Presentation to the joint 2005 lecture program

Engineers Australia, ITEE, IEEE, IEE and Environmental Engineering Society

Facilitating Wind Power Development in Australia

Dr Iain MacGill

Research coordinator - Engineering

Centre for Energy and Environmental Markets

Senior Lecturer

School of Electrical Engineering and Telecommunications

The University of New South Wales

i.macgill@unsw.edu.au

www.ceem.unsw.edu.au

CEEM established …

- *to formalise* growing interest + interactions between UNSW researchers in Engineering, Commerce + Economics… + more
- *through UNSW Centre* providing Australian research leadership in interdisciplinary design, analysis + assessment of energy + environmental markets, associated policy frameworks
- *in areas* of
  - Physical energy markets
  - Energy-related derivative markets
  - Environmental market-based approaches
  - Policy frameworks and instruments in energy and environment

- *Wind power raises interesting research questions for both NEM and associated Aust. environmental markets such as MRET….*

Presentation outline

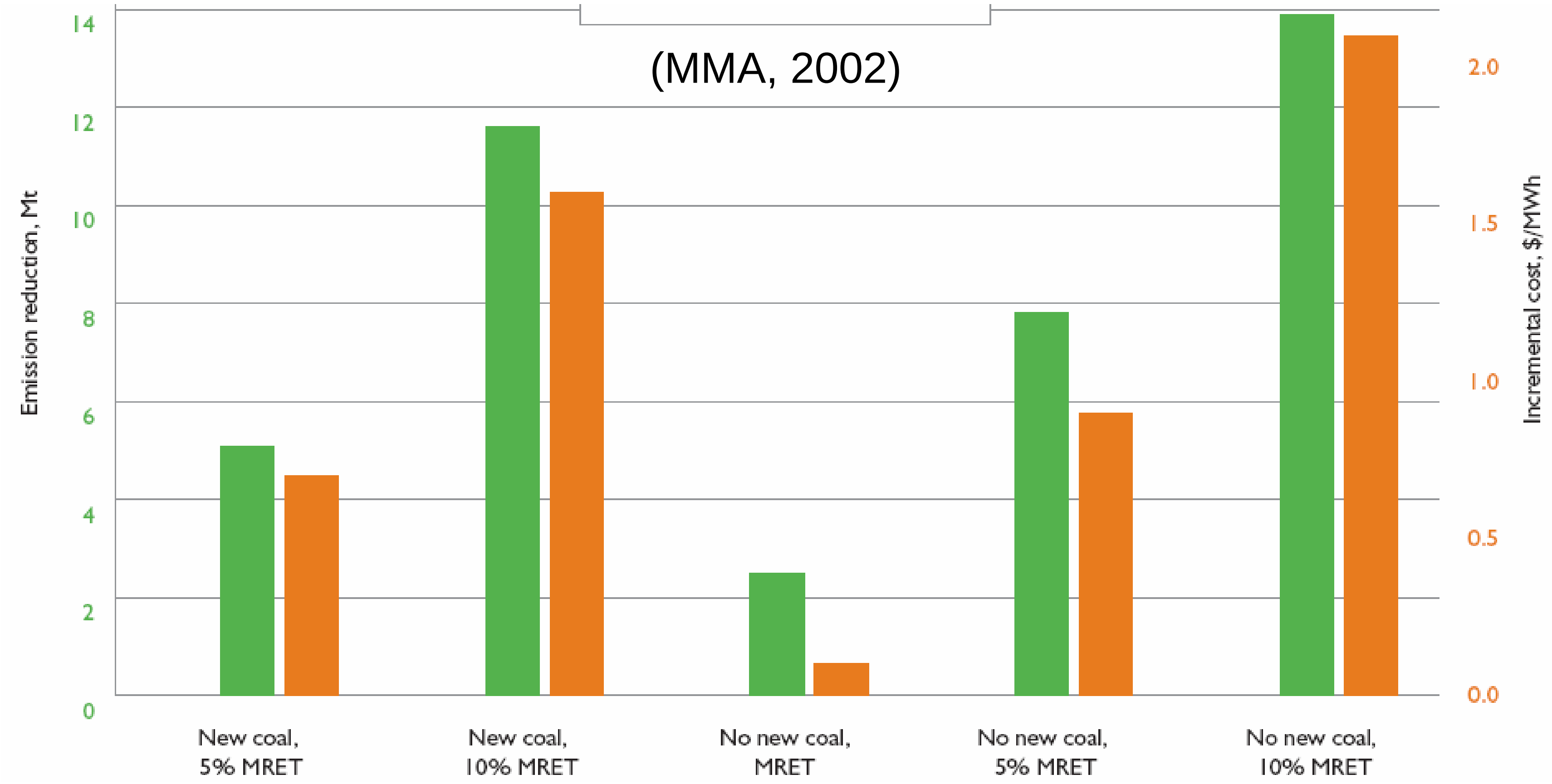
- The Australian energy policy context + wind power
  - Role of economic, energy security + environmental drivers
- Australia's energy options in a greenhouse world
  - how does wind rate?
- The sustainability of wind
  - Its social, economic and environmental context
- Successfully integrating wind into the NEM

Australia’s electricity industry policy drivers

- Economic
  - Energy’s role in economic development
  - Maintaining the value of Australia’s energy exports
  - Continuing market-based industry restructuring
- Energy security
  - Short-term: secure operation that can withstand contingencies
  - Longer-term: investment to ensure future secure operation
- Environmental
  - Australian EI responsible for about 1/3 of greenhouse emissions, has high emissions growth

Electricity industry economics + wind

- Wind one of our lowest cost ‘new renewables’
- Significant expansion of Australian renewable generation appears possible at relatively low cost



Electricity industry restructuring + wind

- Drivers for EI restructuring include efficiency objectives
  - Technical or productive: reduce costs of production
  - Allocative: most appropriate choices b/n supply + demand options
  - Dynamic: support innovation + response to change

    This is the most important for longer-term
- Good market design
  - Allocate costs + benefits to participants appropriately as possible
  - Foster competition via a level playing field
    - don't favour incumbent technologies + participants against 'new entrants'
  - Support appropriate innovation to meet emerging challenges + change
- Wind an emerging technology + industry that
  - can help us meet emerging greenhouse challenges
  - has very different characteristics from conventional resources (the first serious intermittent power)
  - Poses challenges to existing power system operation + investment

Energy security + wind

⇒ Short-term power system security
  ⇒ operate PS to maintain supply/demand balance at all points in network under normal conditions yet also contingencies

⇒ Longer-term electricity industry security
  ⇒ Ensure appropriate supply/demand side investment given possible trends, resource constraints

  eg. gas reserves, possible future coal constraints?

- Wind
  - Intermittency (variable, partially controllable + somewhat unpredictable output) with different characteristics compared with conventional gen
  - A ‘free’, locally sourced energy resource

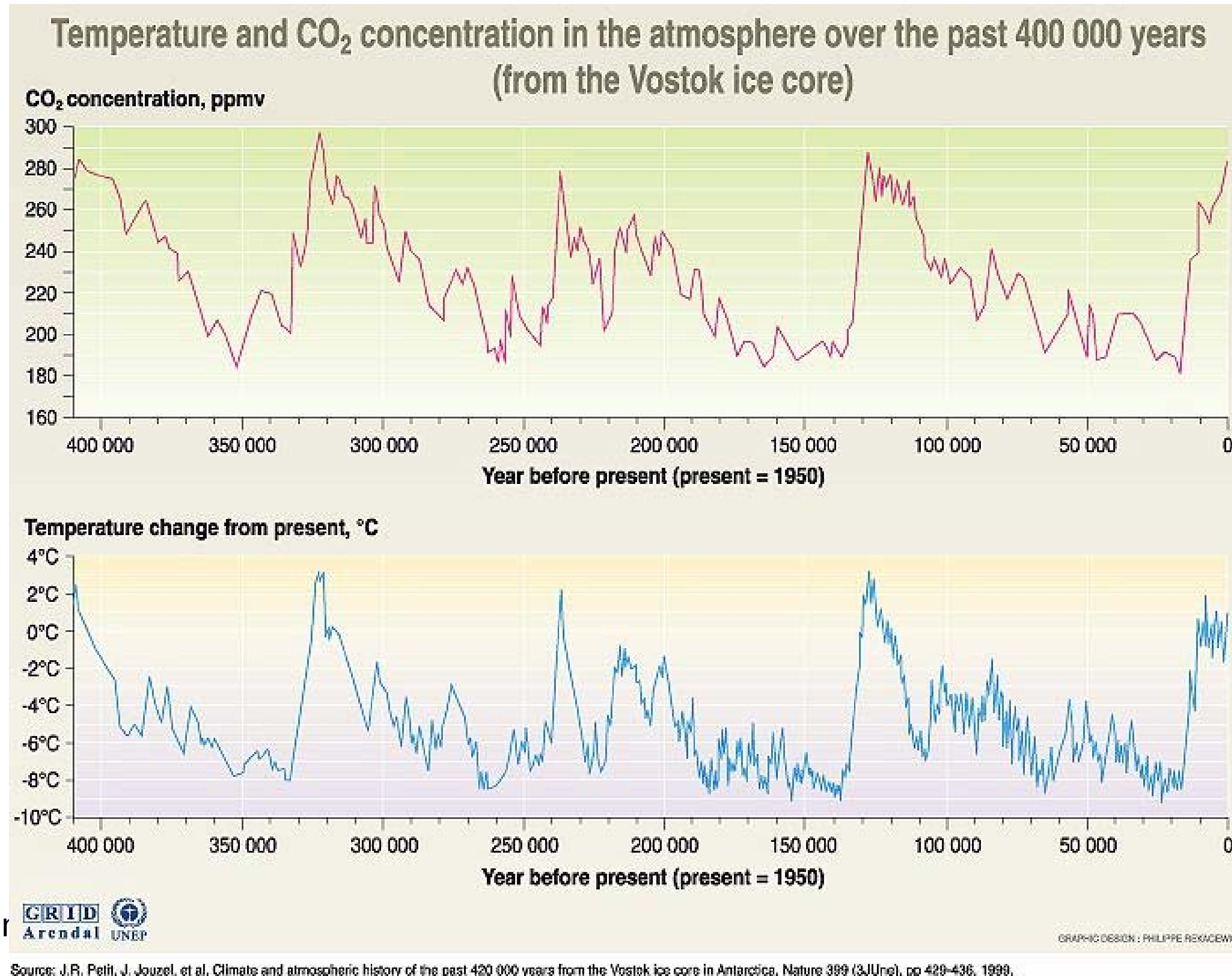
EI environmental impacts + wind

- Wind one of our lowest cost zero-emission technologies
- Actual emissions reductions in electricity industry depends on context
  - Amount of wind, generation mix, load profile, losses
- **Nevertheless**, wind farms into PS with largely thermal gen will
  - Reduce operational emissions
  - Can, in the longer term, influence nature of investment in other generation sources

- *eg.* ESIPC wind study – SA wind generation can reduce CO2 by approx. 0.52Mt/MW

The link between climate change and CO2

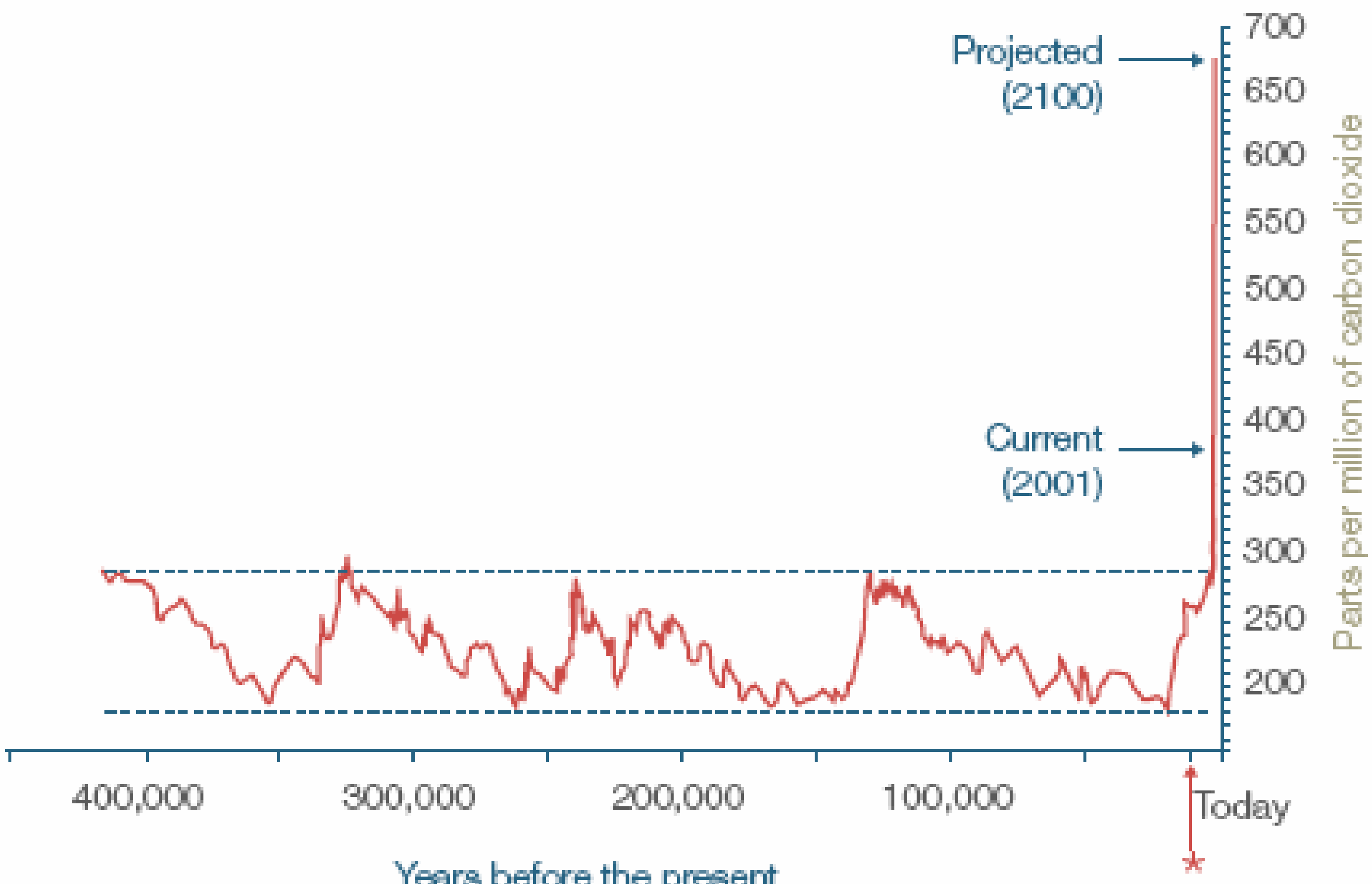
Source: http://www.grida.no/climate/vital/



CO2 concentration in the atmosphere

(Climate Action Group, 2004)

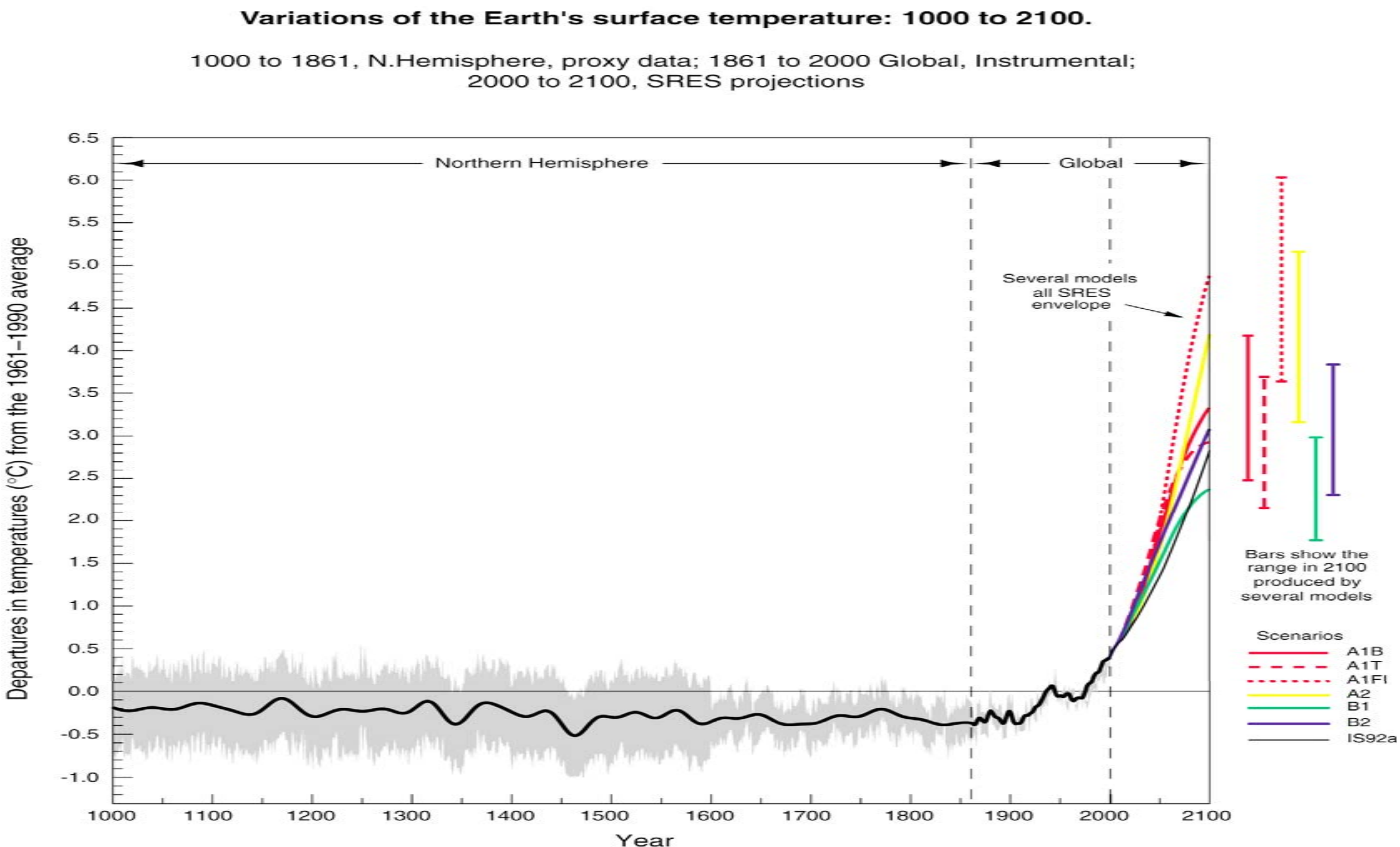
Source: Co-operative Research Centre for Greenhouse Accounting, 2001



*Note: Civilisation began 7,000-10,000 years ago

It all suggests major warming if emissions continue

(www.ipcc.ch)



Global warming concerns continue to grow

The Independent

Global warming approaching point of no return, warns leading climate expert

January 24, 2005

Global warning has already hit the danger point that international attempts to curb it are designed to avoid, according to the world's top climate watchdog.

Dr Rajendra Pachauri, the chairman of the official Intergovernmental Panel on Climate Change (IPCC)… personally believes that the world has "already reached the level of dangerous concentrations of carbon dioxide in the atmosphere" and called for immediate and "very deep" cuts in the pollution if humanity is to "survive".

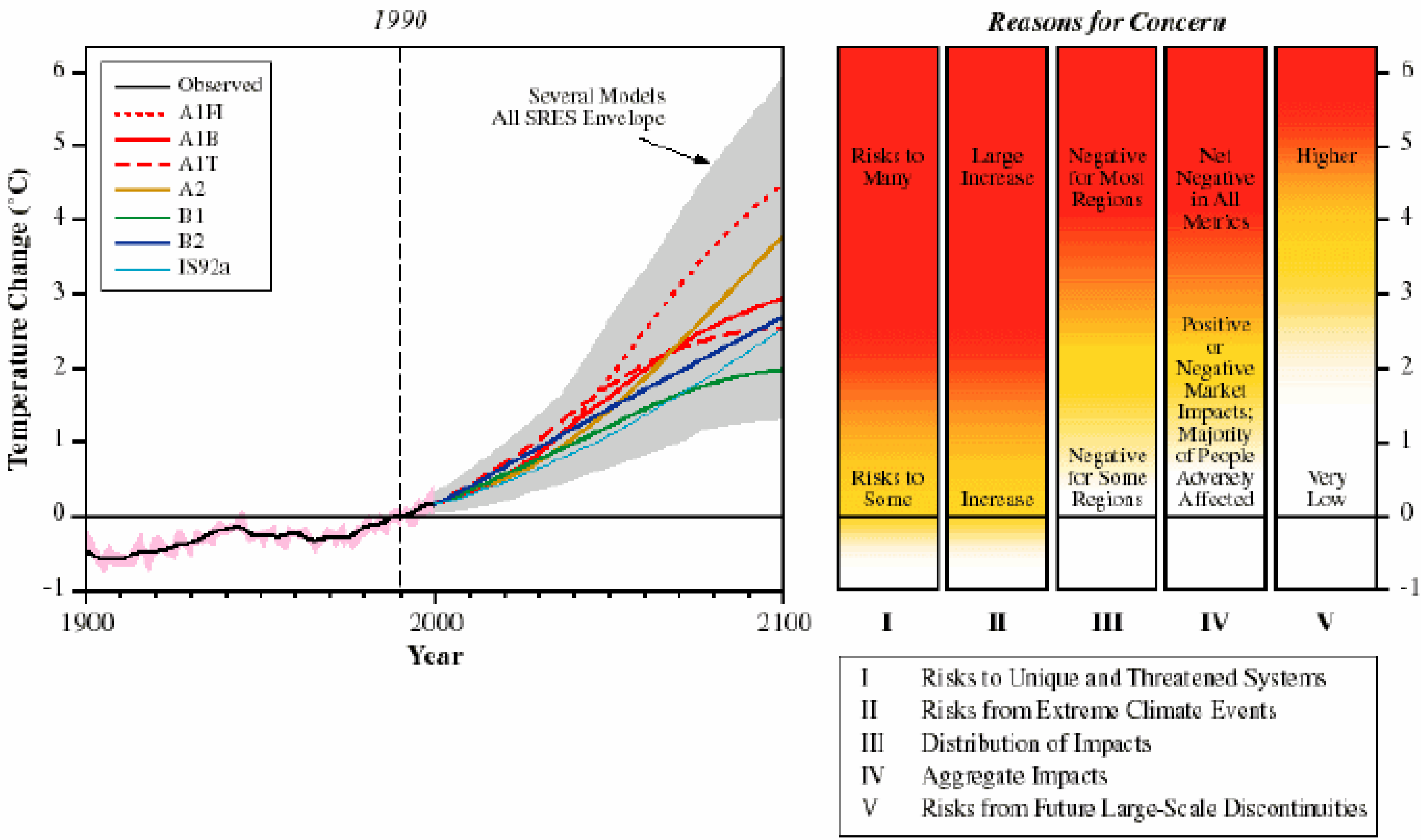
…He told delegates: "Climate change is for real. We have just a small window of opportunity and it is closing rather rapidly. There is not a moment to lose."

…He also cited alarming measurements… suggesting that climate change may be accelerating out of control.

….. He concluded: "We are risking the ability of the human race to survive."

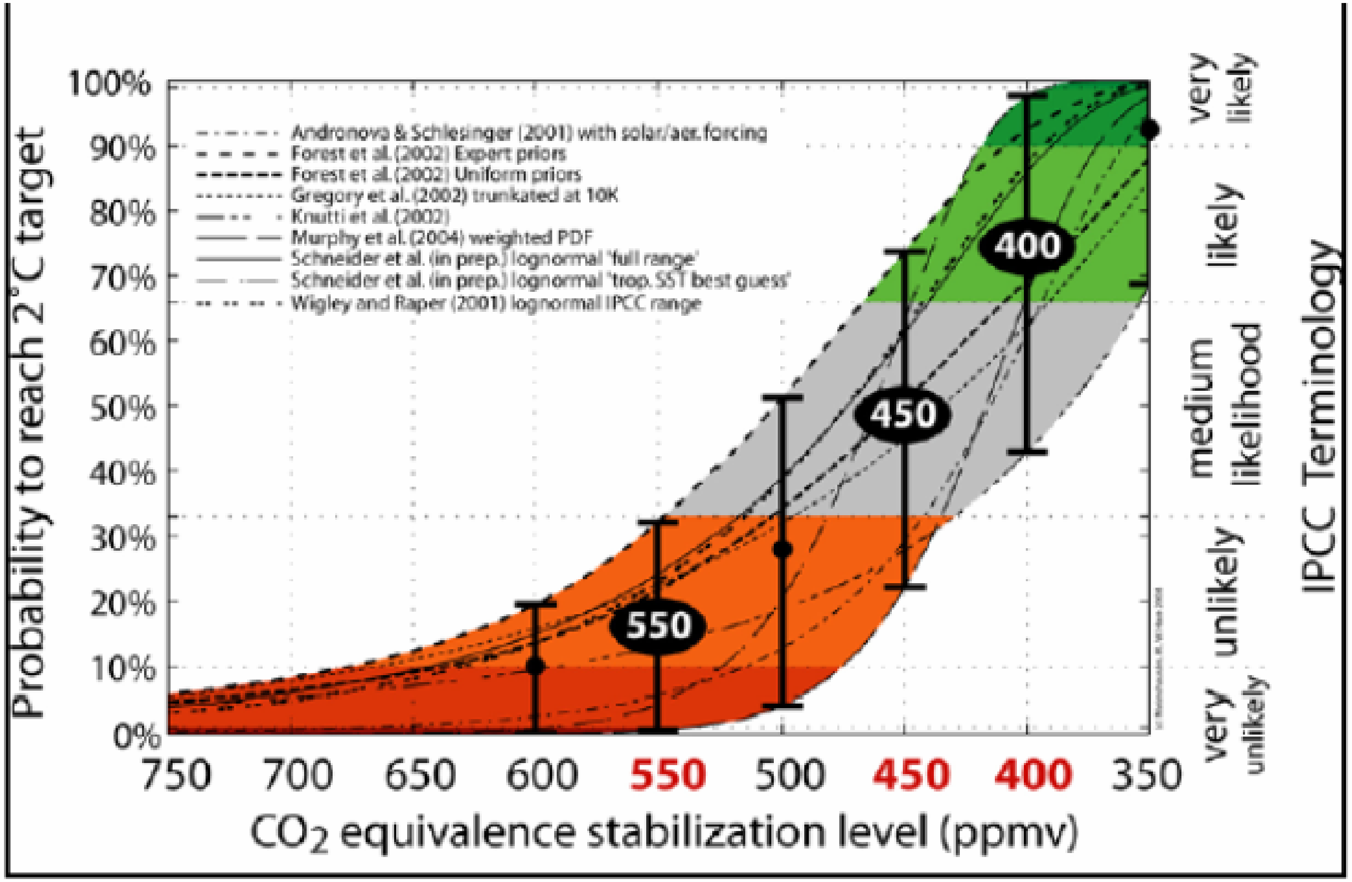
Avoiding dangerous climate change – stay <2 deg.C

(IPCC, Third Assessment Report, 2001)

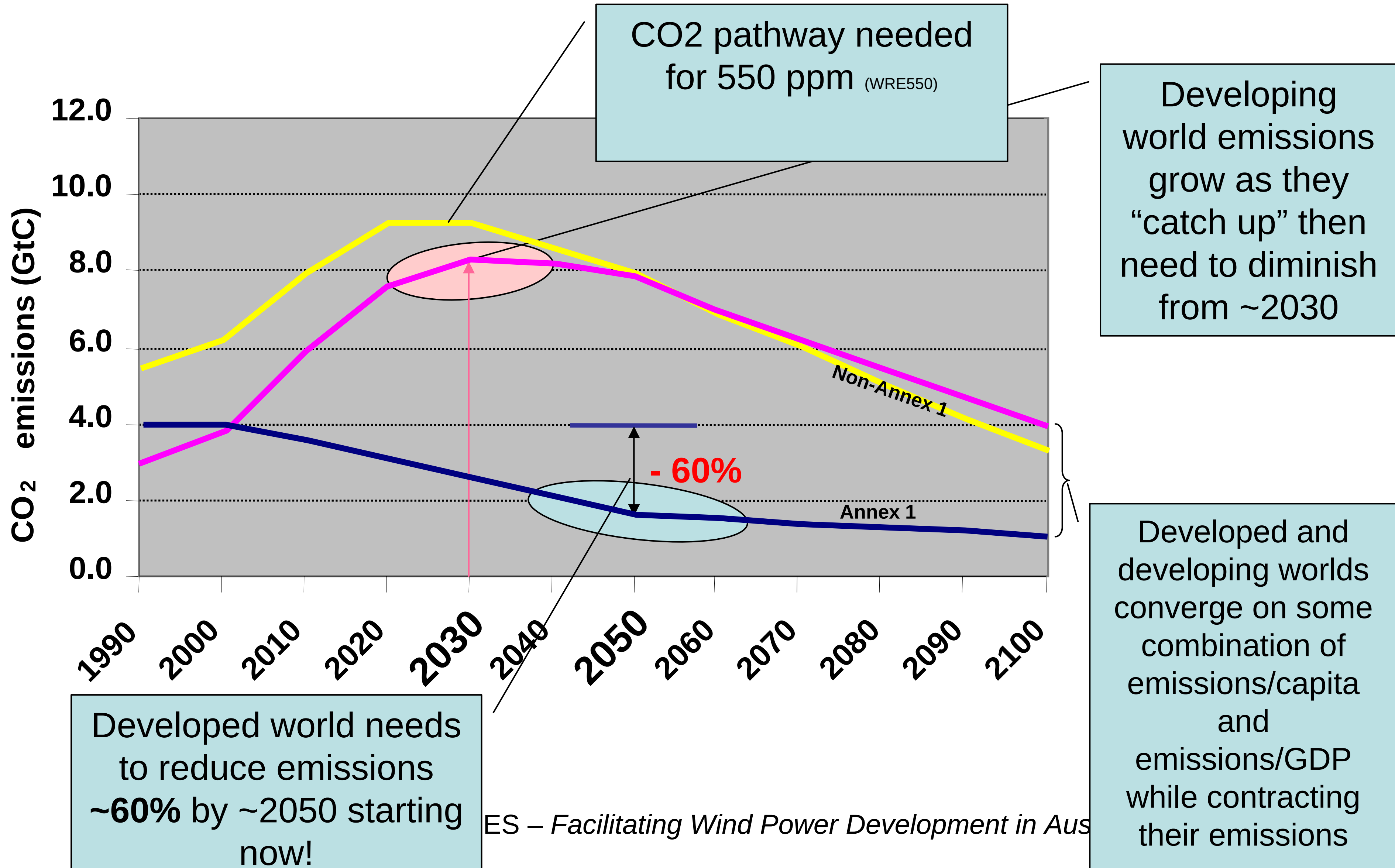


What stabilisation target might then be required?

(EEAC, 2004)



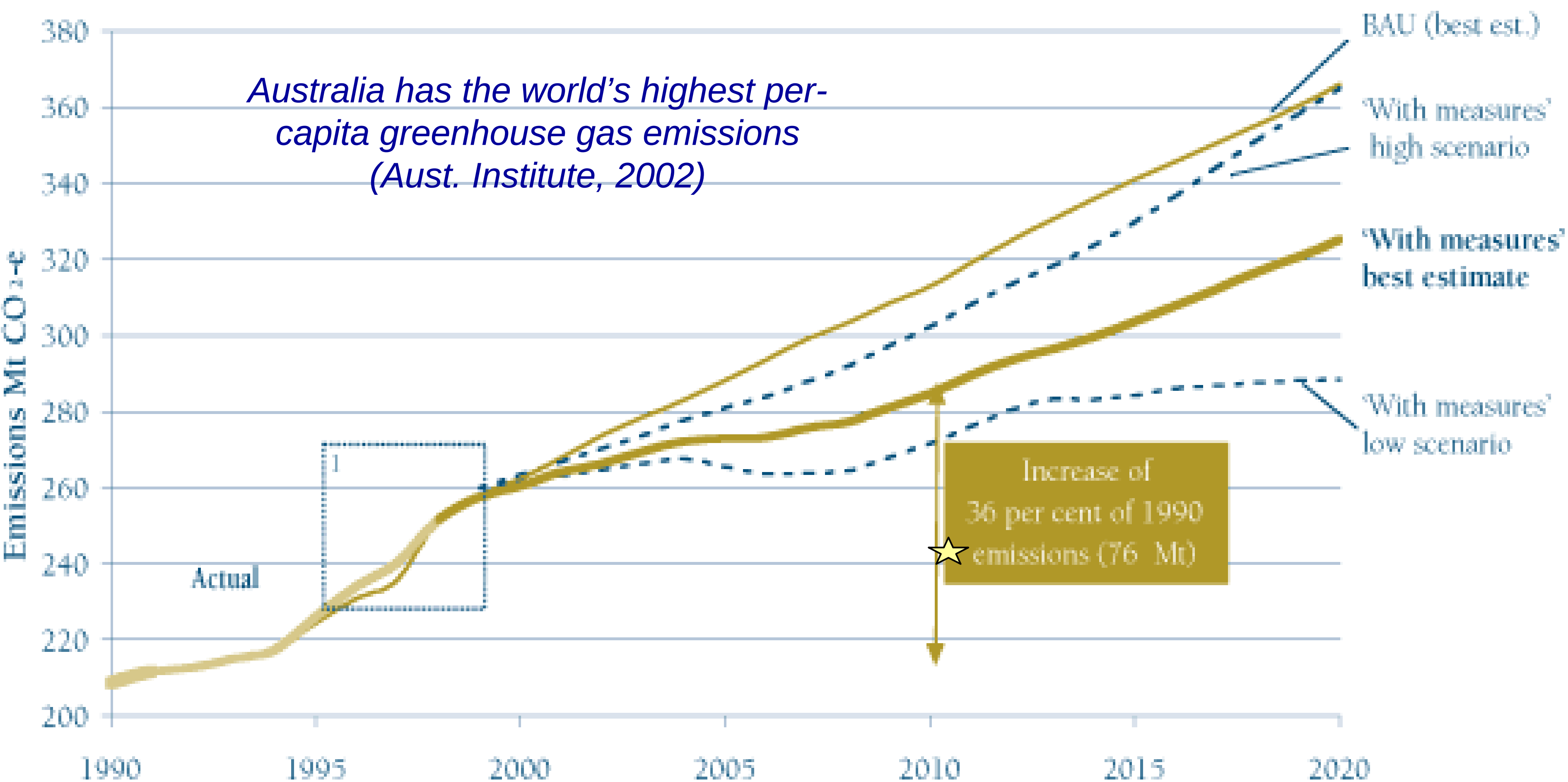
Possible emissions scenario for stabilisation (Bourne, 2004)



Thoughts on Australian GHG abatement policy

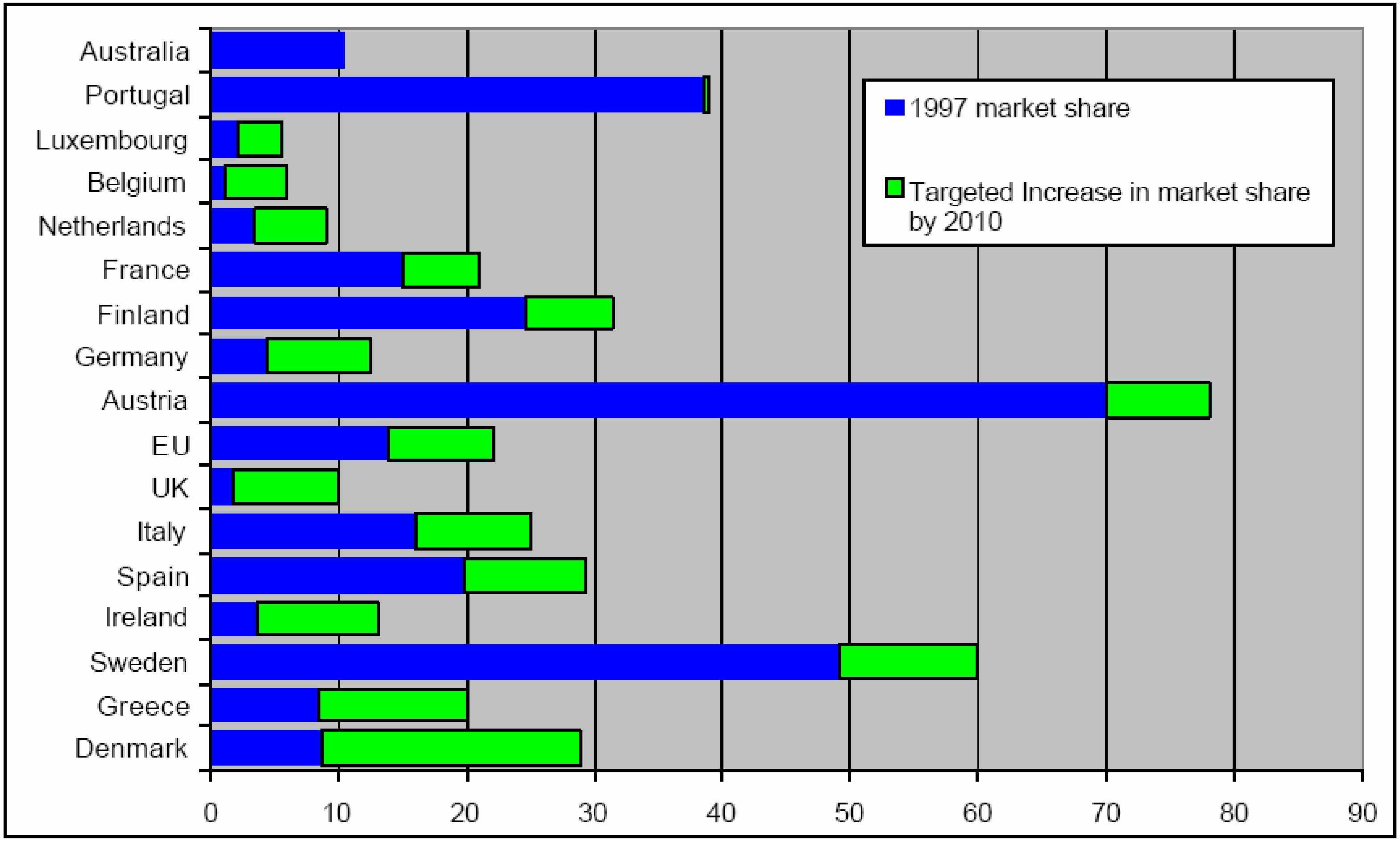
- **Little evidence of coherent abatement + innovation strategy**
  - Challenge is not to meet Kyoto greenhouse target (stopping land clearing) but beginning major emissions reductions reqd to avoid dangerous CC
  - *Energy White Paper* focuses largely on technological push (eg. innovation fund), rather than market pull (eg. enhanced MRET, strong EE regulation) *this is very unlikely to be optimal policy approach*
- For our different abatement options
  - ***Renewables* – needs R&D but, critically, deployment support eg. Expanded MRET. Emerging techs like HDR need R&D&Demo support**
  - *Energy efficiency* – has been woefully neglected, needs R&D yet, critically, targeted (mainly regulatory) deployment support
  - *Gas generation* – present immature Aust. gas market needs to be strengthened (CoAG, 2002), policy support for base-load NGCC, also CHP
  - *Carbon Capture & Storage* – an important area for R&D + demonstration that should focus on key question of storage uncertainty + site specificity.
- **We need EE, renewables + gas now to buy us time to develop CCS**

Projected emissions from Stationary Energy sector, 1990-2020



Source: Australian Greenhouse Office (2002)

Some international renewable energy targets



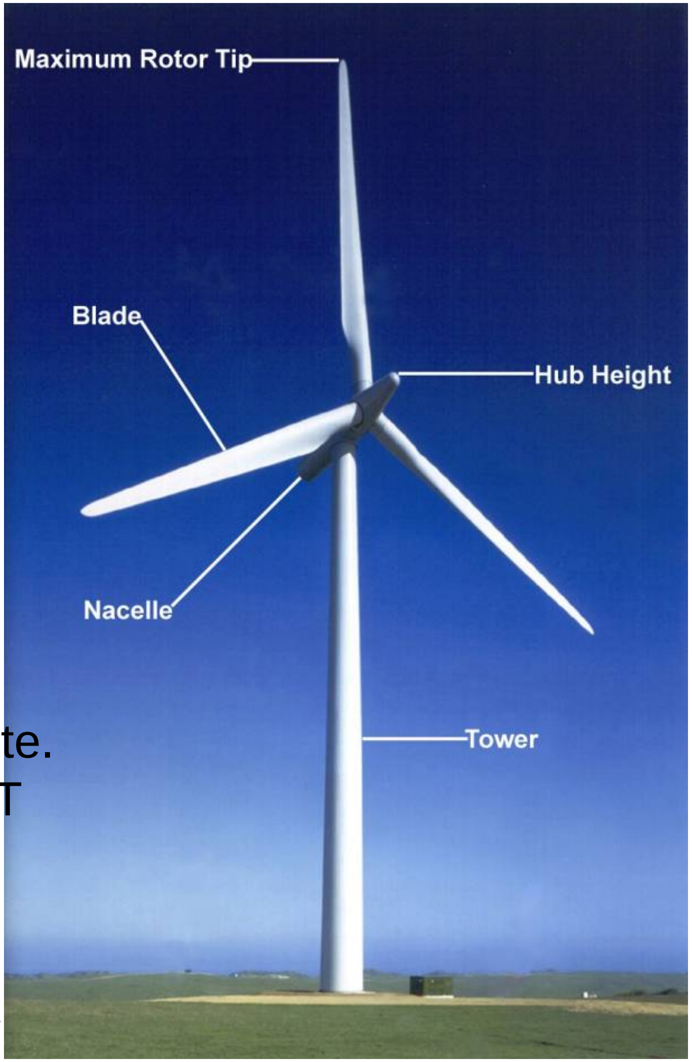
A modern 2MW wind turbine

- Vestas V80 (eg. Canunda, SA)
- Rotor Diameter: 80 m
- Speed revolution: 9 - 19 rpm
- Tower Hub height: 60 - 67 - 78 - 100 m

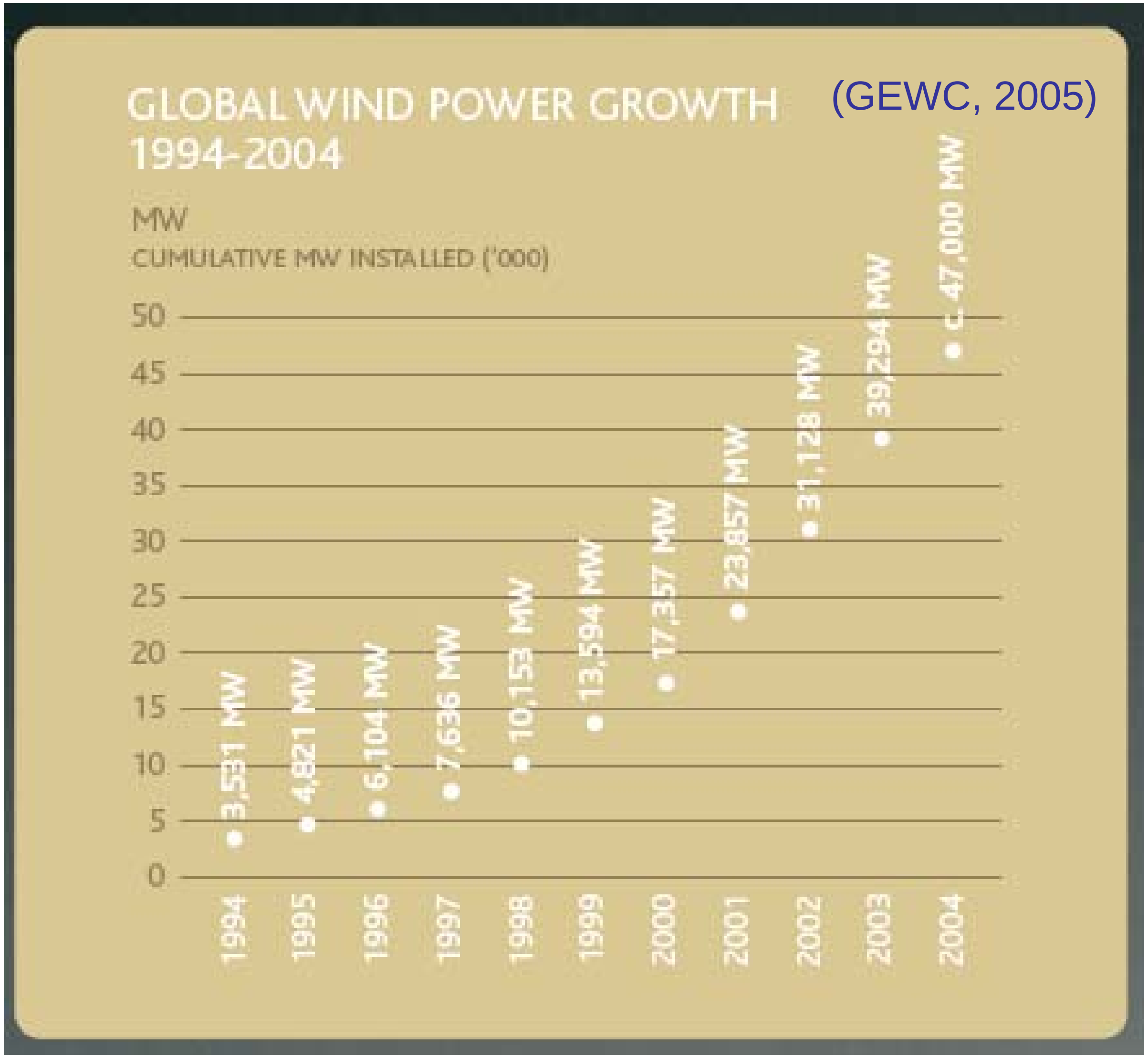
- Operational data
  - Cut-in wind speed: 4 m/s
  - Nominal wind speed: 15 m/s
  - Stop wind speed: 25 m/s

- Generator Type: Asynchronous
- Gearbox Type: Planet/parallel axles

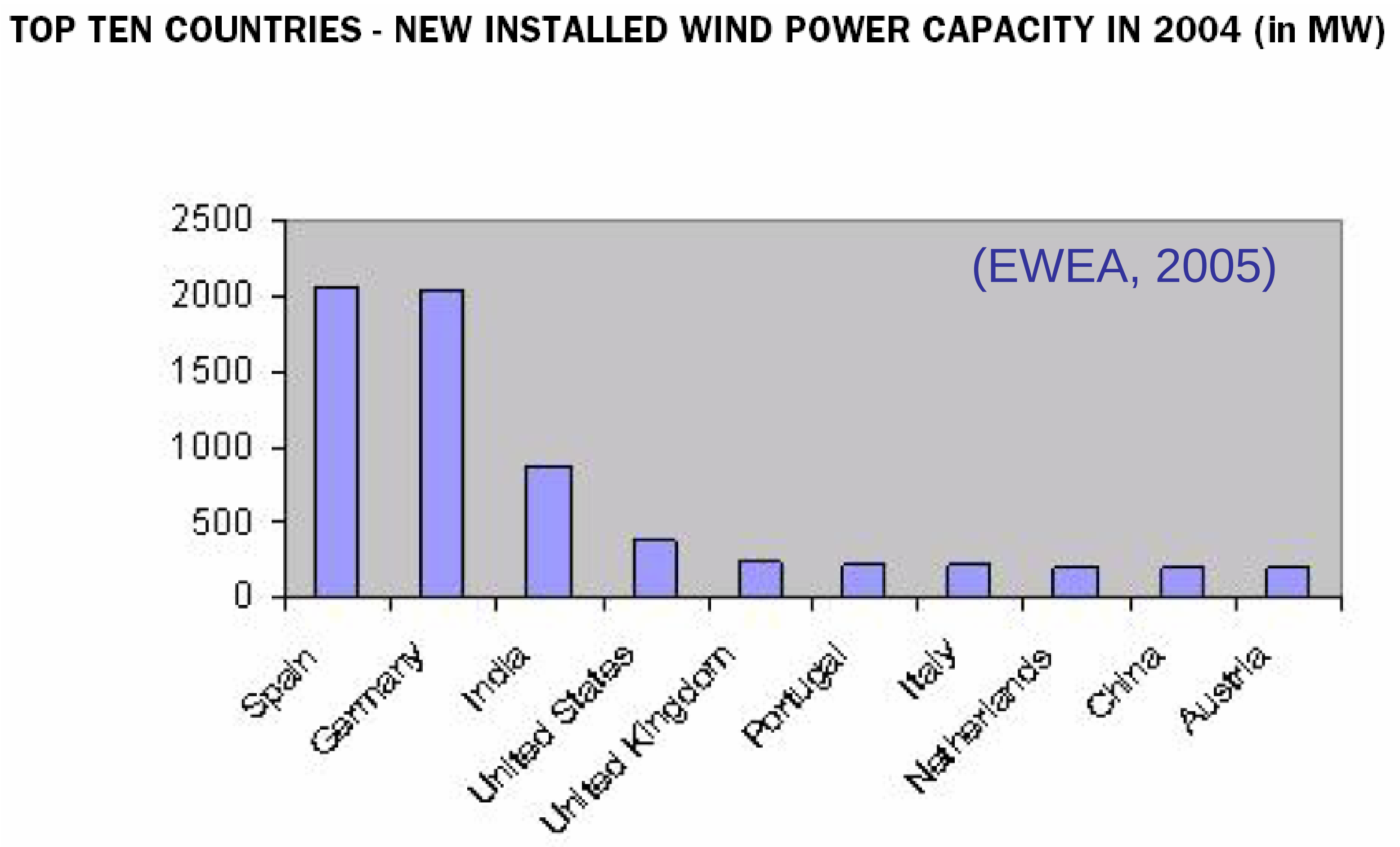
- Control Type: Microprocessor; optional remote. Output regulation and optimisation via OptiSpeedT and OptiTip® pitch regulation.



The worldwide wind industry

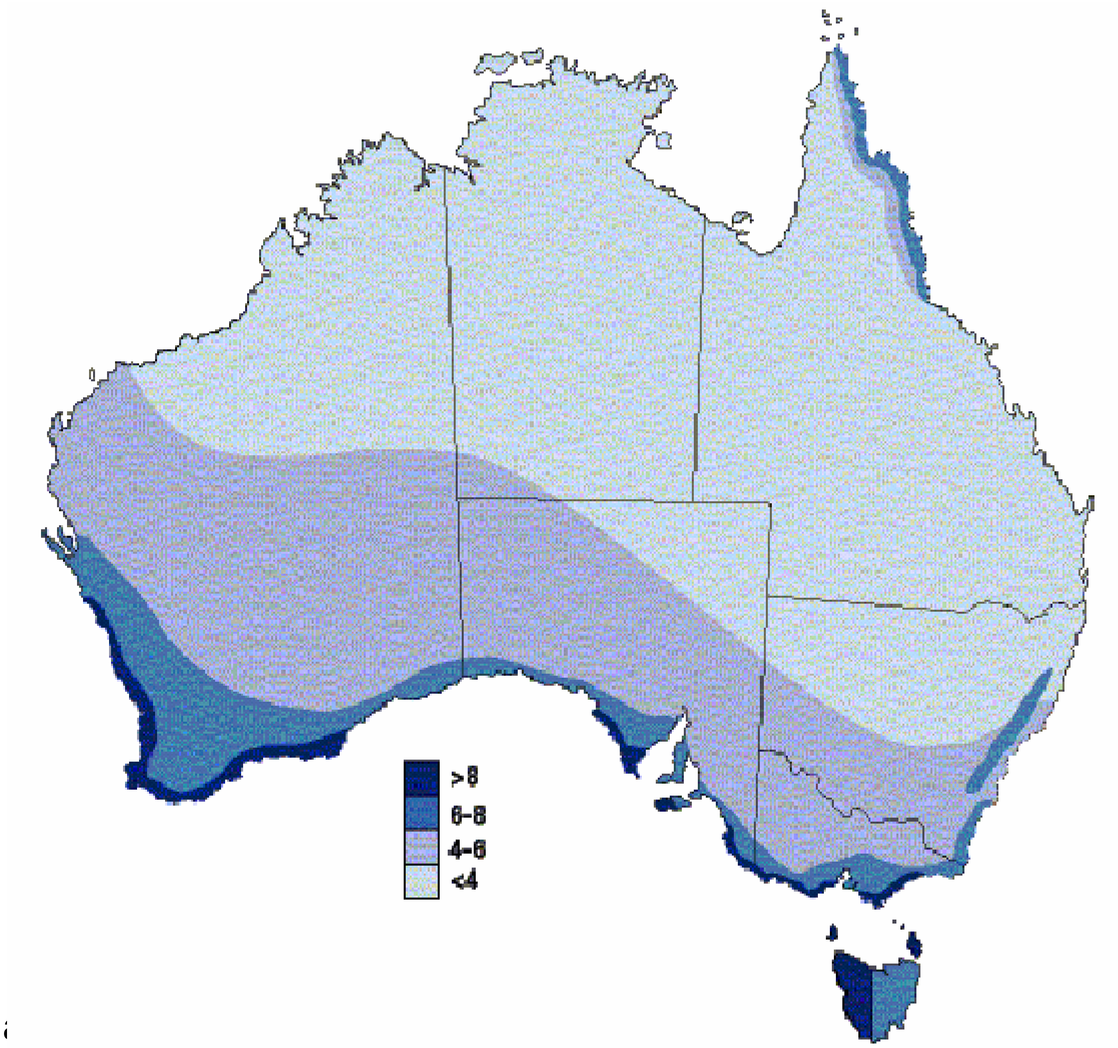


Worldwide industry growth

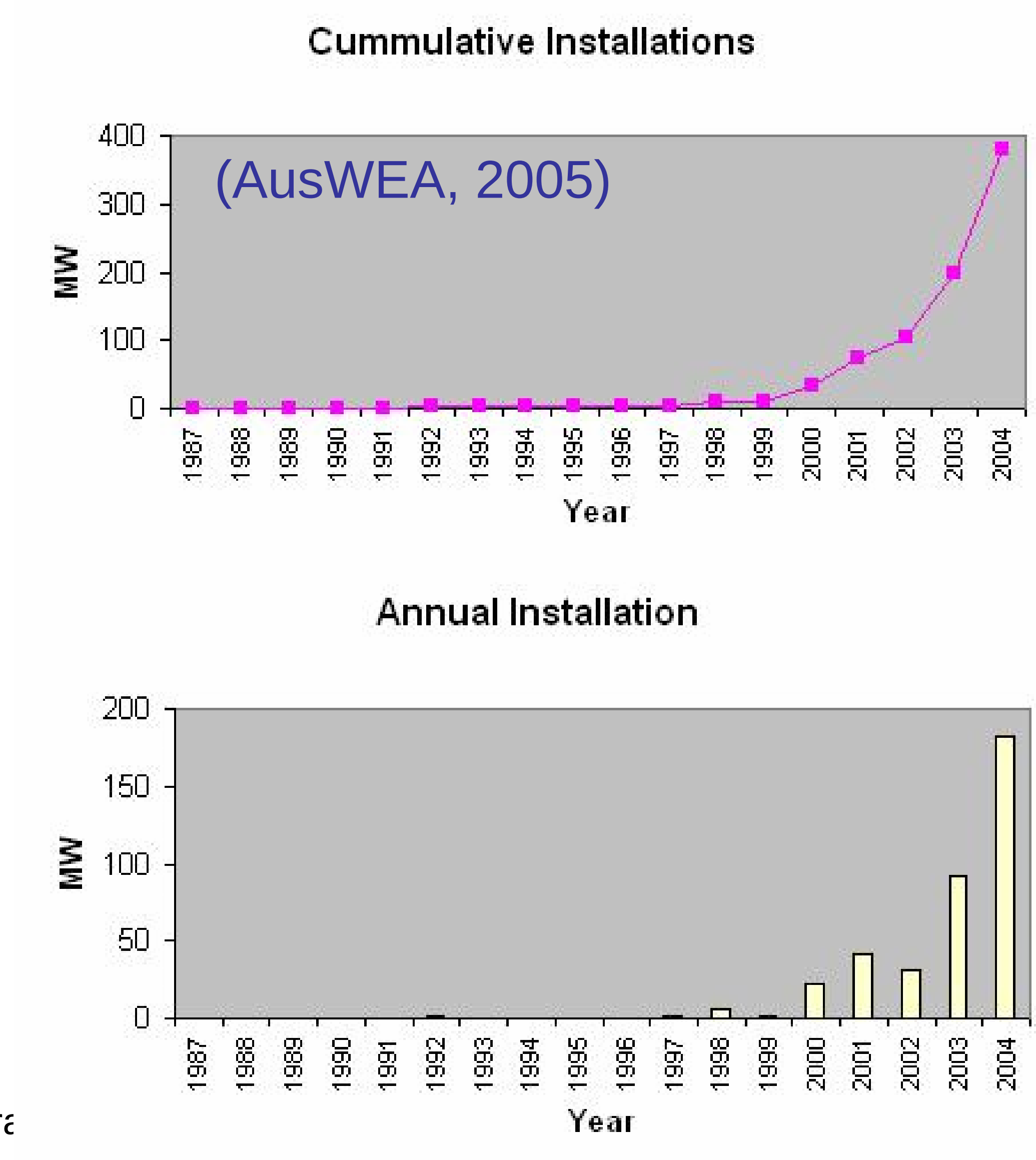


Australian wind resource

(Simple estimates of background wind – AGO)



The Australian wind industry



However, are renewables actually sustainable?

- Australia's Federal Treasury view
  "Even though renewable energy is renewable, it does not necessarily mean it is environmentally benign. Like fossil fuels, renewable energy can also impose external costs on the community… the large-scale use of wind turbines may adversely affect landscapes, migrating bird species, and pristine wilderness areas. Additionally, it may result in noise and aesthetic pollution…"
  Treasury (2002) "Renewable energy – a clean alternative?" *Economic Roundup,* 2002

⇒ renewable technologies aren't inherently sustainable but *appropriate* renewable energy systems can be

⇒ Key decisions are in the planning phase

The planning process for wind farms

- Wind farms have important externalities:
  - Costs + benefits of activity that fall on parties other than those undertaking activity => don't *necessarily* influence decision making
  - Costs + benefits can be economic, environmental or social
  - Those effected by externalities are 'stakeholders' so wind farms have many: - project developers *but also* governments, other developers, local communities, the electricity industry, NGOs…
- Wind farms are not independent projects:
  - Economies of scale in network connection
  - Possible interference between shared wind resources
  - **Shared social & environmental impacts, particularly at the regional level**

A government role for wind farm planning

- Hard to internalise all externalities at project level
  - Many externalities depend on cummulative wind projects
  - Potential for poor outcomes + social discord
  - May be ‘internalised’ only after great expense + effort already undertaken
  - May engender generalised resistance to future projects

=> Govts required to provide appropriate frameworks

  - externalities and stakeholders identified
  - project developers + stakeholders can negotiate solutions

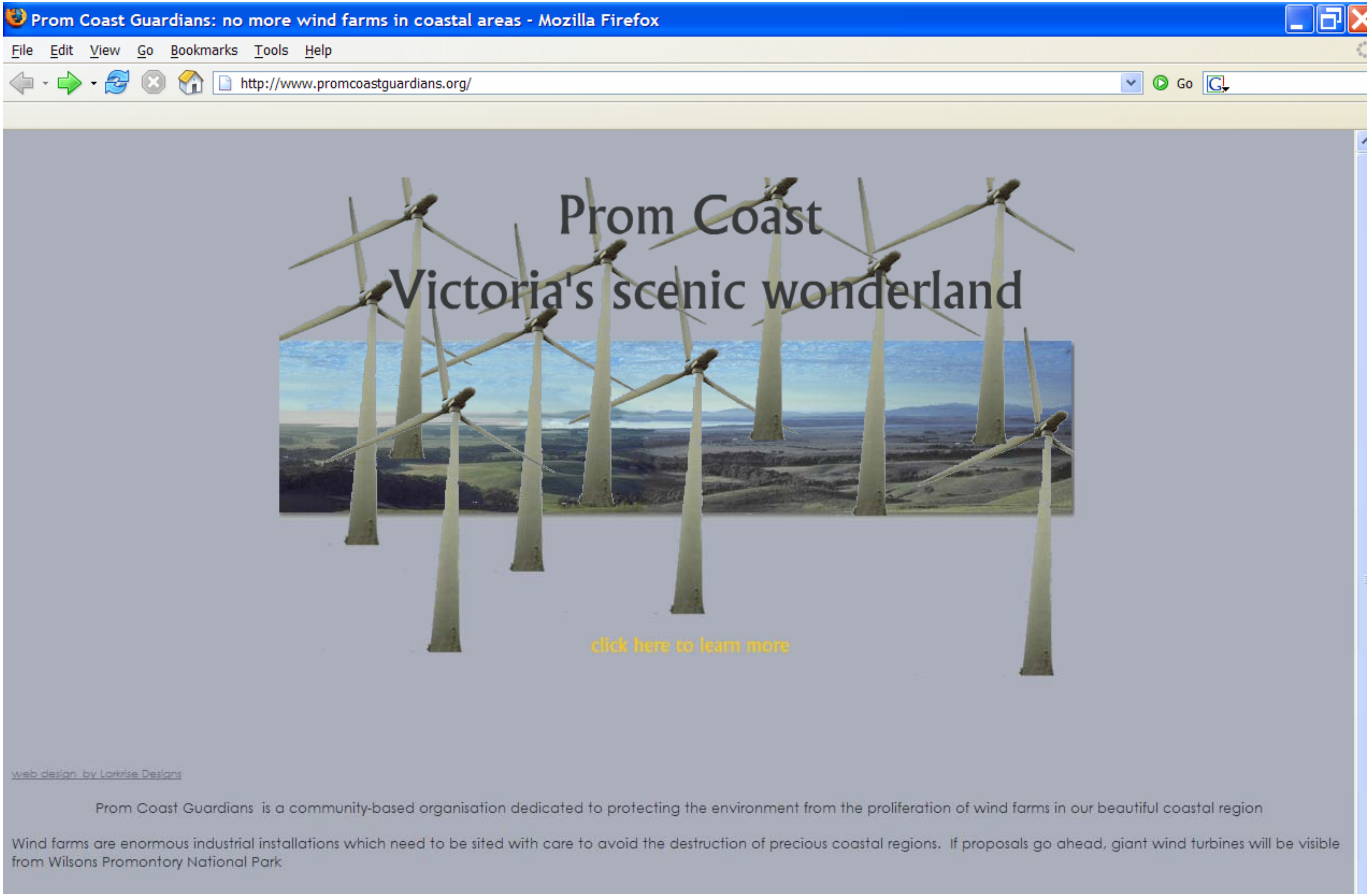
Analysing European public resistance to wind farms

(Wolsink, 2000)

- 4 general categories of resistance
  - A: Positive to wind farms but not here (NIMBY)
  - B: General opposition to wind energy (NIABY)
  - C: Initially positive but put off by a bad experience
  - D: Approval subject to meeting certain criteria

- Some possible lessons
  - Generally strong public support for wind farms
  - **However**, this doesn't necessarily translate to local support
  - Poor planning processes can create local opposition, erode general support and increase general opposition

A recent example in Australia



Possible ways forward for planning

- Develop a comprehensive + coherent wind farm planning framework - federal, state, local:
  - Staged regional development process via stakeholder consultation:
    - Resource evaluation
    - Regional wind development & grid connection strategy with integrated forecasting processes
  - On-going monitoring & evaluation

- Opportunities to adapt other models –eg. minerals industry

Queensland Government
Natural Resources and Mines

Queensland Coal Seam Gas Regime (2002)
"The regime provides greater certainty for explorers and developers to invest in coal seam gas projects as well as provide clear rules, rights and obligations for the coal and gas industries to work cooperatively in developing the resource."

Key issues for wind energy integration

- Physical complexity:
  - Shared, non-storable, time-varying wind energy flux
  - Shared, non-storable, time-varying electrical energy flow in network
- Commercial complexity:
  - Electricity industry infused with short- to long-term risks that are difficult to commercialise (correctly allocate to industry participants)
- Institutional complexity:
  - Shared issues in wind farm approvals, grid connection & management of power system security

➔ ***High wind energy penetration tests adequacy of electricity industry restructuring:***

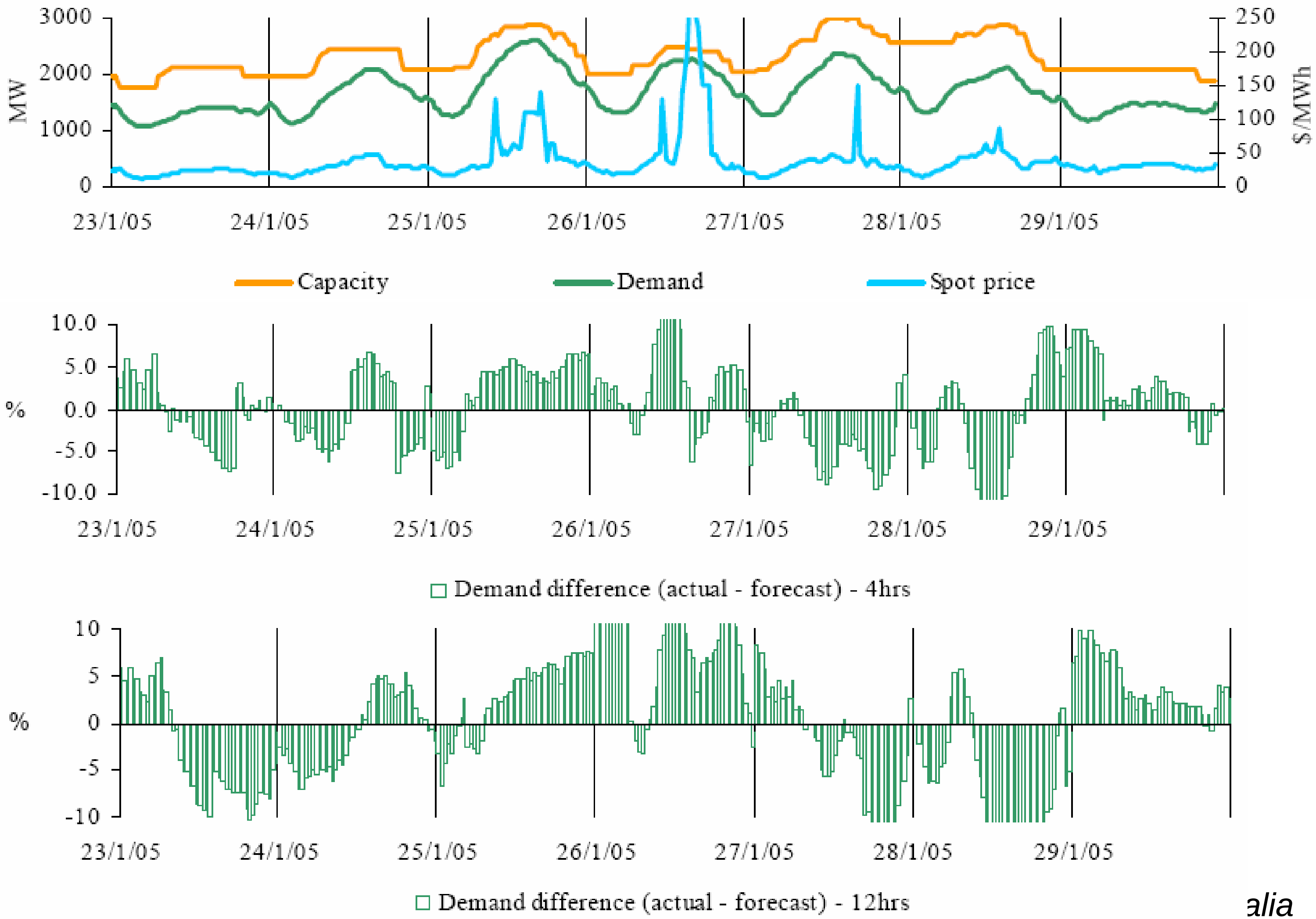
➔ ***In its technical, commercial & regulatory aspects***

Integrating significant wind into power systems

- All loads and generators have electrical flows that are
  - Variable over time
  - Never more than partially controllable
  - Somewhat unpredictable
- Major part of network value arises b/c enables diversification
  - help manage variability and stochasticity of all power system resources (load, generation and network elements)
- **Wind**
  - A **very reliable** but highly variable and somewhat unpredictable generation resource with limited control options
  - The first such type of generation to achieve significant grid penetrations

Load variability and unpredictability

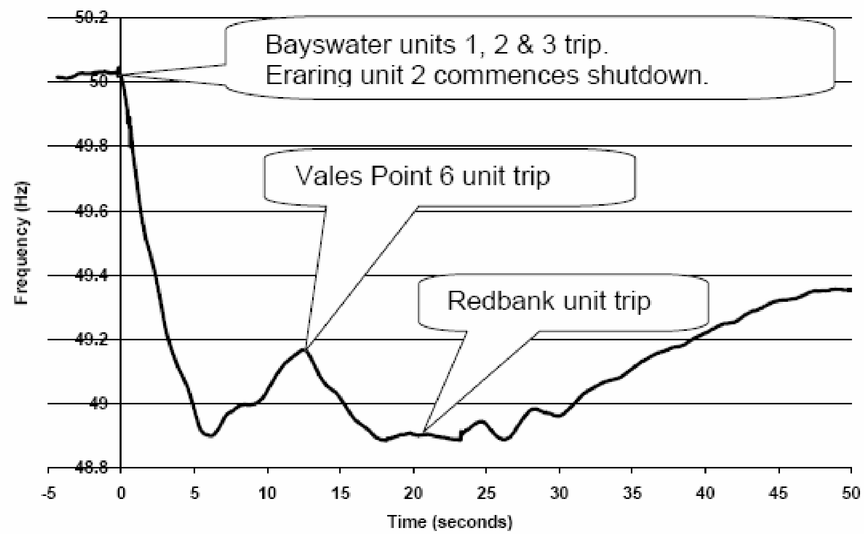
SA electricity demand cf forecasts, (NECA, Market Analysis 23-29 January, 2005)

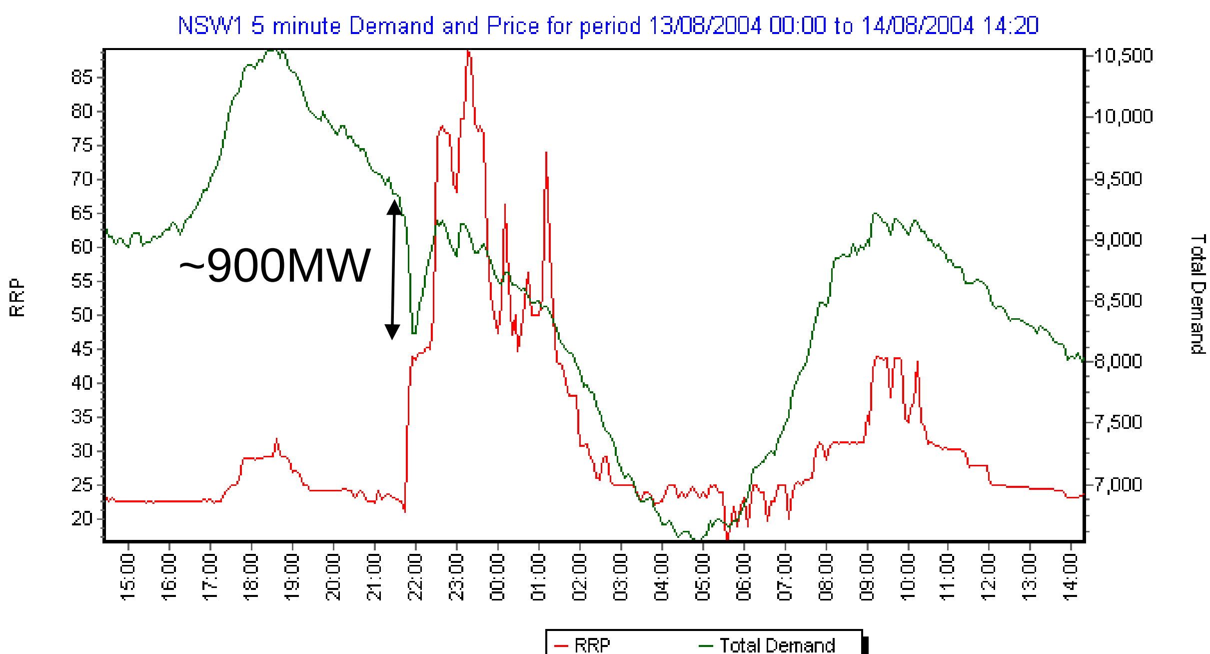


Gen variability + unpredictability

Transformer failure on Friday 13/8/04 causes 6 coal-fired NSW generators to trip totalling 3100MW:
Approx. 2100 MW load shed in NSW, Qld & Vic (also some in SA)
(www.nemmco.com.au)

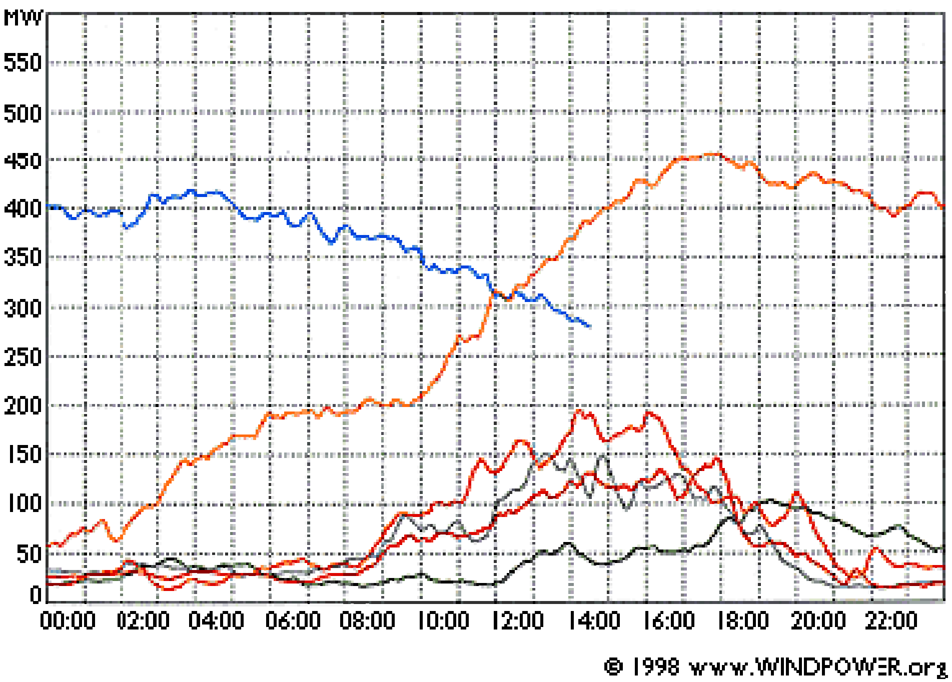
Figure 1-5: Power System Frequency

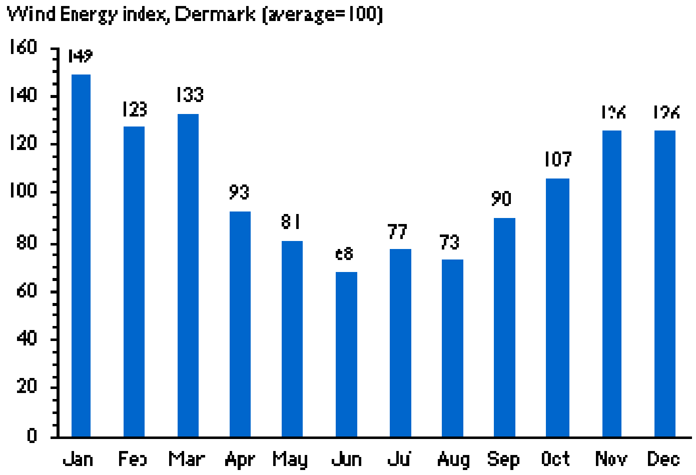


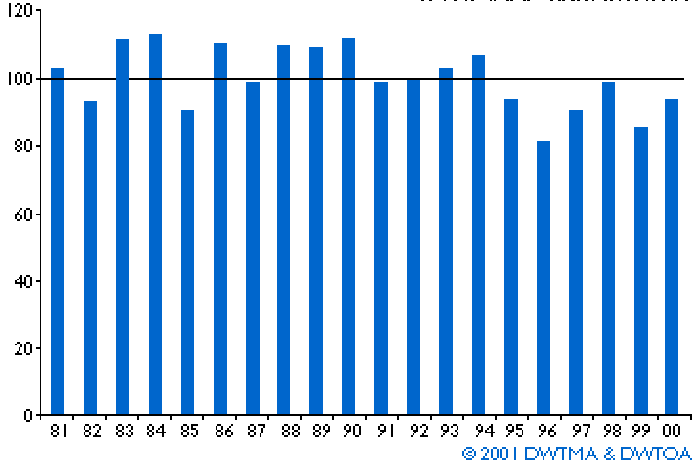


Wind power variability + unpredictability

(Danish Data, www.windpower.org)



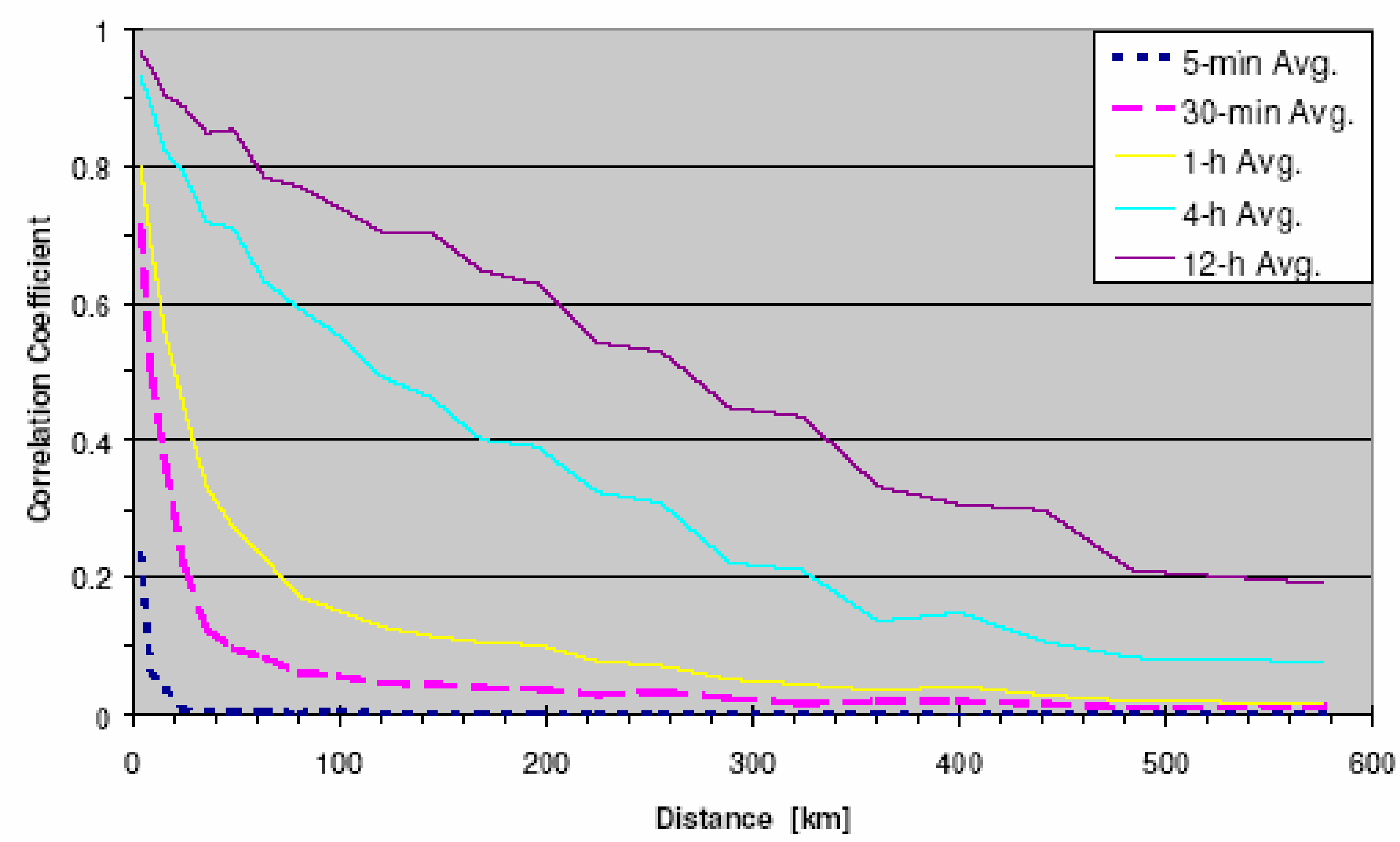




Short-term, daily, seasonal and annual variations in wind speed

Overall variability depends on distribution of wind farms

Cross-correlations between measured power outputs of German wind farms (Giebel, 2000)

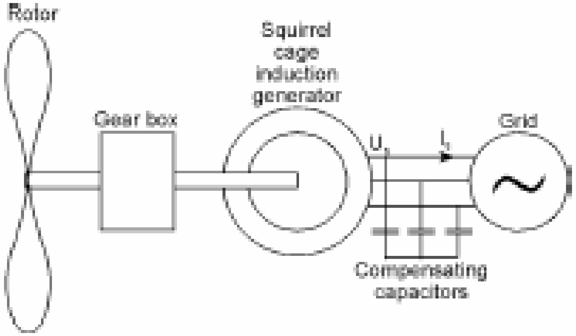


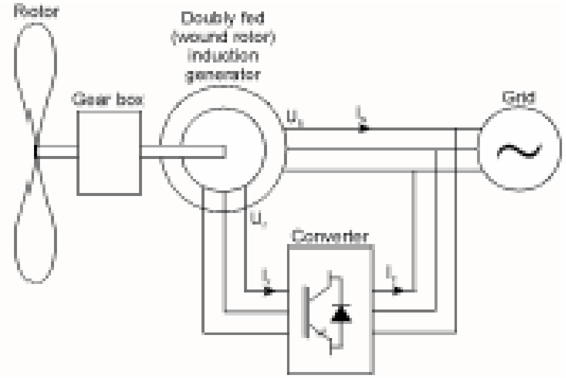
NEMMCO ‘issues’ with intermittent generation

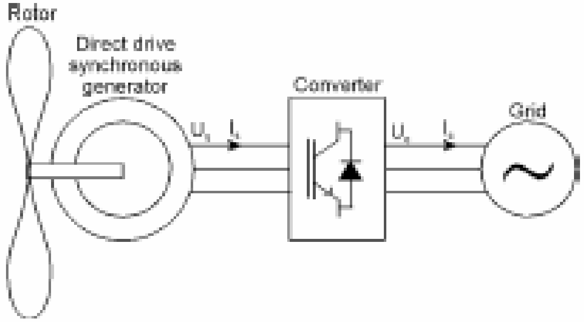
- Network management
  - impacts on V regulation, sub 5min flows on network may cause power quality + stability issues
- Frequency control ancillary services
  - increase in usage + cost of these
- Forecasting
  - Increased errors in price + reserve forecasts

Turbine technology can assist in N/W management

(Slootweg & Kling, TU Delft, 2003, http://local.iee.org/ireland/Senior/Wind%20Event.htm)







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Dynamic behaviour of different turbines

(Slootweg & Kling, TU Delft, 2003, http://local.iee.org/ireland/Senior/Wind%20Event.htm)

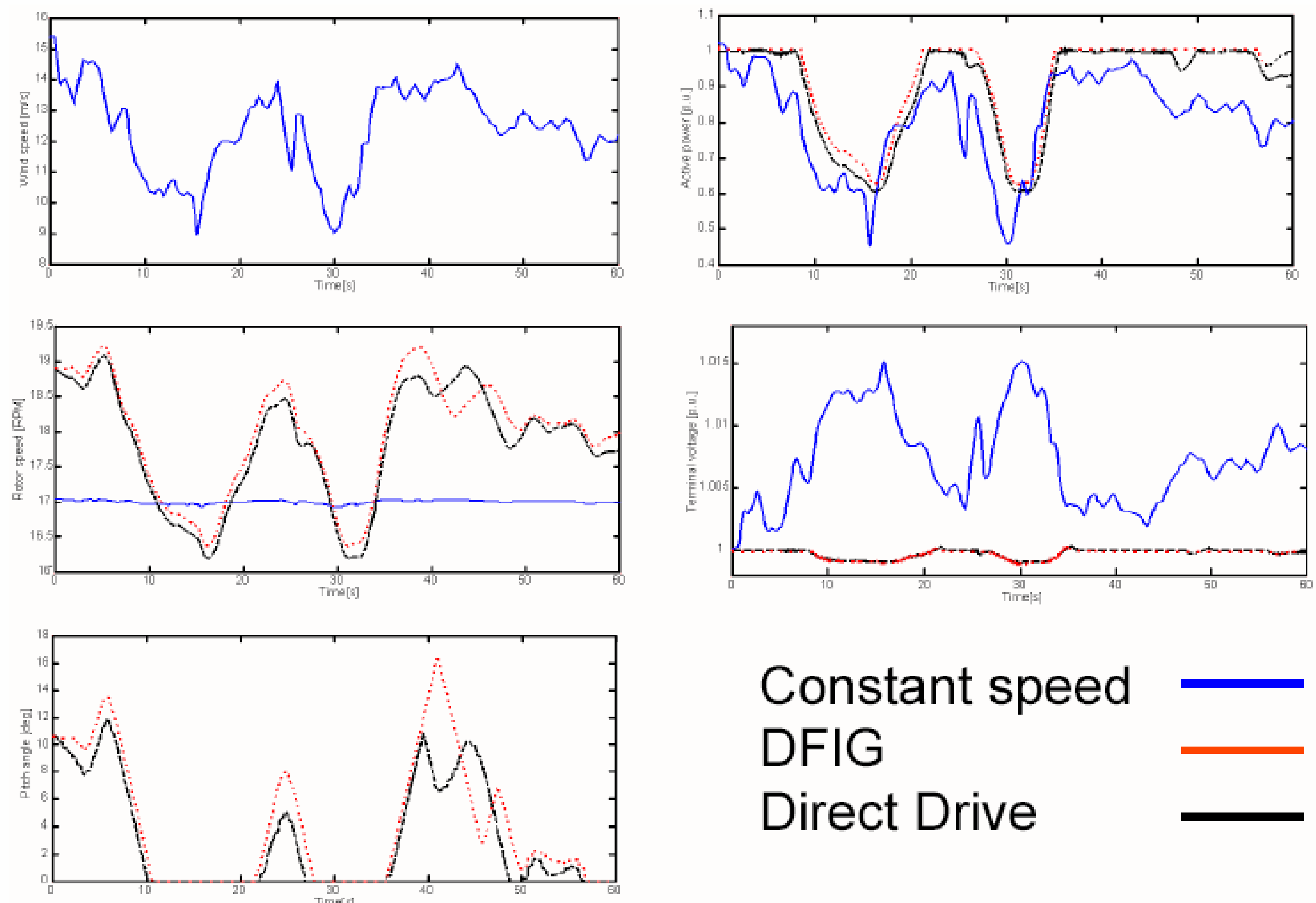
Wind speed

Output power

Rotor speed

Output voltage

Blade angle



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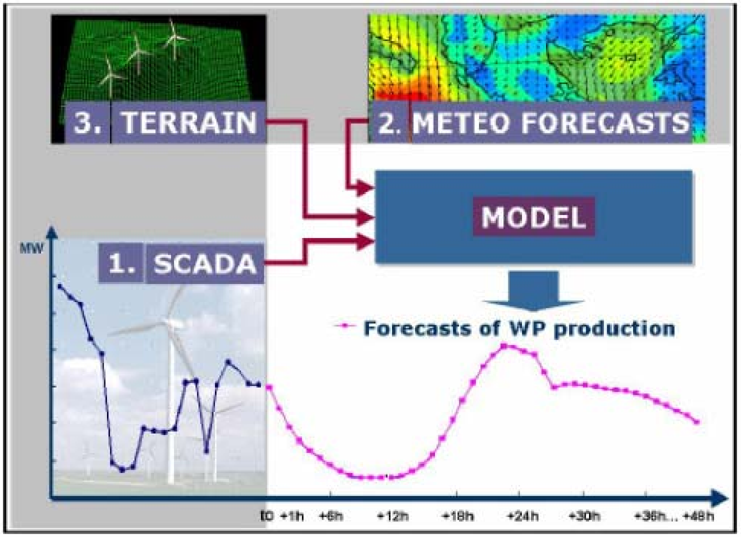
Forecasting wind energy production

(CSIRO, *Report to NEMMCO*, 2004)



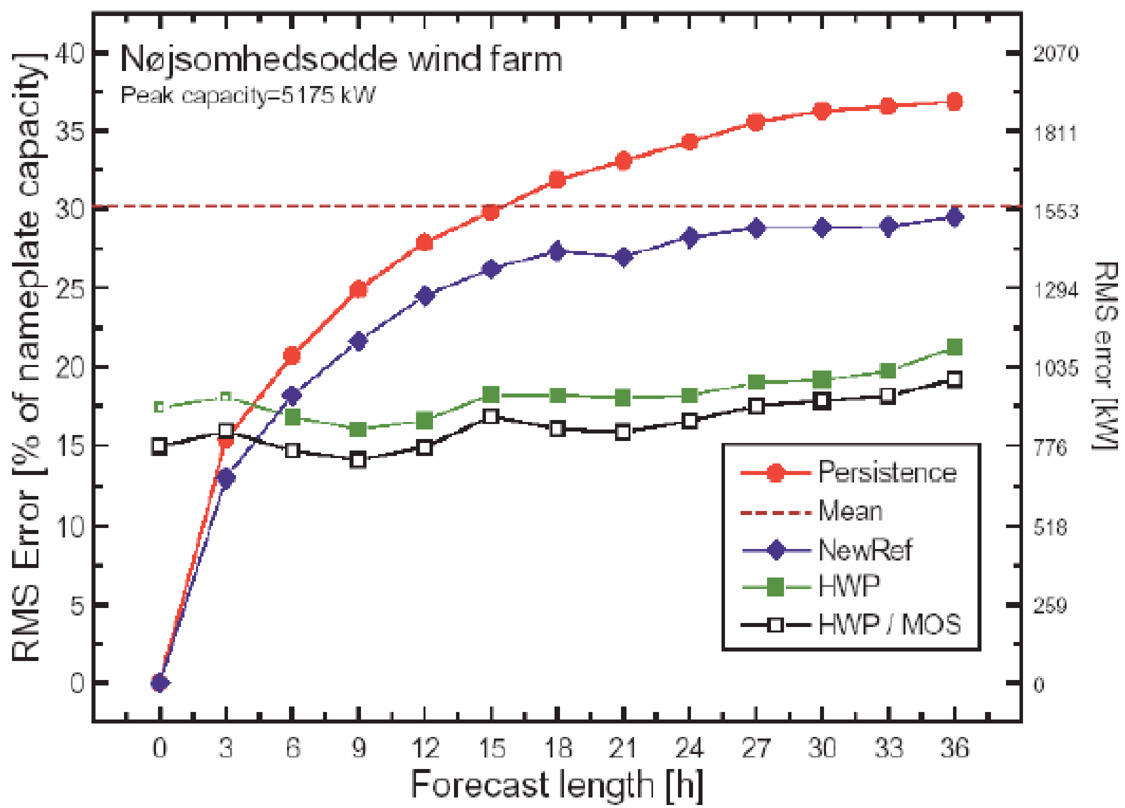


Figure 9 Root Mean Square (RMS) error for different forecast lengths and different prediction methods. Upper curves are statistically based systems, lower curves are weather forecast-based systems, from Giebel et al. (2003).

Wind interconnection - possible ways forward

- Network management
  - Improved turbine technologies + control strategies can help
  - High penetrations can still have significant local/regional impacts
  - Technical standards, pricing signals can play a useful role, strategic investments by Govts may also be required
- Frequency control ancillary services
  - Short-term reserve requirements set by N-1 contingency (typically sudden loss of largest generator or interconnector flow)
  - Wind may, however, add to the use of FCAS – especially regulation
  - Seems reasonable to have at least some ‘causer pays’
- Longer-term variability
  - Forecasting key – requires real-time data from wind farms, longer-term modelling using NWP probably best done centrally (AGO, NEMMCO and CSIRO collaboration)
  - Wind’s longer-term unpredictability already reflected in part through lower forward contract prices

‘Readily acceptable’ wind penetrations

- Readily acceptable – there are technical solutions to any associated problems that are not prohibitively expensive

- NEM might be able to readily accept up to 8000MW ***if***
  - Wind installed in progressive manner
  - Wind farms widely + evenly dispersed within NEM
  - Wind farms used advanced turbine technology + control systems with remote monitoring + control
  - Advanced wind forecasting techniques developed for regional projections up to 2 days ahead

  (Outhred, 2004)

Some possible take-home messages

- Wind an essential part of any meaningful response to climate change
- Coherent and consistent policy support will be required – *expanded MRET can play vital role: a possible role for State Governments*

- Wind farm developers
  - Community must be satisfied that wind is not just renewable, but sustainable
  - Significant wind penetrations can raise important challenges for NEM at local, regional and potentially, *at very high penetrations*, national scale
    - It is reasonable to assign at least some of these associated costs to them
- Network service providers and power system operators
  - These challenges should be readily manageable as long as
- Policy makers take action to ensure
  - Regional planning frameworks
  - Regional wind forecasting
  - Markets are fair to new technologies and participants
  - Market signals drive appropriate project development – location, machines, control strategies etc.
  - Possible that strategic investments required