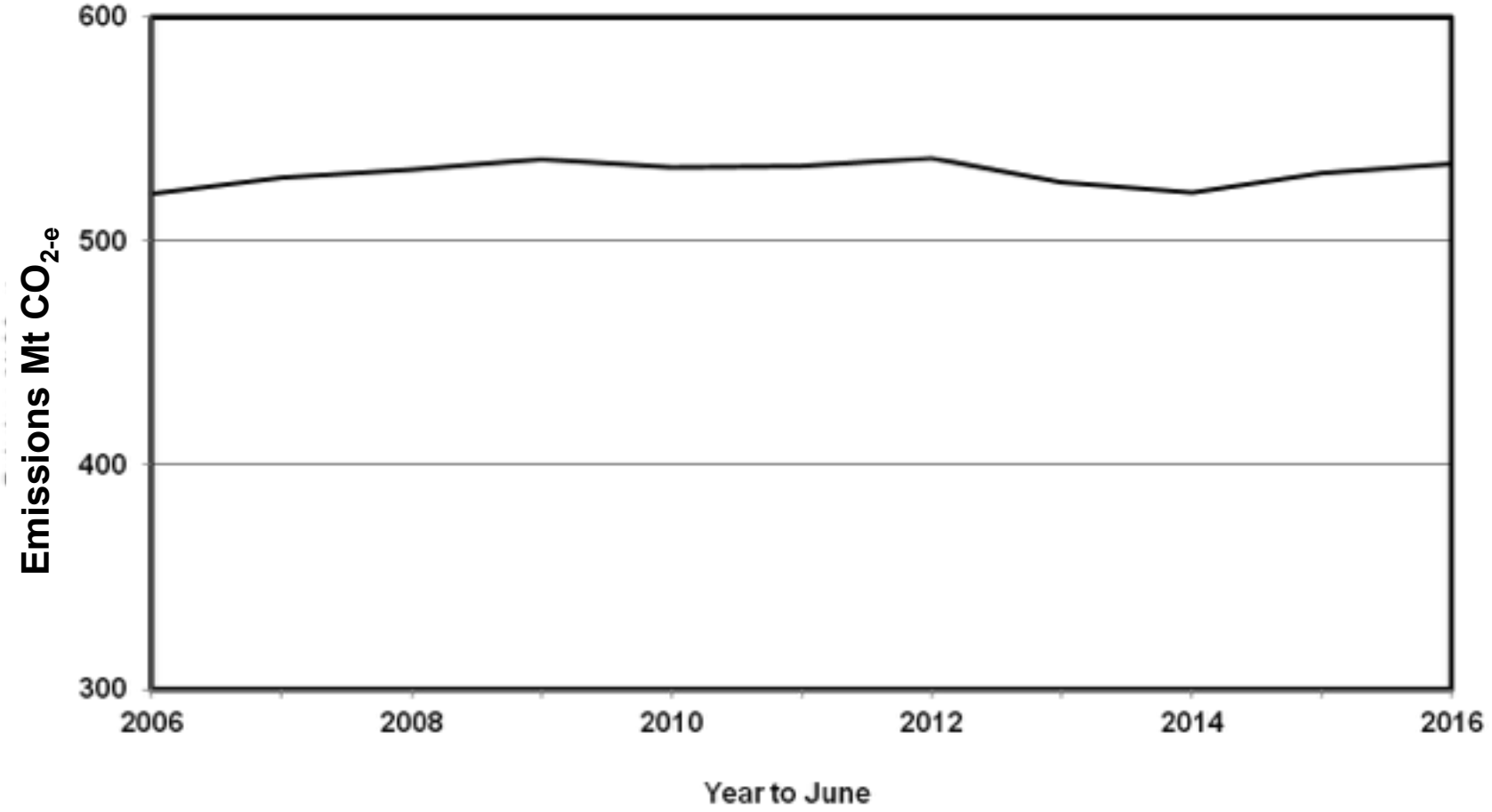
**Current US, EU, China & India emission pledges leave no room for other countries to emit in a 2°C emission budget (66% chance)**

# Australia's "fair share"

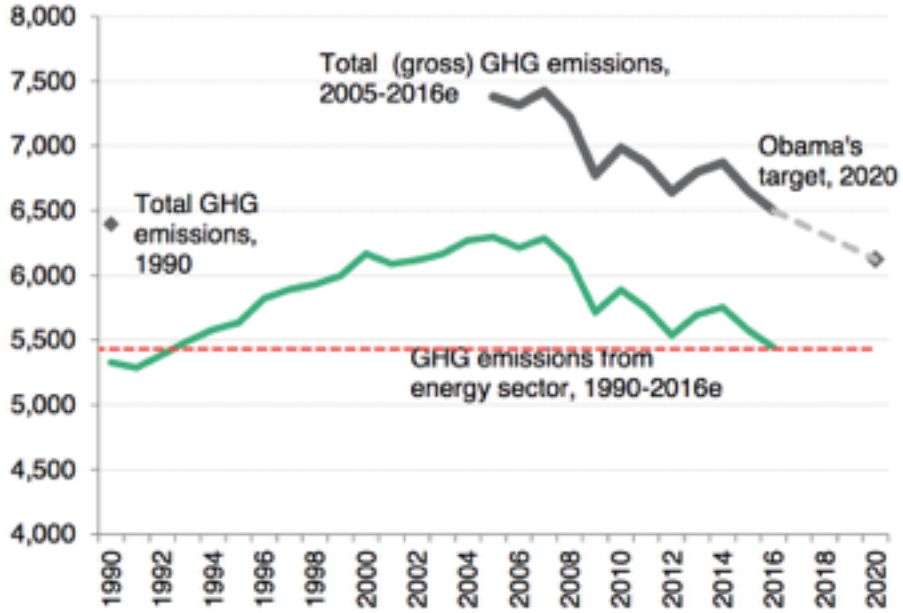
## Climate Authority conclusions:

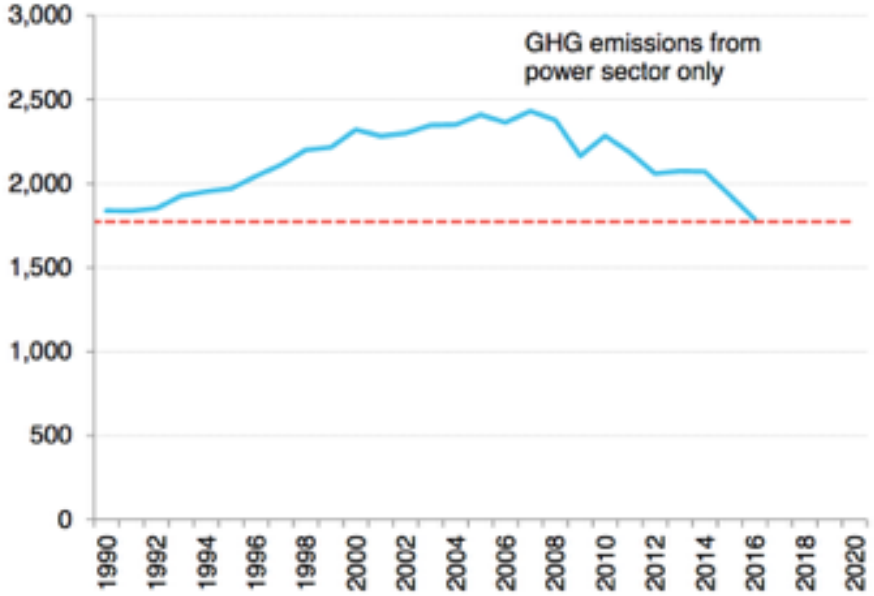
- 5% reduction target inconsistent with Australia's "fair" contribution to the long-term global goal
  - Wont keep pace with actions in many other countries
  - Stronger targets are easier to achieve than previously thought
- Suggest:
  - 2020 target of 15% below 2000 levels- carry over from pre Kyoto commitment gives19% below 2000
  - 2030 target of 40-60% below 2000
  - National carbon budget of:
    - 4,193 Mt $CO_{2e}$ 2013-2020
    - 10,100 Mt$CO_{2e}$ 2013-2050
    - c.f. current annual emissions of about 600 Mt $CO_{2e}$

# National Greenhouse Gas Inventory Department of Environment and Energy



# US energy overview, Bloomberg, $MtCO_{2e}$

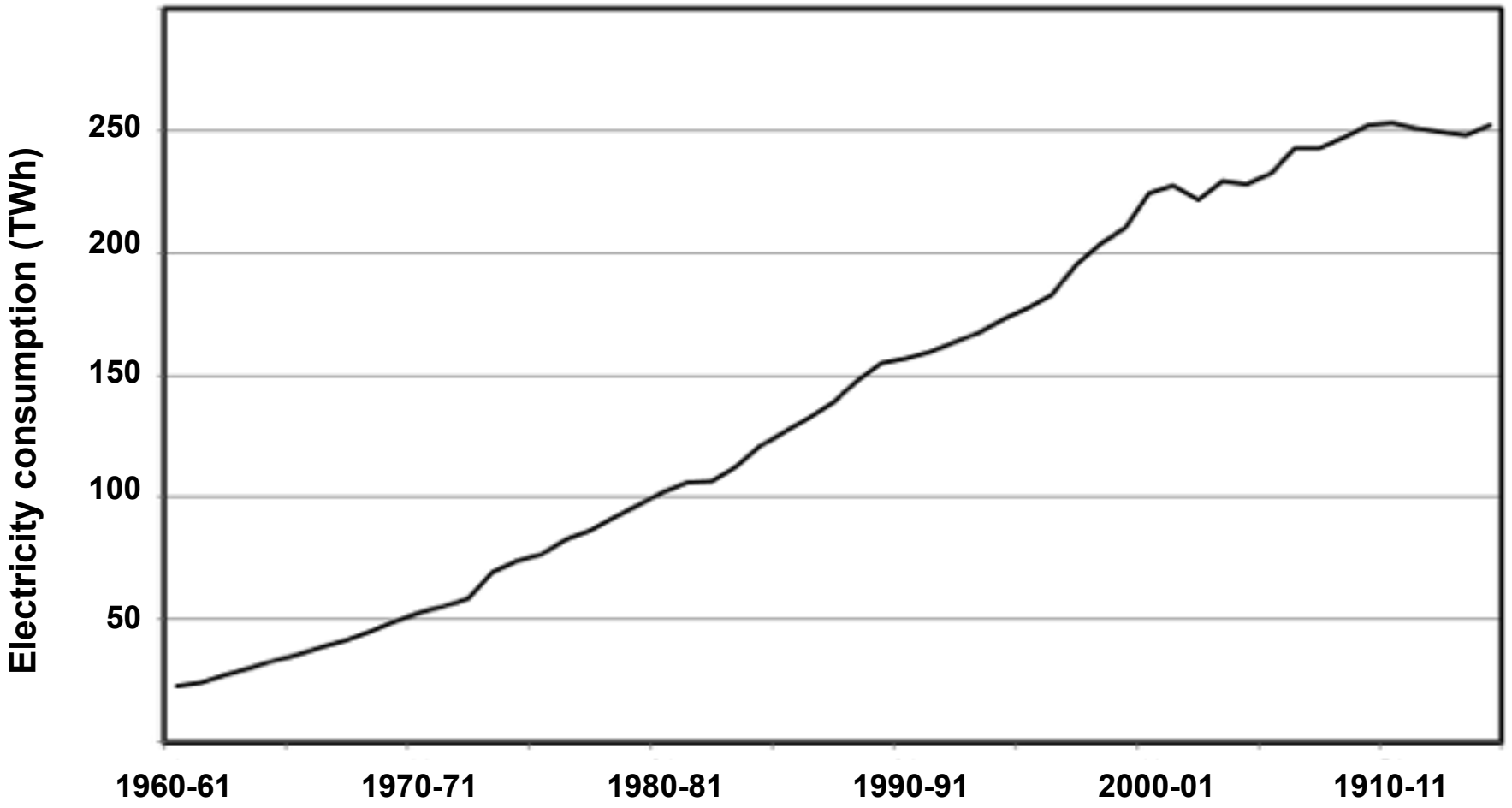



**US emissions are at 25 year low, 12% below 2005**

**Power sector emissions 24% below 2005 levels**

# Australian electricity consumption



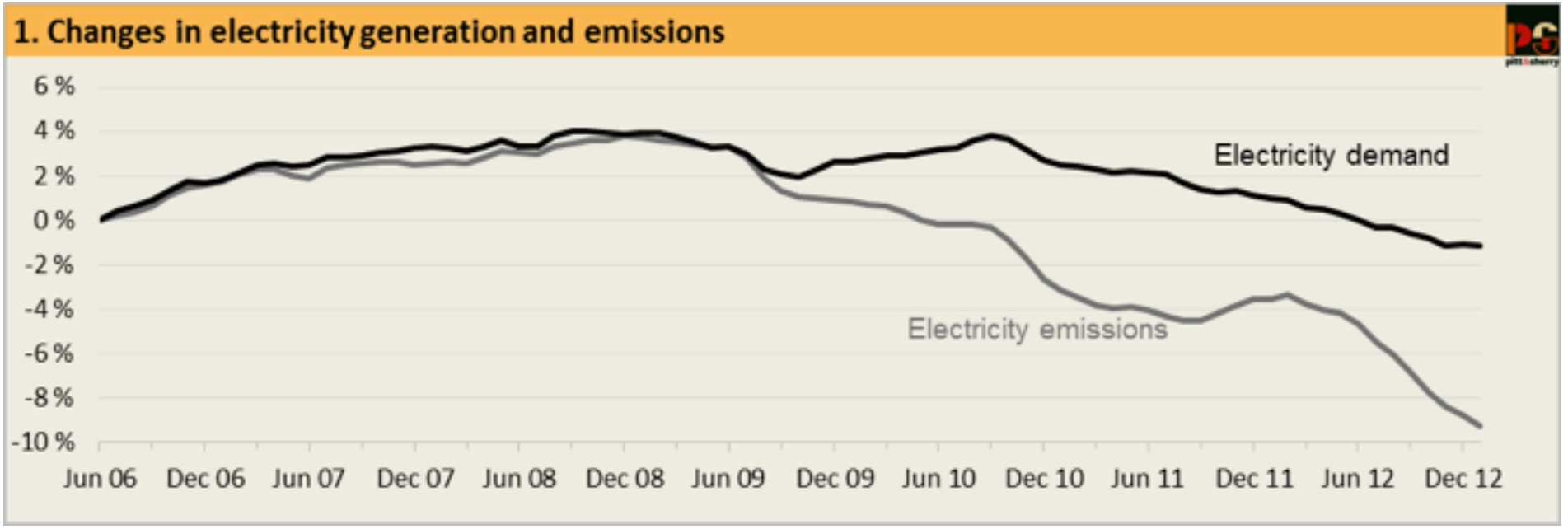
## Contributing factors →

***Intervention***

- **Home insulation**
- **Efficiency standards - appliances**
- **Efficient light bulbs**
- **Solar feedback tariffs/panels**
- **Mothballing capacity**
- **Public awareness???**

***Market***

- **Price hikes (market at work)**
- **Carbon price scare campaign**
- **Slowing manufacturing**
- **Wind development**
- **Commercial advertising???**



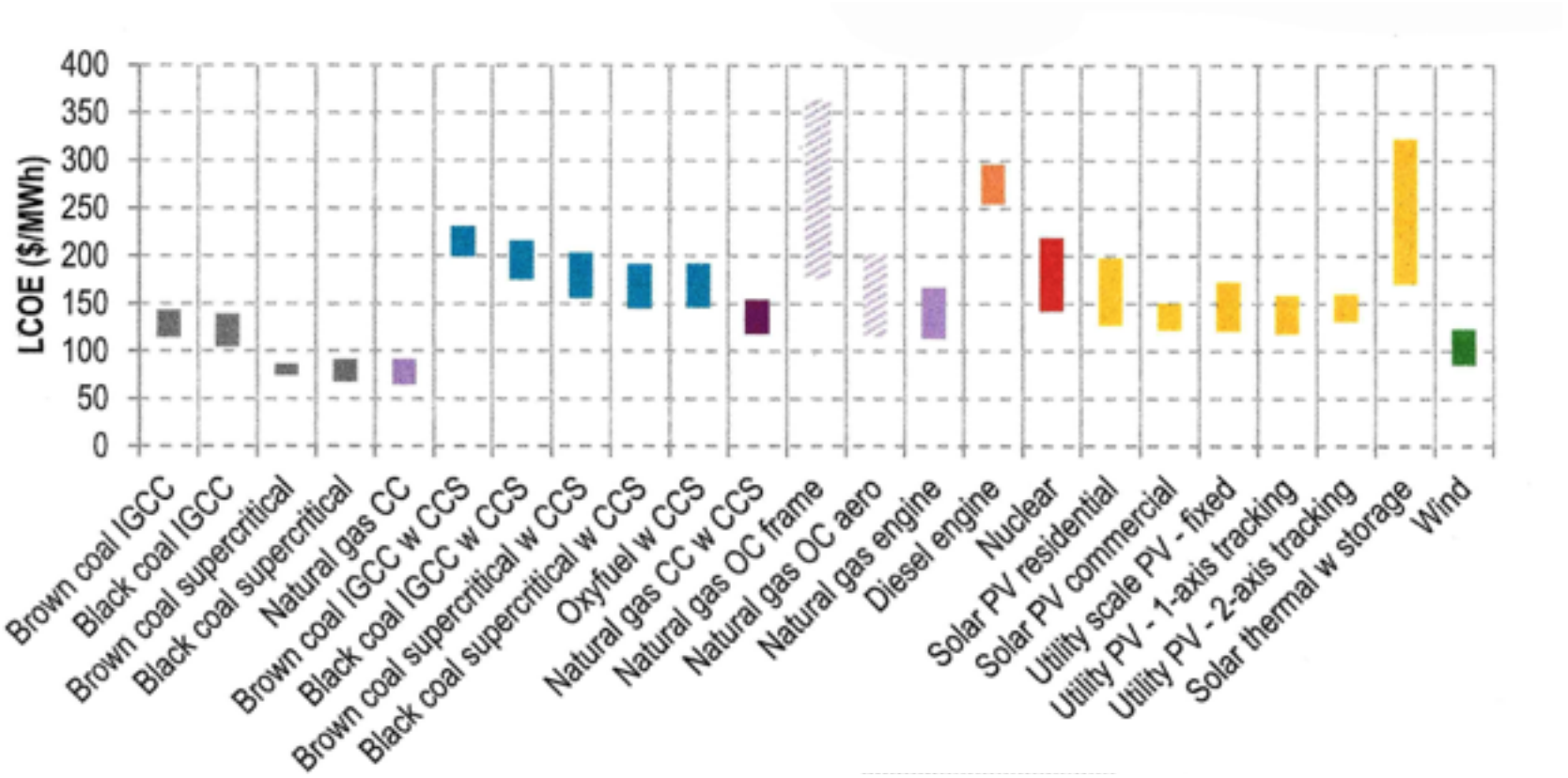
# The challenges

- **Australia's "fair" share**
  - Should be 19% below 2000 levels by 2020, or a budget of 1150 MtC by 2100 c.f. annual emission of 163 MtC
- **No clear Australian plan exists to reach targets**
  - Energy White Paper, 2015 - focus on gas
- **Exports of energy/carbon**
  - Represent a huge proportion of our "fair" share
  - Questions of equity and stewardship
- **Vested interests**
  - Deliberate effort to contain disruptive technology
  - Delay in carbon capture & sequestration technology
  - Costs: agricultural production, human health, infrastructure, national security, etc.
  - Demands holistic, TBL accounting

# IEA World Energy Outlook 2016: Selected projections

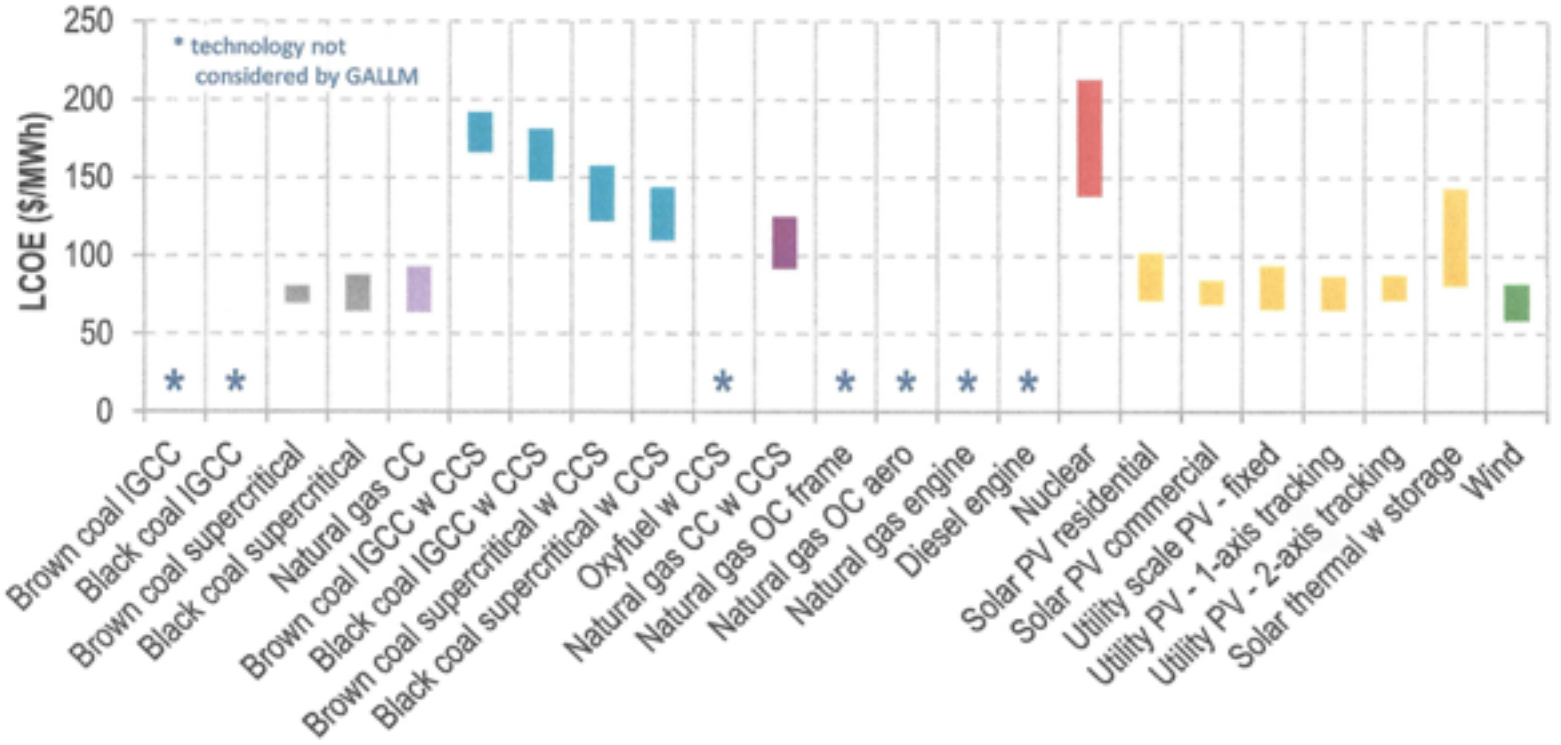
- Climate pledges & climate goals
  - An agreement about energy futures
- Renewables-led transformation
  - New debate over power market design & electricity security
- World energy needs continue to grow
  - But many millions are left behind
- Efficiency is the motor of change
  - e.g. Electric vehicles ready to move
- Renewables break free
- The 2$^{o}$C pathway is very tough
  - 1.5$^{o}$C goes through uncharted territory
-

# Levelised cost of electricity ($/MWh), 2015




**Australian Power Generation Technology Report CO2CRC**

# Levelised cost of electricity ($/MWh), 2030




**Australian Power Generation Technology Report CO2CRC**

# Martin Moore, CEO of CS Energy ABC interview 16 Feb 2017

***Dismissed Malcolm Turnbull's call for the construction of new coal-fired power stations***

**"It's not game-changing. You've still got to think that ultra-super-critical produces twice the emissions of gas-fired technology".**

***So would he, the CEO of a coal-powered generator, build one?***

**"Well, I think CS Energy certainly has no intention of building any coal-fired power plants, ultra-centre super-critical or not. And it would surprise me greatly if there was any more coal-fired technology was built in Australia"**

# Examples of resource exploitation: Two gas fields, one coal field, gas futures

| Reservoir | Company | Stated resource | | | | Production ($Mt\ yr^{-1}$) | | Multiple of annual emissions | | Fraction of emissions "budget", % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $10^{12}\ ft^3$ | $10^{12}\ m^3$ | GtC | $GtCO_2$ | $CH_4$ | $CO_2$ | Annual | Secular | |
| Cooper Basin | Beach Energy | 120 | 3.40 | 1.74 | 6.37 | N/A | 106 | 0.18 | 11 | 76 |
| Gorgon/Jansz-Io | Chevron | 35 | 1.00 | 0.51 | 1.88 | 0.07 | 31 | 0.05 | 3 | 22 |
| Carmichael | Adani | N/A | N/A | 1.96 | 7.17 | N/A | 119 | 0.20 | 12 | 85 |
| Gas Market Report, 2015 | LNG 2020 annual capacity | | | 0.05 | 0.17 | | | | 0.3 | 41 |

e.g. Chevron:

- annual emissions, wherever they occur, are 5% of current Australian emissions, excluding ejected well $CO_2$ & $CH_4$ leakage
- Reservoir emissions are 22% of long-term budget (8,400 Mt) if Australia is to contribute to avoiding greater than 2°C warming

Potential Upside:

- Secure energy resources
- Export earnings
- Jobs

Potential downside:

- Commitment to exceed emissions target
- Conflict with other land use
- Societal displacement
- Stranded assets/risk management

# Risks, outlook & the energy nexus

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- **Role of engineers**

# Overall objective to get from where we are to where we need to be:

- With no major economic/social dislocations
- Capturing opportunities to build a new economy & related social structures
- Achieving win-win outcomes in an holistic strategy for the future

# Examples of where engineers are needed

- **Adaptation**
  - **Coastal protection:** Breakwaters, building redesign
  - **Water management:** Capture, efficiency, drainage, treatment
  - **Bushfire protection:** Fire fighting, buildings, escape
  - **Extreme storms:** Bridges, roads, buildings, drainage, flooding
- **Mitigation**
  - **Energy efficiency:** Buildings, transport, smelting, heat/cooling
  - **Carbon capture & sequestration:** Direct $CO_2$ capture
  - **Electricity:** Generation, management, storage, distribution
  - **Methane management:** Low leakage

# Need for engineering with holism: The bio-energy example

| | |
|---|---|
| Global net primary production | 58 GtC $yr^{-1}$<br>≡ 2100 EJ $yr^{-1}$ |
| Global primary energy demand | 500 EJ $yr^{-1}$<br>≡24% of NPP |
| Current human appropriation | ~40% of NPP |
| IEA bio-energy 2050 strategy is for | 250 EJ $yr^{-1}$<br>≡12% of NPP even if converted with 100% efficiency to usable energy |

# Rise of a "post-truth" political culture

- **Opinion/ideology override facts & populism**
  - Not a credible evidence base informing policy-making
- **Scientists/engineers generally agree:**
  - A real, physical, world exists that we can observe, albeit imperfectly
  - Our values & prejudices (our heuristics) can "blindside" us
- **We have techniques for reducing those influences, i.e.**
  - Replication, randomisation, procedural controls, assessment of results without knowledge of the initial treatment
  - Explicitly encouraging/requiring that knowledge is continuously challenged
  - Inventing ever-more detailed ways of observing the world to test theories, challenge or refine old understandings
- **We aim for ever-more reliable understanding of the world**
  - We may never reach the absolute truth. But we will get closer; that is where value & excitement lies