Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA



Current status and prospects of key 'clean coal' competitors in the evolving electricity industry

Dr Iain MacGill

Joint Director, CEEM

Future Clean Coal: Carbon Capture and Storage

IBRC Conference

Brisbane, November 2007

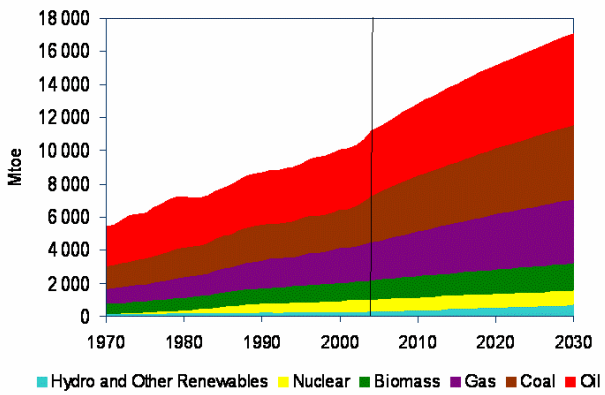
Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA

A largely fossil fuelled world…

- Fossil fuels dominate the global energy mix although renewables have key role in some, mainly developing, countries

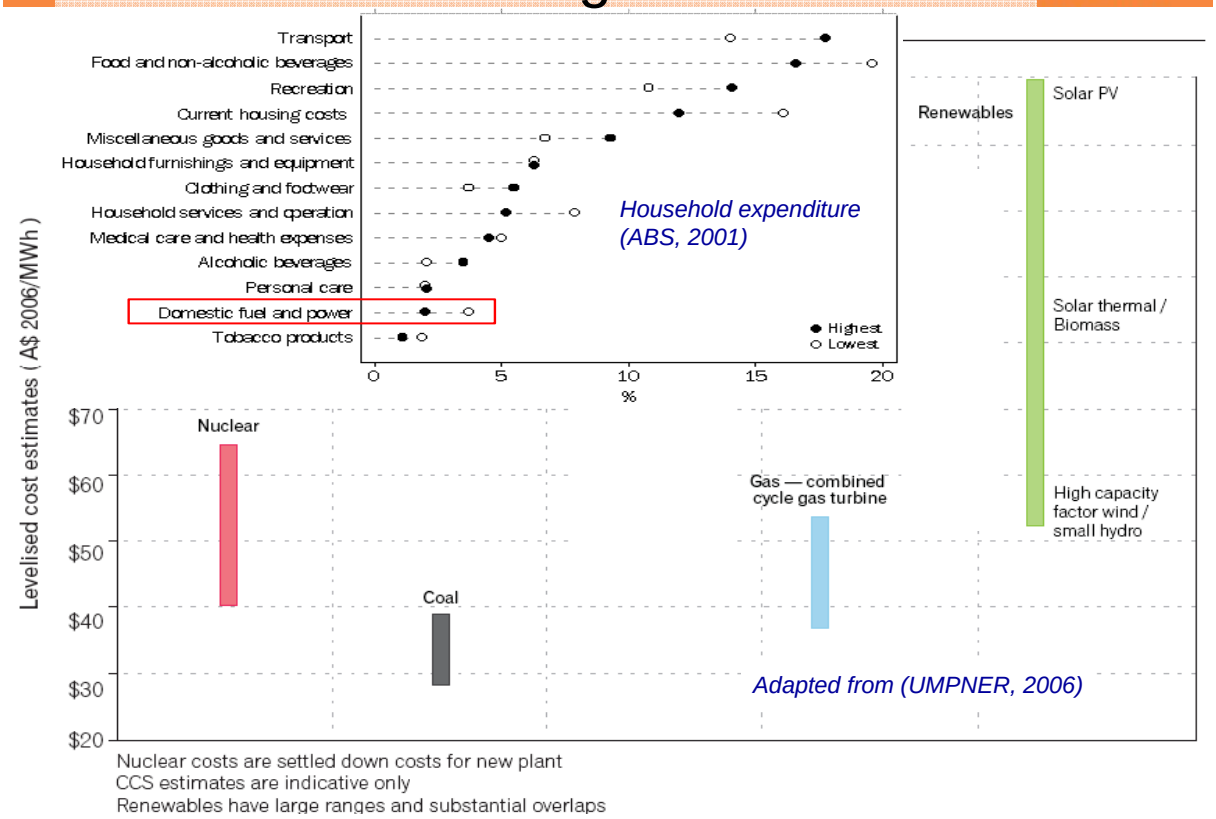
World Primary Energy Demand by Fuel in the Reference Scenario



Centre for Energy and Environmental Markets

UNSW

…. for good reason

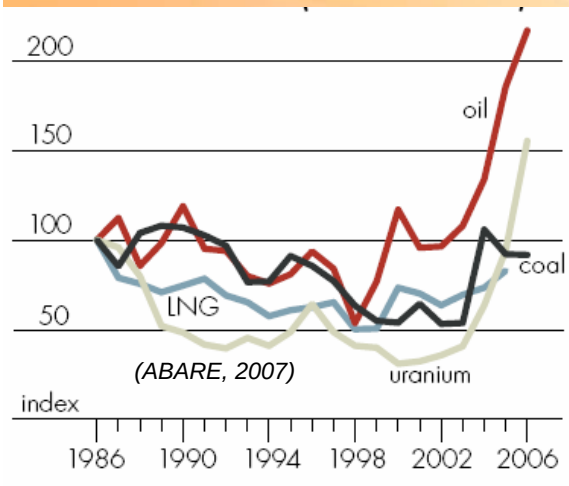


Nuclear costs are settled down costs for new plant
CCS estimates are indicative only
Renewables have large ranges and substantial overlaps

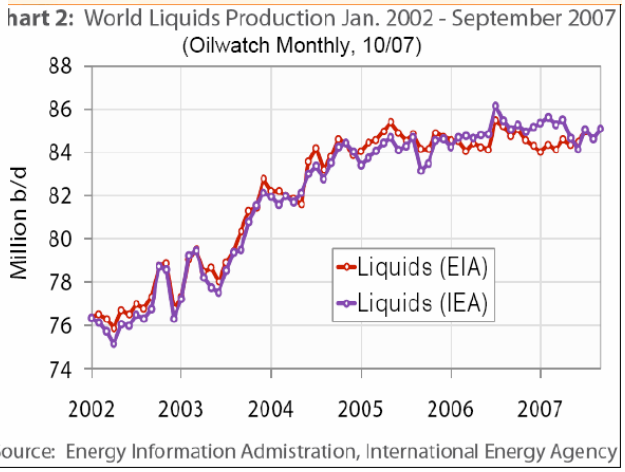
Centre for Energy and Environmental Markets

UNSW

Energy security concerns grow…



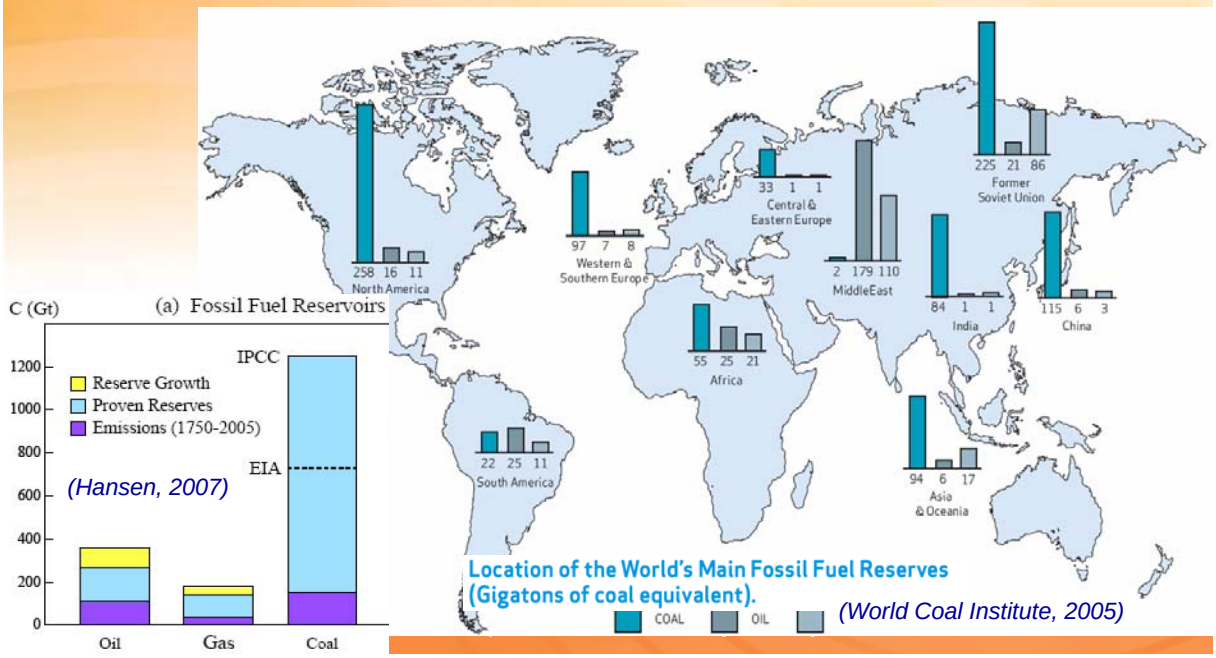
(ABARE, 2007)



Source: Energy Information Admistration, International Energy Agency

Status and prospects of key 'clean coal' competitors i

Regional issues with oil & gas, plentiful coal … and we are unlikely to run out of fossil fuels

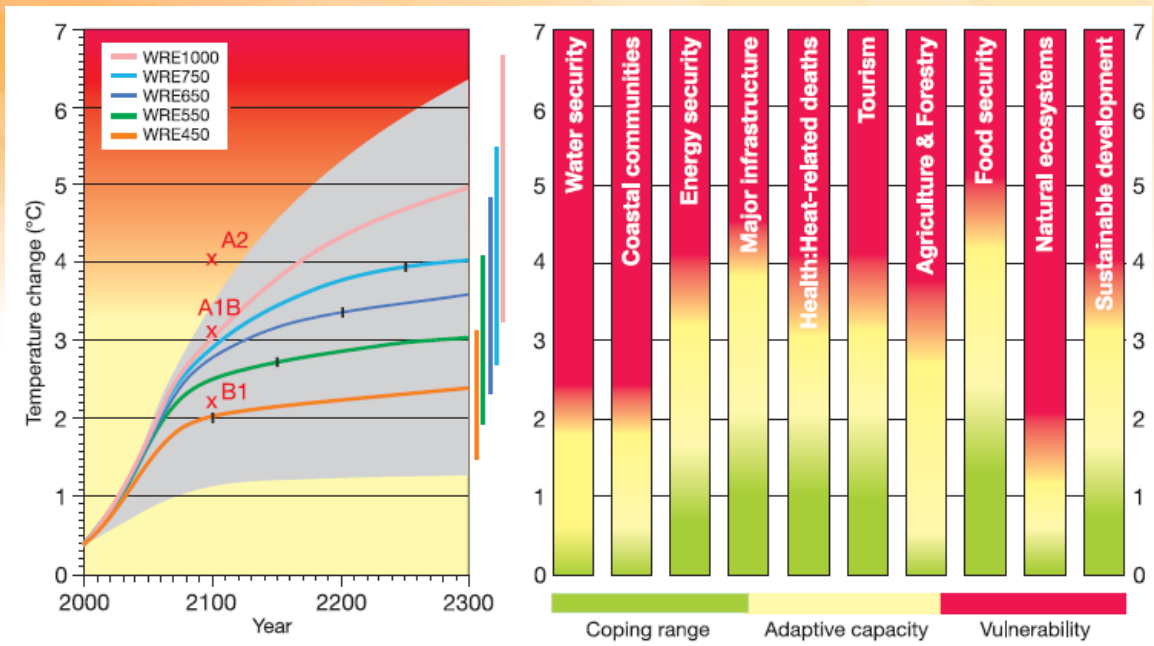


(World Coal Institute, 2005)

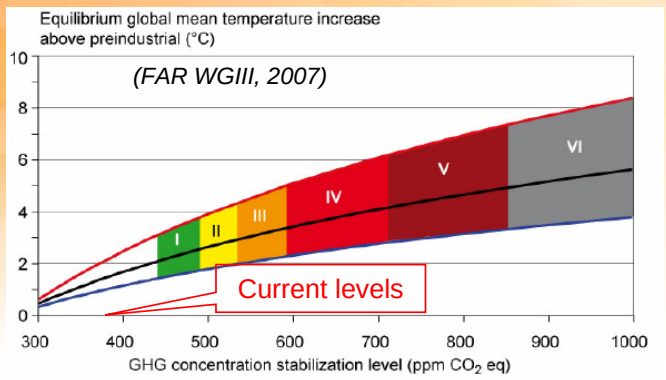
(Hansen, 2007)

..before global warming concerns dominate

Australian and NZ vulnerability *(IPCC WGII, 2007)*



Avoiding dangerous warming - stabilisation



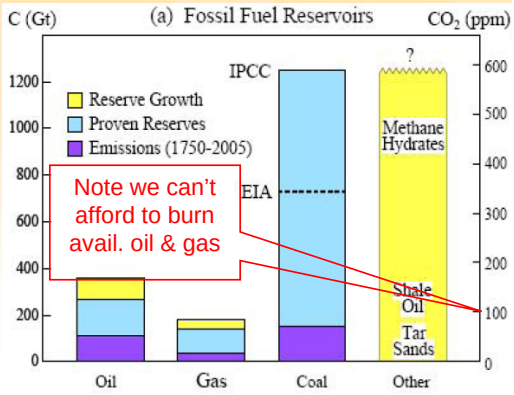
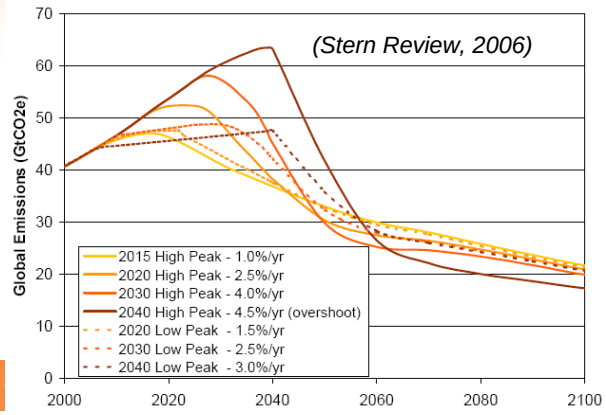


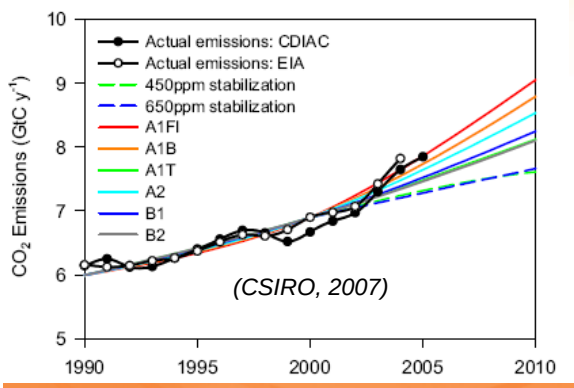
Table SPM.5: Characteristics of post-TAR stabilization scenarios [Table TS 2, 3.10][a)]

Category	Radiative Forcing (W/m^{2})	CO_2 Concentration[c)] (ppm)	CO_2-eq Concentration[c)] (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[b), c)] (°C)	Peaking year for CO_2 emissions[d)] (year)	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[d)] (%)	No. of assessed scenarios
I	2.5 – 3.0	350 – 400	445 – 490	2.0 – 2.4	2000 - 2015	-85 to -50	6
II	3.0 – 3.5	400 – 440	490 – 535	2.4 – 2.8	2000 - 2020	-60 to -30	18
III	3.5 – 4.0	440 – 485	535 – 590	2.8 – 3.2	2010 - 2030	-30 to +5	21

…. and possible emission trajectories

- Note high 'price' of delay
  - Waiting 20 years to act requires emissions to fall 3-7 times faster to a lower level
- *… current trajectory exceeds the 'worst case' IPCC scenarios from TAR*

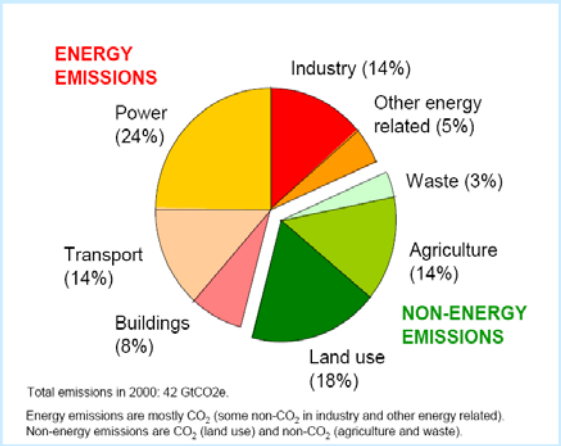




Abatement options *(Stern, 2006)*

- Reducing demand for emissions-intensive goods + services
  - Energy conservation / frugality
- Increased efficiency
  - Particularly end-use efficiency, but also in supply + distribution
  - Can save both money and emissions
- Action on non-energy emissions
  - Land-use, agriculture, waste
  - non-CO2 industrial emissions
- Switching to lower-carbon technologies for power, heat and transport
  - Renewables, Nuclear, Gas Carbon Capture and Storage

Figure 1 Greenhouse-gas emissions in 2000, by source



Source: Prepared by Stern Review, from data drawn from World Resources Institute Climate Analysis Indicators Tool (CAIT) on-line database version 3.0.

Centre for Energy and Environmental Markets
UNSW

Key drivers in assessing our energy options

- *Their ability to contribute to large, rapid and sustained global emission reductions while maintaining energy security*
  - Technical status
    - unproven => mature; emerging => widespread
  - Delivered benefits
    - **GHG emission reductions,** flexibility, dispatchability
  - Present costs where known – + possible future costs
  - Potential scale of deployment
    - possible physical, technical + cost constraints
  - Potential speed of deployment
    - time and effort required to achieve scale
  - Other possible societal outcomes
    - eg. other environmental impacts, **energy security implications**

Q - What is Clean Coal?

A - ongoing process of technological progress

- Following path determined by earlier successes
  + evolving policy drivers
  - Economic efficiency, Energy security & Environmental sustainability.
- Technology emphasis therefore also evolving
  - More efficient use, Cleaner use
  - **Reduced greenhouse impacts**
    Carbon Capture and Storage – the key

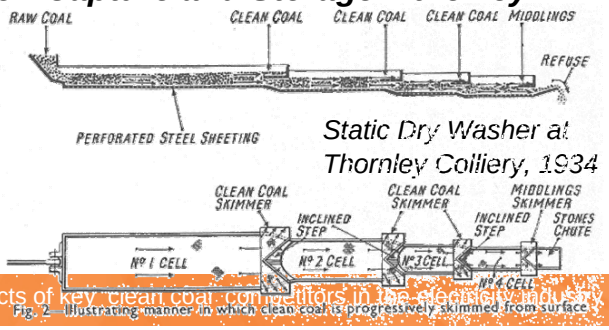


Fig. 2.—Illustrating manner in which clean coal is progressively skimmed from surface.

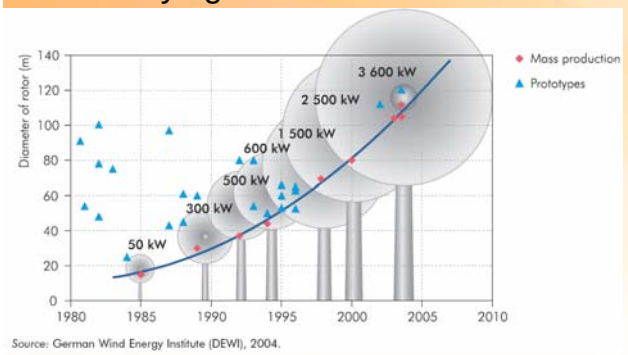
Static Dry Washer at Thornley Colliery, 1934

Colliery Engineering

Our options – technical status

Energy Efficiency	Many off-the-shelf high efficiency options and considerable potential for technical progress
Renewables	Mix of very mature (eg. Hydro) established (eg. Wind) and emerging (eg. Hot Rock)
Lower emm fossil-fuel techs	Off-the-shelf CCGT and Cogen plants – micro cogen technologies still emerging
Nuclear	Established Generation II plants, Gen III designs still being proven up
Carbon Capture + Storage	Not yet demonstrated at scale and fully integrated for electricity generation – demonstration projects not yet implemented

Wide range of RE technologies but varying technical status



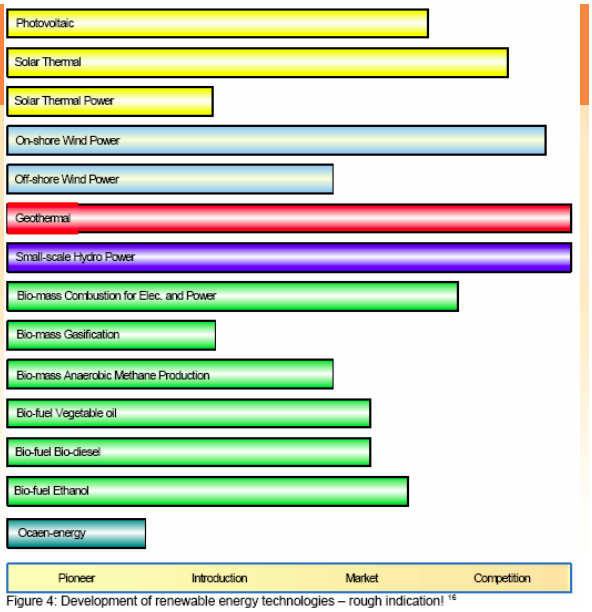
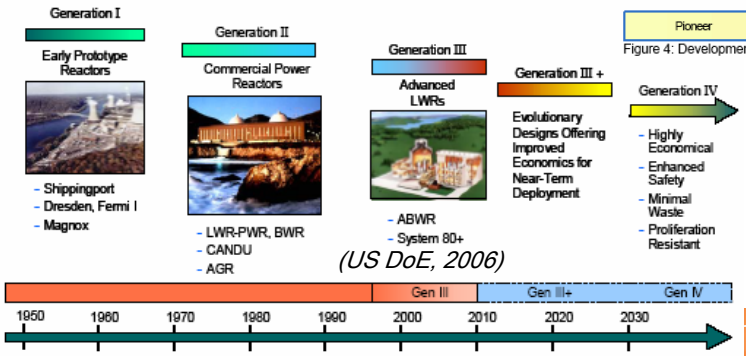


Figure 4: Development of renewable energy technologies – rough indication! [16]

(IEA, 2006)



(US DoE, 2006)

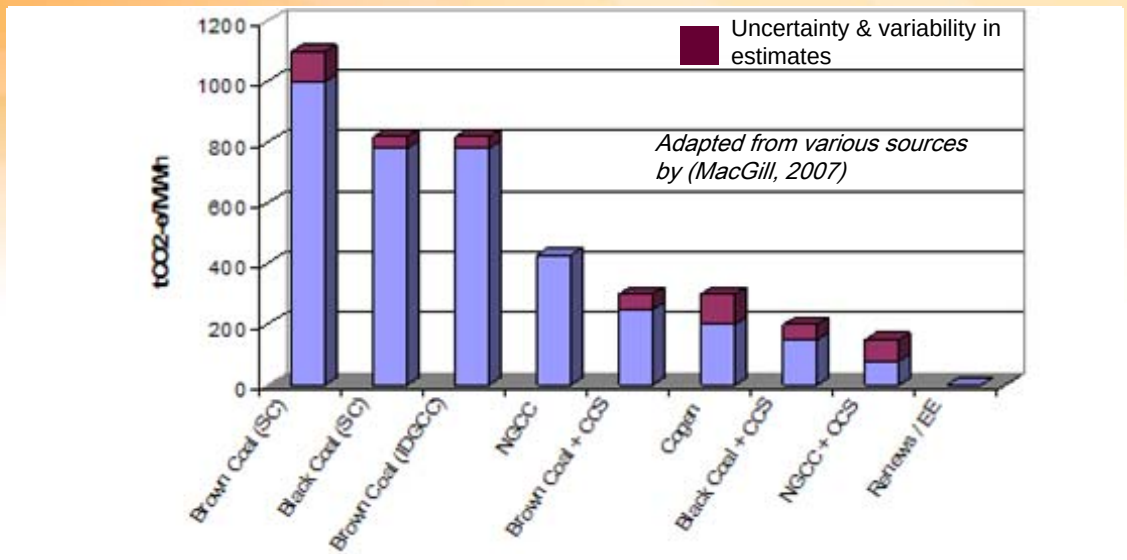
Generation III nuclear plants still being proven up

eg. Westinghouse AP1000 still to be built, first EPR under construction

Our options – delivered benefits

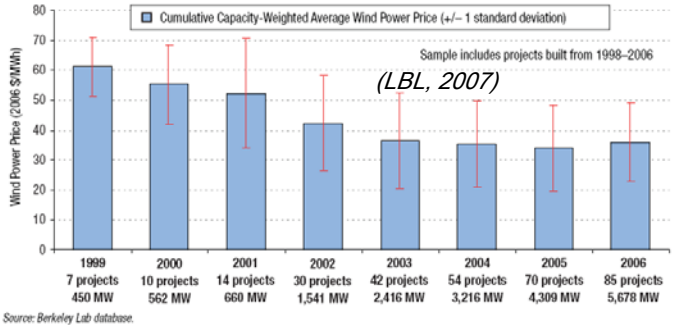
Energy Efficiency	Large emission reductions where emissions-intensive energy, distributed benefits
Renewables	Very secure CO2 abatement (as fossil fuels), some potential distributed benefits, **intermittency issues for some technologies including wind**
Lower emm fossil-fuel techs	Limited abatement with advanced coal generation but CCGT & cogen have <50% emissions of coal, good fit with existing infrastructure, cogen distributed benefits
Nuclear	Reasonable fit with existing infrastructure – existing plants relatively inflexible operation
Carbon Capture + Storage	IGCC+CCS approx. 20% emission of conv. coal plant but long-term storage needs to be proved, reasonable fit with existing centralised infrastructure

Our options – emission reduction potential



Our options – costs.. now + future

Energy Efficiency	Many options offer net cost savings independent of abatement value
Renewables	'new' biomass + wind costs generally falling but still significantly more expensive than conventional options, high uncertainty for emerging technologies
Lower emm fossil-fuel techs	Costs of gas plant very dependent on gas prices – not cost competitive for baseload in Australia
Nuclear	Very difficult to fully cost. emerging designs promise cost reductions….
Carbon Capture + Storage	CCS for electricity generation has highly uncertain + potentially variable costs depending on capture + sequestration. Some potential for cost reductions with learning (as with many emerging technologies)

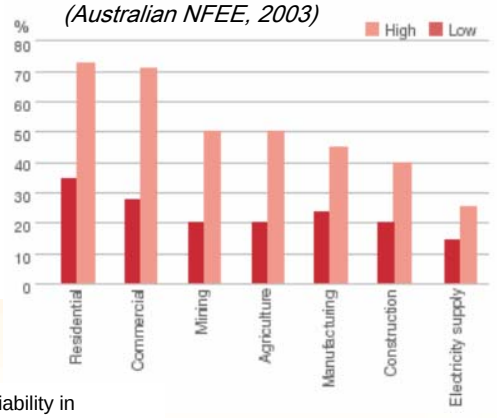


(LBL, 2007)

Figure 9. Cumulative Capacity-Weighted Average Wind Power Price over Time

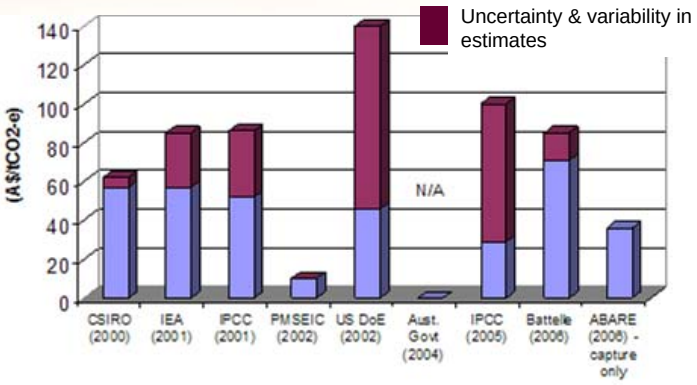
Figure 4: Percentage cost–effective energy consumption reduction potential across different sectors.

(Australian NFEE, 2003)



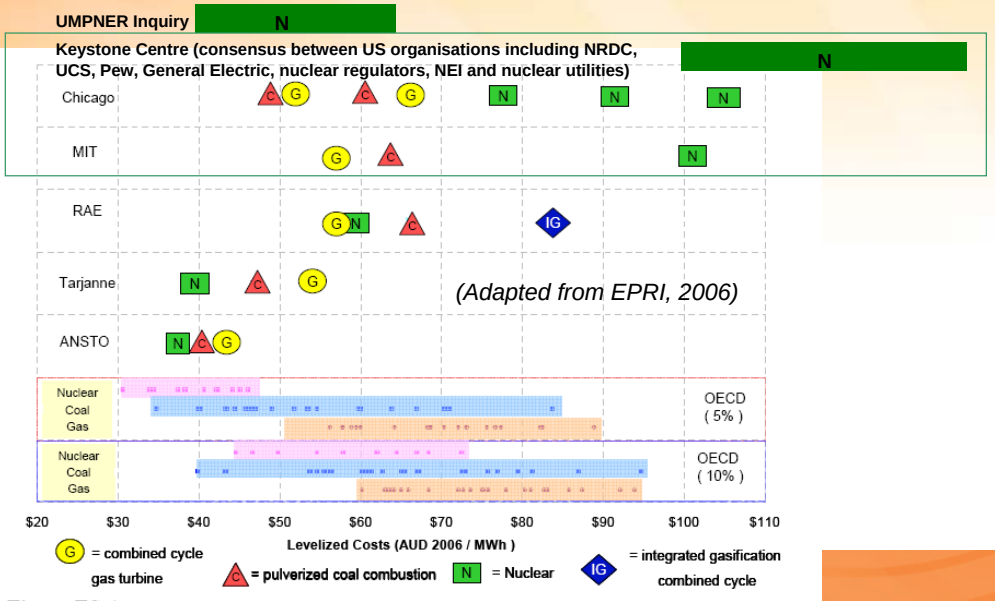
Some estimates of CCS costs

adapted from various sources (MacGill, 2007)



Some nuclear cost estimates….

- Little agreement on nuclear costs – hard to price uncertainties & evolving plant techs
- EPRI estimates Australian nuclear costs 10-15% more than US with its well established nuclear industry, UMPNER cost estimates difficult to justify in this context
- A nuclear energy future for Australia likely incompatible with present electricity-intensive industry development objectives – other nukes countries will have competitive advantage



(Adapted from EPRI, 2006)

Our options – potential scale

Energy Efficiency	Potentially very large (Factor 4, Factor 10), but inherently limited + competing against econ. growth
Renewables	Most individual technologies limited by available fuel supply (hydro, biomass) or face important intermittency issues (**wind**, PV). In combination, however, potentially large. High present uncertainty for Hot Rocks.
Lower emm fossil-fuel techs	Potential for CCGT driven by likely available gas supplies (possible issues in Eastern Australia), CHP has high penetrations (40%) in some countries
Nuclear	Potentially very large but questions of longer-term uranium supply
Carbon Capture + Storage	Potentially very large, although difficult to estimate given present uncertainties on long-term storage – particularly in saline aquifers & coal seams

Current and potential wind penetrations worldwide are significant

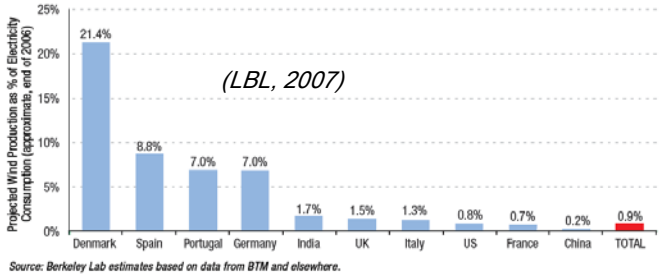
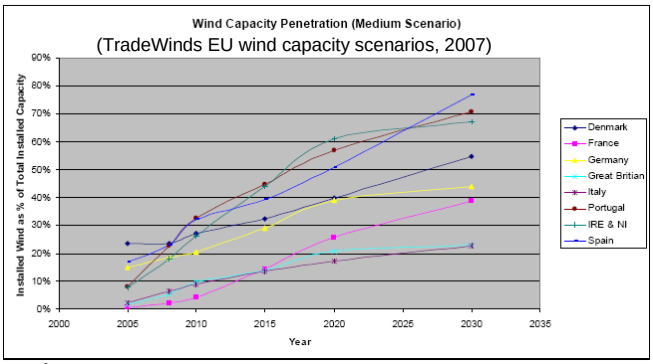
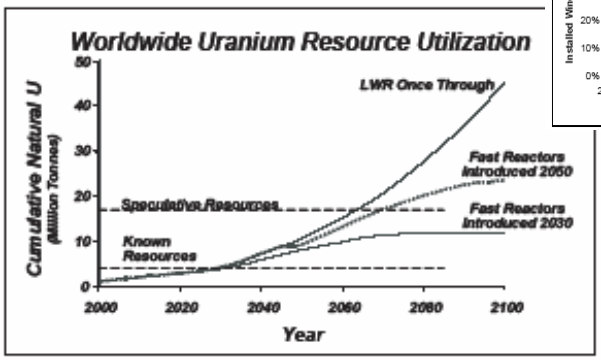


Figure 3. Approximate Wind Power Penetration in Countries with the Most Installed Wind Capacity



Potential Uranium resource constraints? *(US DoE, 2005)*

Scenario assumes constant %nuclear contribution to global electricity supply



Our options – potential speed of deployment

Energy Efficiency	Some options can be rapidly deployed, others have longer capital stock turnover (eg. house construction)
Renewables	Key technologies including Wind and PV growing fast from relatively small base and experiencing some growing pains. Some other technologies still requiring successful demonstration
Lower emm fossil-fuel techs	Very fast for CCGT and fast for cogen – well established technologies backed by large industries
Nuclear	Long lead and build times – unlikely in Australia before 2020. Requires major institutional capacity
Carbon Capture + Storage	Technologies for electricity generation still not demonstrated, institutional capacity and social acceptance still key issues

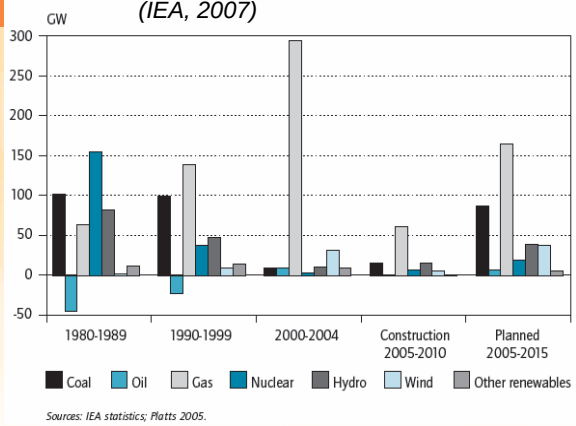
Most installed OECD capacity in last 5 years is gas and wind (considerably more than coal or nuclear

Continuing debate over likely deployment of CCS in electricity generation

Study scenario	Approximate period where significant deployment of CCS in electricity generation begins
PMSEIC (2002)	2005
IEA (2004)	2010
DoE (2004)	2020
IPCC (2005) MiniCAM MESSAGE	 2015-20 2040
ABARE (2006)	2015
CO2CRC (2006)	2030
Battelle (2006)	2025

Net changes in OECD generation capacity (units installed, under construction and planned, 1980-2015) show shift from gas towards coal

(IEA, 2007)

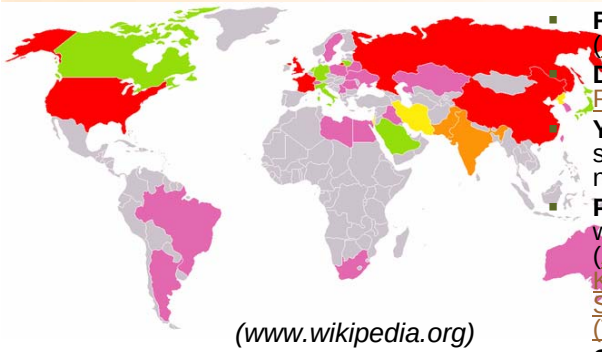


Our options – other societal outcomes

Energy Efficiency	Very promising employment + investment opportunities. Low societal risks, no env. Impacts. **High energy security value**.
Renewables	Promising employment + investment opportunities, including regional areas for many techs. Some env. impacts for some techs – eg. biomass. Land-use issues for wind. **High energy security value**
Lower emm fossil-fuel techs	A range of direct air, water + land env. impacts with fossil fuels. **Energy security a possible issue** with gas for many countries, coal with some countries
Nuclear	**Fraught!**
Carbon Capture + Storage	Direct env. risks from sudden or slow escape of CO2 to atmosphere or ground waters. Coal an important contributor to Aust. economy + high energy security

Potential nuclear proliferation

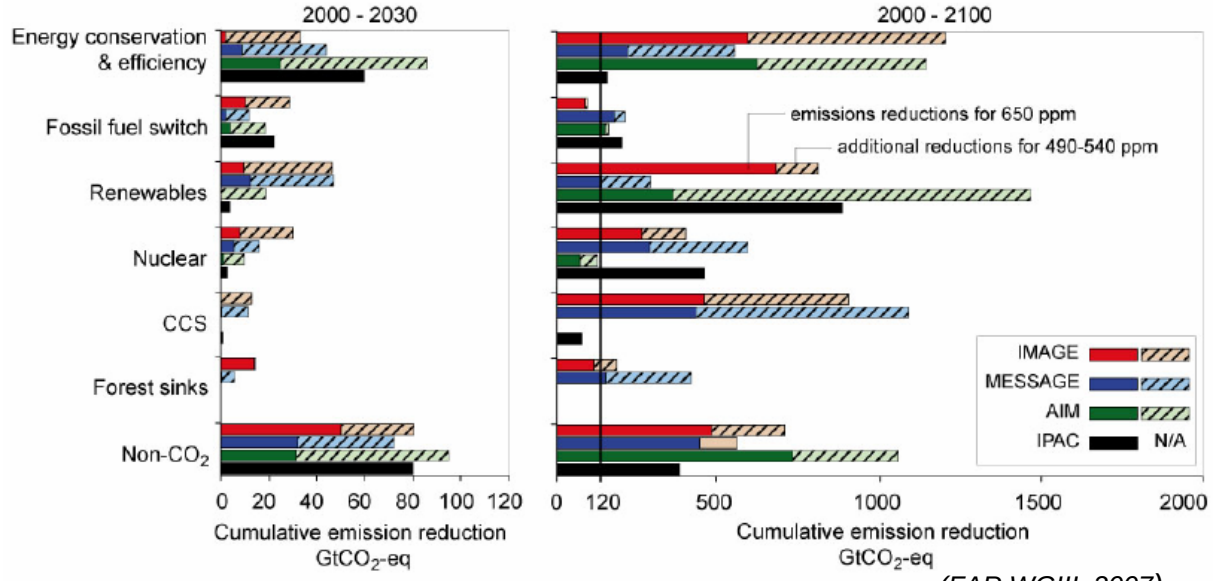
- By some measures 'atoms for peace' and NPT a success
  - Only 4?5 nations have definitely acquired nuclear weapons since it was signed: (*none were signatories at the time*
  - *"Increased Australian uranium exports would not increase the risk of proliferation of nuclear weapons" (UMPNE, 2006)*
- However, IAEA estimates 35-40 non-weapon states now possess technical know-how – nuclear club could grow fast



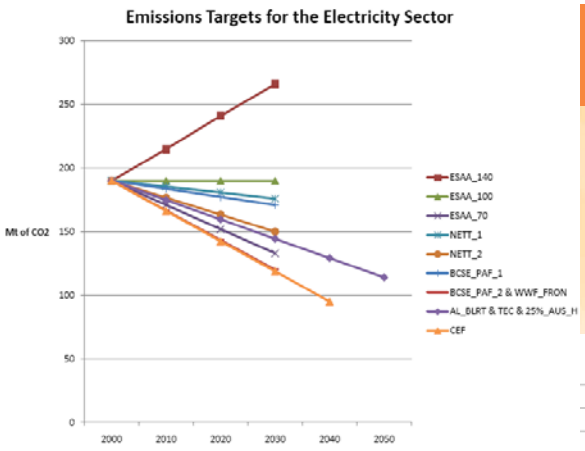
(www.wikipedia.org)

- **Red**: Five "nuclear weapons states" from the NPT. (US, Russia, United Kingdom, France and China)
- **Dark orange**: Other known nuclear powers. (India, Pakistan).
- **Yellow**: States suspected of having possession of, or suspected of being in the process of developing, nuclear weapons. (Israel, North Korea and Iran).
- **Purple**: States which at one point had nuclear weapons and/or nuclear weapons research programs. (Argentina, Australia, Belarus, Brazil, Egypt, Iraq, Kazakhstan, Libya, Poland, Romania, South Africa, South Korea, Sweden, Switzerland, Republic of China (Taiwan) Yugoslavia).
- **Green**: Other states capable of developing nuclear weapons within short amount of time. (Canada Italy, Germany, Japan,, Lithuania, Netherlands and Saudi Arabia).

Putting it all together: future energy scenarios

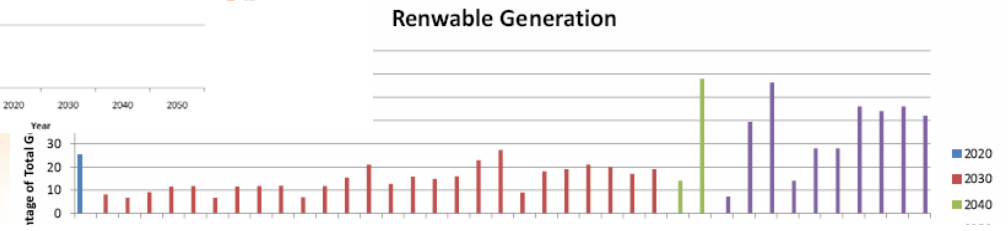


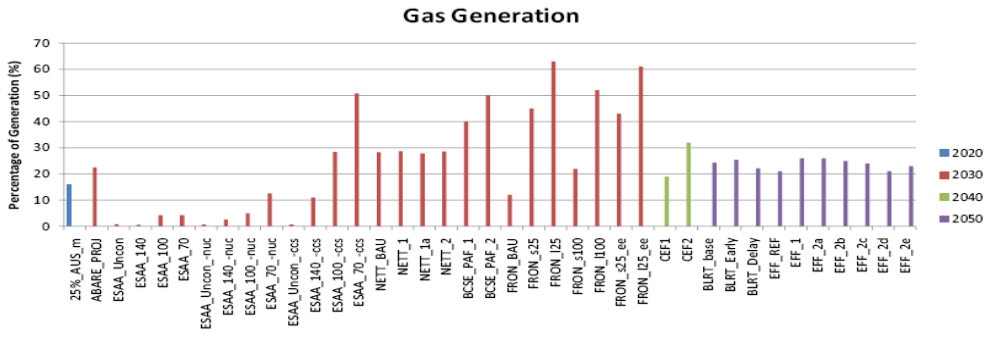
(FAR WGIII, 2007)



UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA

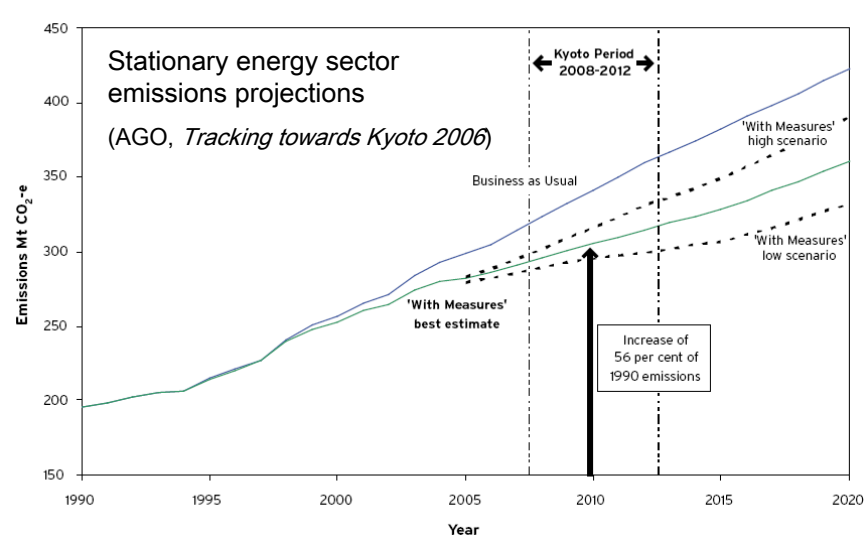
Australian scenarios show wide variations *(Morris, 2007)*





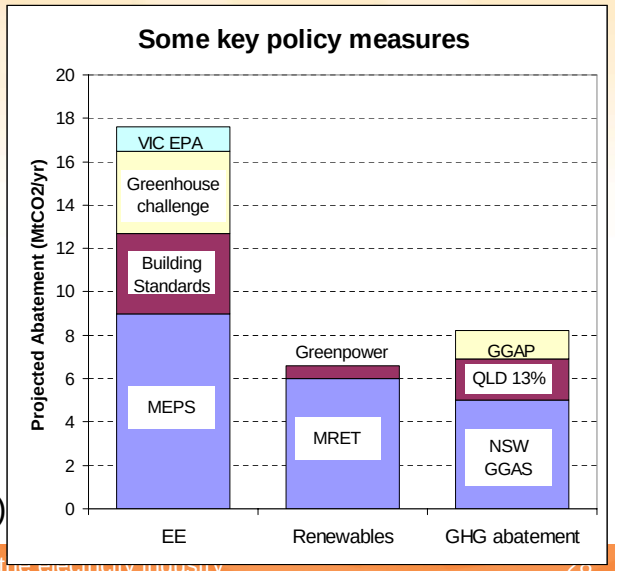
Australia's context for climate policy

- The world's highest per-capita emissions
- Energy-related emissions climbing – 70% of total
  - Estimated +35% over 1990–2004, projected +56% in 2010 and approx. +85% in 2020 under current policy measures



Current Australian Policy efforts

- Major proportion of energy-related abatement expected with current Federal policies from EE and renewables
  - Wind around 25-33% of MRET
- Coming Federal measures
  - National Emissions Trading with initially 'modest' caps below BAU growth, offsets + low penalty fee for exceeding target
  - Clean Energy Target for 2020 approx. 3X current MRET
  - NFEE expansion (stage II?)
  - R&D & Demonstration of low-emission techs focused on Carbon Capture & Storage(CCS)



Some policy conclusions

- Policy priorities: quick & large emission reductions
  - EE & conservation our highest priorities – *will require carbon price & specific policies to target behaviour (ie. regulation)*
  - CCGT & Cogen have vital early role – *will require carbon price & specific policies (eg. market barriers to distributed generation)*
  - Commercial, scaled-up & moderate cost renewables have vital early role; wind a key renewable for Australia – *will require Clean Energy Target & supporting policies (eg. planning)*
- CCS & other emerging options & nuclear are lower priorities
  - Need to deploy EE, gas & renewables to buy CCS & nuclear time to be developed up / institutional capacity established
  - Will require quick and large demonstration programs involving public & private investment & supporting policy frameworks
- *Current delays in establishing these demonstration programs in Australia & worldwide are greatly damaging potential role of CCS in protecting the climate*