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The renewable energy integration challenge & international experience

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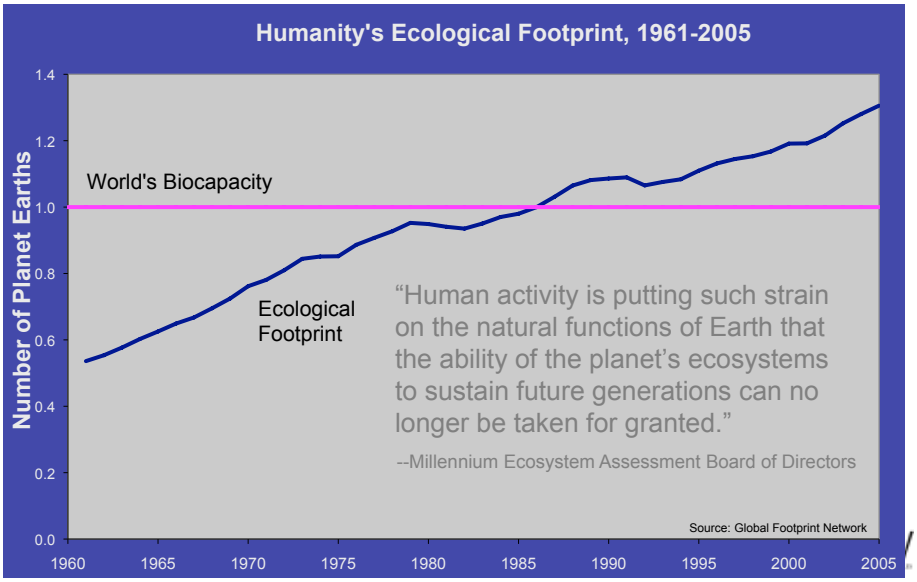
Outline

- Drivers for renewable energy development:
  - Oil flow constraints & environmental impacts
- Key issues in RE integration:
  - Technical, policy & regulatory, commercial, skills
- Progress to date with RE integration:
  - Europe, North America, Australia
- Conclusions

Earth's Carrying Capacity:

If we had more planets… (WWI, 12 January 2010)



What is technology?

(www.iiasa.ac.at)

An outcome of human decision-making

Software & Orgware are critical in complex ***socio-technological systems*** *such as we have created in* ***the stationary energy sector***

The Art of Knowing and Doing

The study of **technology** concerns *what* things are made and *how* things are made. Technology, from the Greek *science of* (practical) *arts,* has both a *material* and an *immaterial* aspect.

Technology = Hardware + Software + "Orgware"

Hardware: Manufactured objects (artifacts)

Software: Knowledge required to design, manufacture, and use technology hardware

"Orgware": Institutional settings and rules for the generation of technological knowledge and for the use of technologies

Technology's most important characteristic: ***Continuous change >>*** ***May require formal acculturation***

Decision-making framework for a competitive electricity industry: DM regimes & core functions

Governance regime	▪ Formal institutions, legislation & policies: ▪ Electricity industry design & governance ▪ *Informal social context including politics*
Security regime	▪ Responsible for core integrity on local or industry-wide basis, with power to override ▪ Should be consistent across a network
Technical regime	▪ Allow connected industry components to function as industry-wide machine: ▪ Connection rules, AMI & override control
Commercial regime	▪ Coordinate competitive, decentralised, commercial decision-making: ▪ By formally designed & informal markets

Key technical issues for high-penetration renewable energy (RE) (Outhred et al, 2007)

- Design & demonstration of RE & complementary resources (generation, storage, end-use response)
- Advanced metering, communication & control for distributed resources
- Improved power electronic devices
- Compact, high-capacity & cost-effective reversible energy storage
- Mathematic modelling & forecasting for renewable energy generation & distributed resources
- Education (RE technical acculturation)

Key regulatory & policy issues for high- penetration renewable energy

(Outhred et al, 2007)

- Institutional issues:
  - Robust security regime with security-constrained dispatch
  - Efficient commercial regime (operation & investment)
  - Effective regulatory framework for network services
  - Compatible arrangements for gas industry
- Policy issues:
  - Appropriate innovation in renewable energy technologies
  - Correct location & timing for investment in renewables & complementary resources
  - Forecasting for security & commercial regimes
  - Active end-user participation (value, timing, efficiency)
  - Education (policy acculturation)

Key commercial issues for high penetration RE

(Outhred et al, 2007)

- Advanced auction-style electricity markets:
  - Spot & derivative energy; ancillary services
    - Within continually updated security constraints
    - With active end-users supported by ESCOs
    - With attention to equity issues & education
- Efficient network access regimes:
  - Network augmentation & extension
  - Availability & quality; active end-user participation
- Renewable energy forecasting tools for:
  - Renewable energy generators
  - Other generators and end-users
  - System operators & policy-makers
- Environmental taxes/permits & command & control

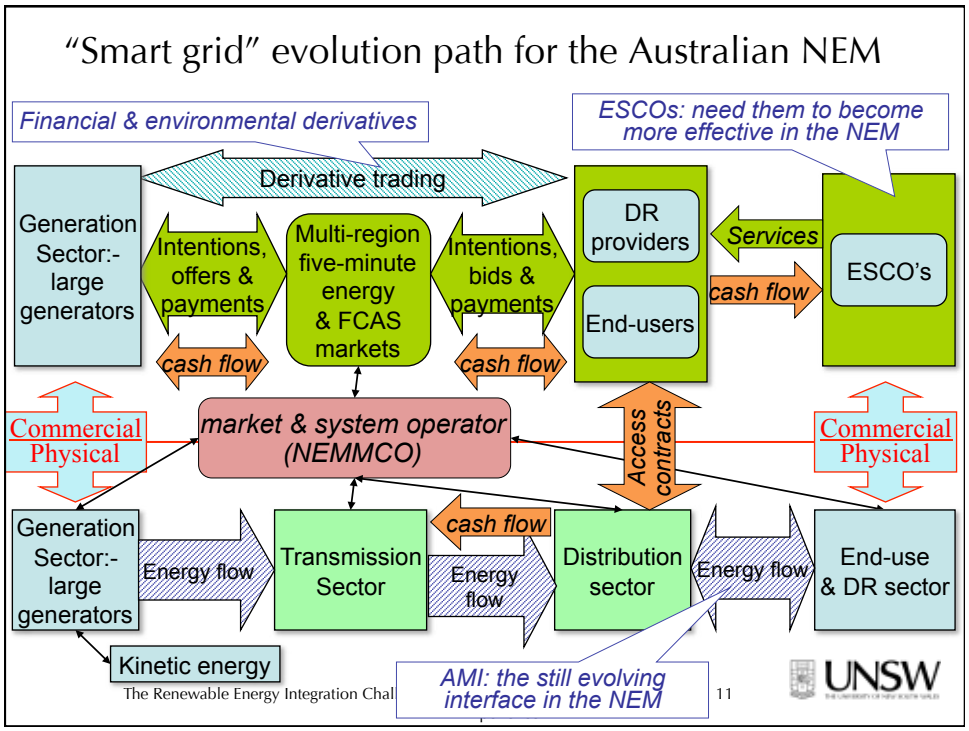
Three pillars of the smart grid

(Tabors et al, HICSS, Jan 2010)

- Smart customer (acculturation):
  - Technologies that allow customers to observe & control their consumption
- Smart "utility" (acculturation):
  - Implementing sophisticated monitoring, control & locational pricing
- Smart market:
  - Facilitates integration of customer & utility to create an economically efficient solution

Some "smart grid" concepts proposed in 1980 that have influenced the Australian NEM design

- Schweppe, Tabors, Kirtley, Outhred, Pickel & Cox (1980), *Homeostatic Utility Control,* IEEE TPAS:
  - "Homeostatic Utility Control is an overall concept which tries to maintain an internal equilibrium between supply and demand. Equilibrating forces are obtained over longer time scales (5minutes and up) by economic principles through an Energy Marketplace using time-varying spot prices. Faster supply-demand balancing is obtained by employing "governor-type" action on certain types of loads. Conventional metering is replaced by a Marketing Interface to Customer (MIC) which, in addition to measuring power usage, multiplies that usage by posted price and records total cost. Customers retain the freedom to select their consumption patterns."
- Outhred & Schweppe, *Quality of Supply Pricing for Electric Power Systems,* IEEE PES Winter Meeting,1980:
  - "quality of supply pricing is one aspect of homeostatic control"


"Smart grid" evolution path for the Australian NEM
Financial & environmental derivatives
ESCOs: need them to become more effective in the NEM
Derivative trading
Generation Sector:- large generators
Intentions, offers & payments
Multi-region five-minute energy & FCAS markets
Intentions, bids & payments
DR providers
End-users
Services
cash flow
ESCO's
cash flow
cash flow
Commercial Physical
market & system operator (NEMMCO)
Access contracts
Commercial Physical
Generation Sector:- large generators
Energy flow
Transmission Sector
cash flow
Energy flow
Distribution sector
Energy flow
End-use & DR sector
Kinetic energy
AMI: the still evolving interface in the NEM
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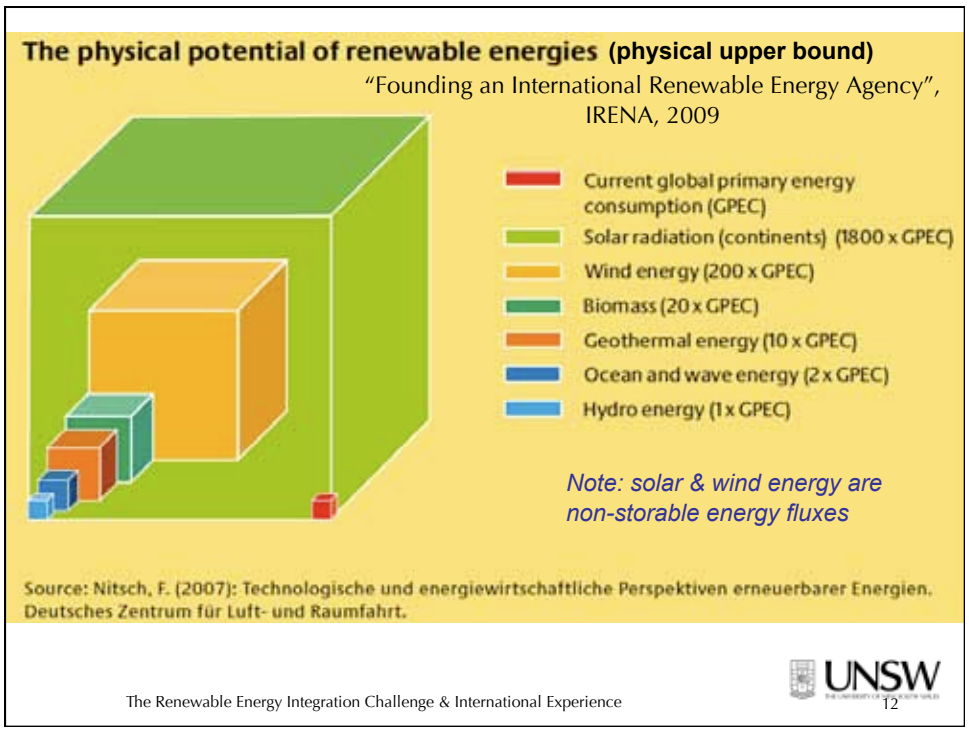
The physical potential of renewable energies (physical upper bound)
"Founding an International Renewable Energy Agency", IRENA, 2009
Current global primary energy consumption (GPEC)
Solar radiation (continents) (1800 x GPEC)
Wind energy (200 x GPEC)
Biomass (20 x GPEC)
Geothermal energy (10 x GPEC)
Ocean and wave energy (2 x GPEC)
Hydro energy (1 x GPEC)
Note: solar & wind energy are non-storable energy fluxes
Source: Nitsch, F. (2007): Technologische und energiewirtschaftliche Perspektiven erneuerbarer Energien. Deutsches Zentrum für Luft- und Raumfahrt.
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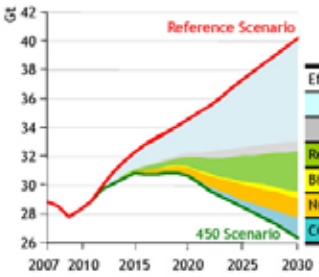
(Fig 9.2, World Energy Outlook, IEA, 2009)



	Abatement (Mt CO_2)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	2 517	7 880	1 999	5 586
End-use	*2 284*	*7 145*	*1 933*	*5 551*
Power plants	*233*	*735*	*66*	*35*
Renewables	680	2 741	527	2 260
Biofuels	57	429	27	378
Nuclear	493	1 380	125	491
CCS	102	1 410	56	646

Efficiency measures account for two-thirds of the 3.8 Gt of abatement in 2020, with renewables contributing close to one-fifth

Integrating Wind in Europe
(TradeWind Study Final Report, 2009)

- Improve European electricity market design:
  - Introduce intra-day rescheduling of generators & interchange
  - Build sufficient interconnection capacity
  - Share reserves among participating countries
  - Widely disperse wind farm sites
  - Invest in complementary supply-side & demand-side resources

Comment: Europe less advanced than Australia

Eastern (USA) Wind Integration & Transmission Study Findings (NREL, 2010)

- 20-30% by energy wind penetration feasible but new transmission would be required to avoid curtailment:
  - Transmission may be slower to build than wind farms
- Wind integration costs are manageable & would be reduced with large operating pools & markets & good forecasting
- Wind displaces coal generation
- Gas generation complements wind generation

Comment: Eastern USA less advanced than Australia

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Western (USA) Wind & Solar Integration Study

(WestConnect, USA, 2010)

Operationally feasible to accommodate 30% wind & 5% solar penetration with:

- Balancing area cooperation or consolidation
- Sub-hourly generation & exchange scheduling
- Full utilization of transmission capacity
- Economic unit commitment & dispatch including downward-dispatch of wind turbines when required
- State of the art wind & solar forecasting
- Complementary supply- & demand-side resources
- Appropriate operating reserves & network capacity

Comment: Western USA less advanced than Australia

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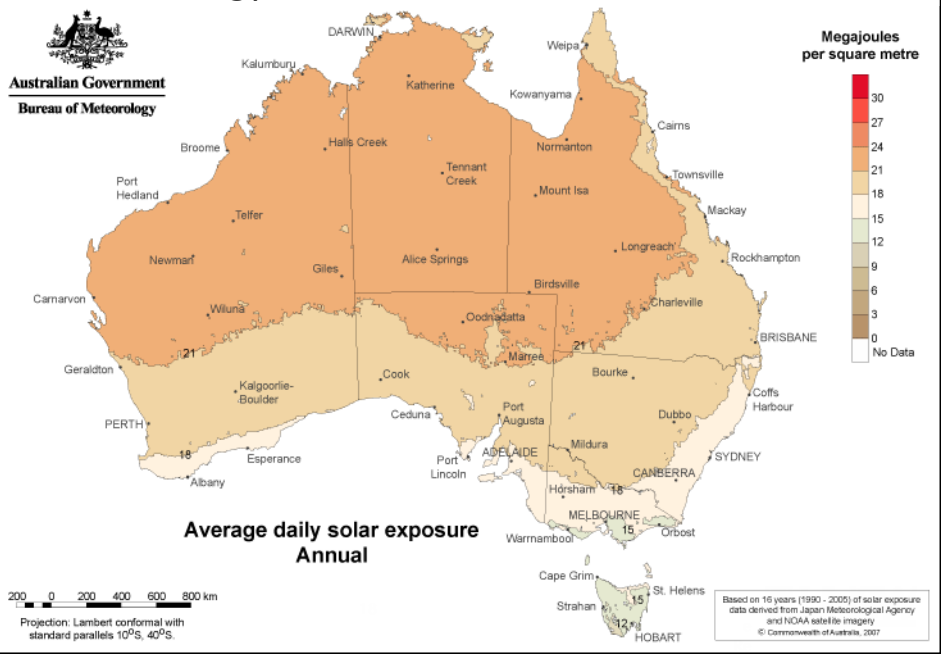
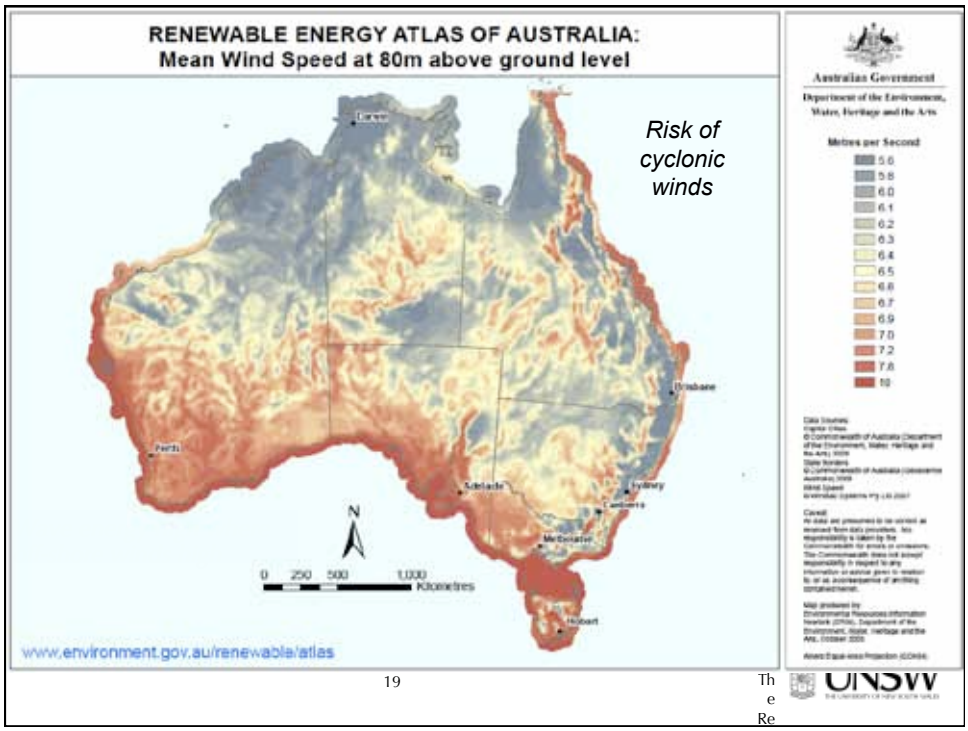
AEMC review of energy markets in the light of climate change policies (Sept 09) *Endorsed by MCE in Dec 2009*

- Overall conclusion:
  - "subject to implementation of the framework changes we are recommending, the energy market framework is generally capable of accommodating the impacts of climate change policies efficiently and reliably" (AEMC, 2009: iv)
- Recommended changes to the energy market framework:
  - Remove remaining retail price regulation & implement a nationally consistent framework for energy customer protection
  - Improve network connection arrangements for clusters of generators & introduce inter-regional transmission charges
  - Improve location signals in generator network charges & in spot market energy prices with respect to intra-regional congestion
- Enhancements already made prior to this review include:
  - Integrated forecasting system for non-storable renewable
  - Wind farms required to participate in spot market
  - Technical requirements for grid connection

Solar energy resource (MJ/M²/day; www.bom.gov.au)




RENEWABLE ENERGY ATLAS OF AUSTRALIA:
Mean Wind Speed at 80m above ground level
Risk of cyclonic winds
Brisbane
Perth
Adelaide
Sydney
Canberra
Melbourne
Hobart
N
0 250 500 1,000 Kilometres
www.environment.gov.au/renewable/atlas
Australian Government
Metres per Second
5.6
5.8
6.0
6.1
6.2
6.3
6.4
6.5
6.8
6.7
6.9
7.0
7.2
7.8
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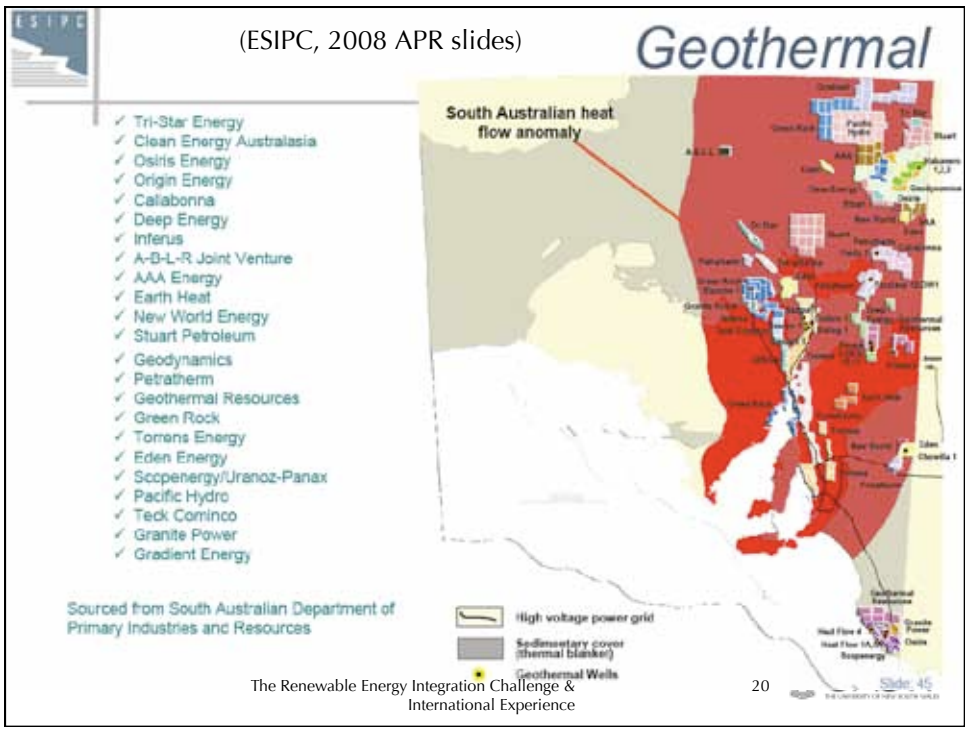
(ESIPC, 2008 APR slides)
Geothermal
Tri-Star Energy
Clean Energy Australasia
Osiris Energy
Origin Energy
Callabonna
Deep Energy
Inferus
A-B-L-R Joint Venture
AAA Energy
Earth Heat
New World Energy
Stuart Petroleum
Geodynamics
Petratherm
Geothermal Resources
Green Rock
Tomens Energy
Eden Energy
Scepenergy/Uranoz-Panax
Pacific Hydro
Teck Cominco
Granite Power
Gradient Energy
South Australian heat flow anomaly
Sourced from South Australian Department of Primary Industries and Resources
High voltage power grid
Sedimentary cover (thermal blanket)
Geothermal Wells
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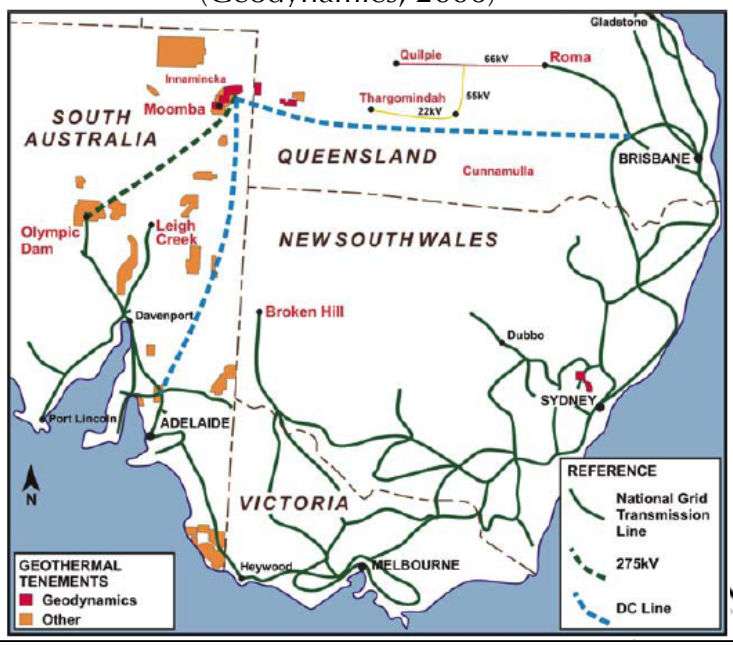
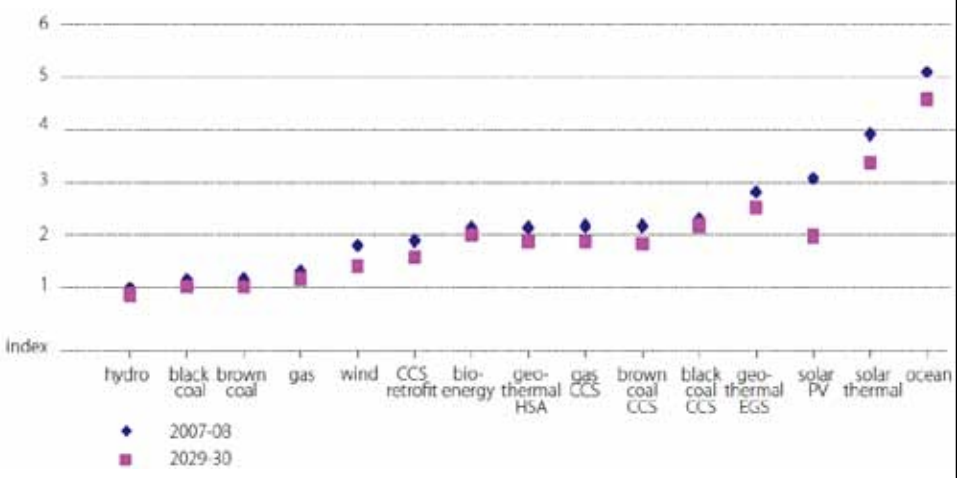
Slide: 45

Geothermal energy - grid connection

(Geodynamics, 2006)



Index of real, levelised cost of electricity generation technologies excluding emission costs (ABARE, 2010)



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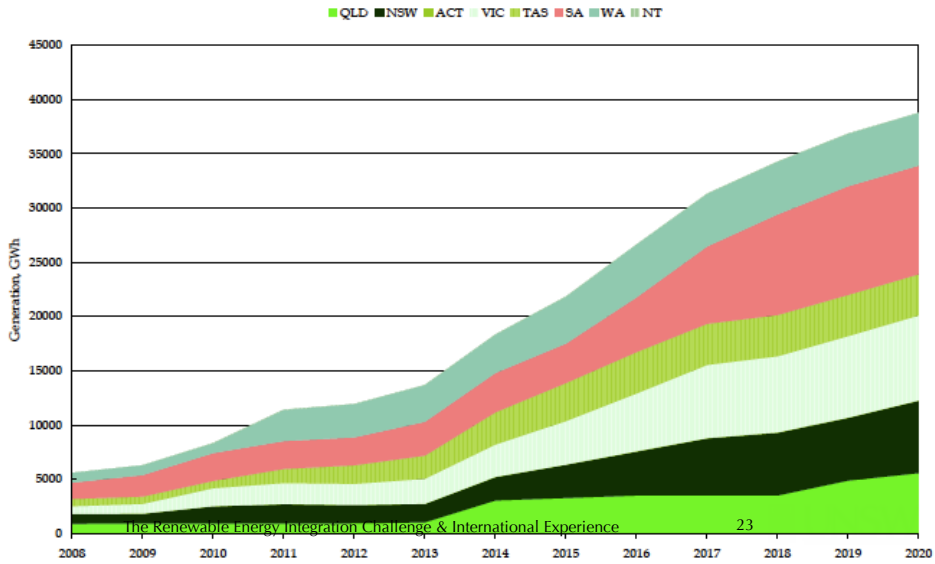
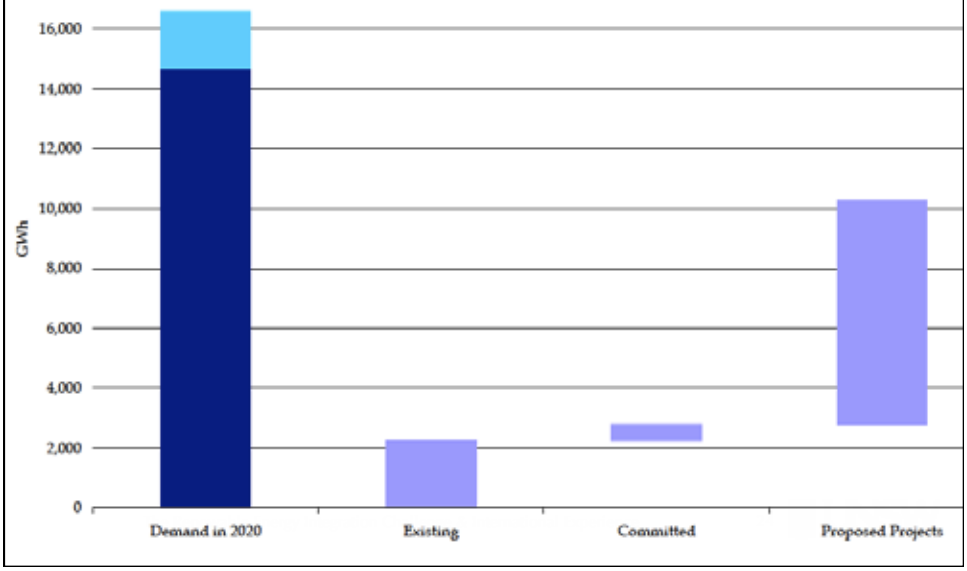
Predicted renewable energy generation by State, low uptake scenario (MMA SA study, 2009)

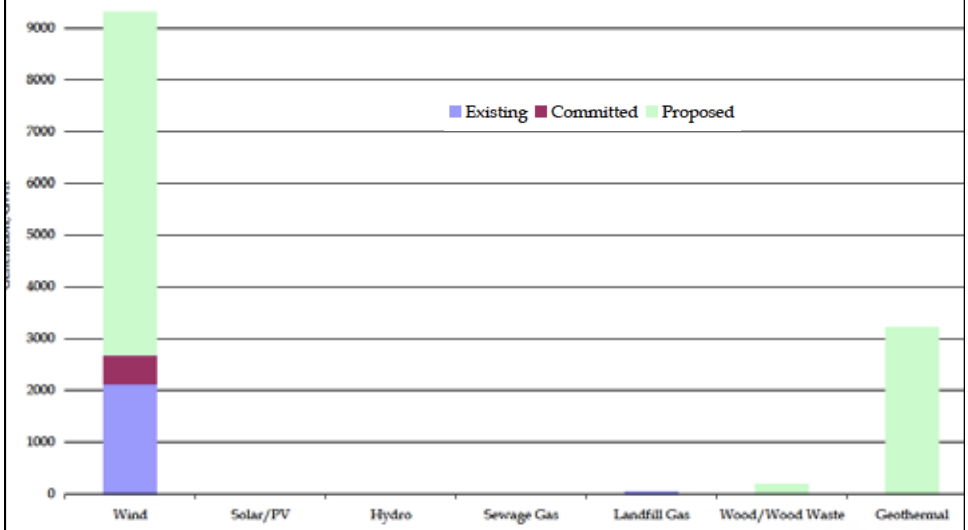


Projected SA Electricity consumption & existing, committed & proposed renewable energy projects

(MMA SA Study, 2009)



Existing, committed & proposed RE projects in SA by technology (MMA SA Study, 2009)



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Operating (2009) & planned (2019) wind capacity

(AEMO, AWEFS overview, Jan 10)

Queensland
12MW operating
300MW planned

New South Wales
170MW operating
2,200MW planned

South Australia
870MW operating
1,400MW planned

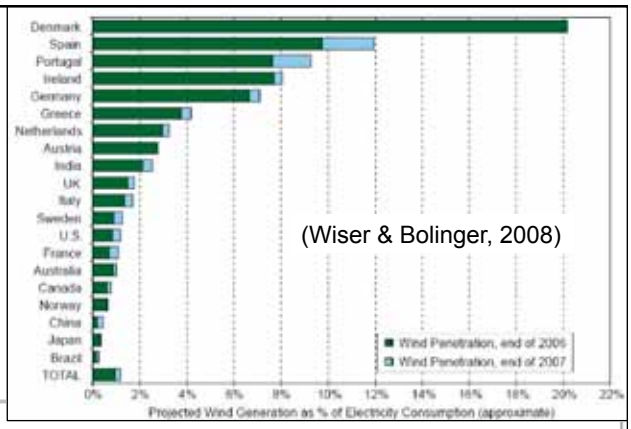
Victoria
430MW operating
2,500MW planned

Tasmania
140MW operating
420MW planned

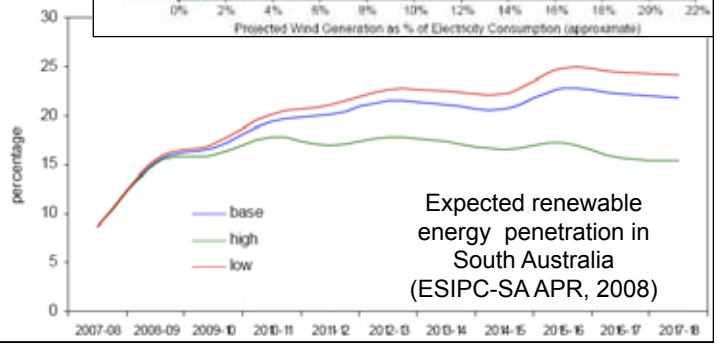
Operating: as of September 2009
Planned: 2009 to 2019

PG3

Wind penetration (%energy) globally & for South Australia

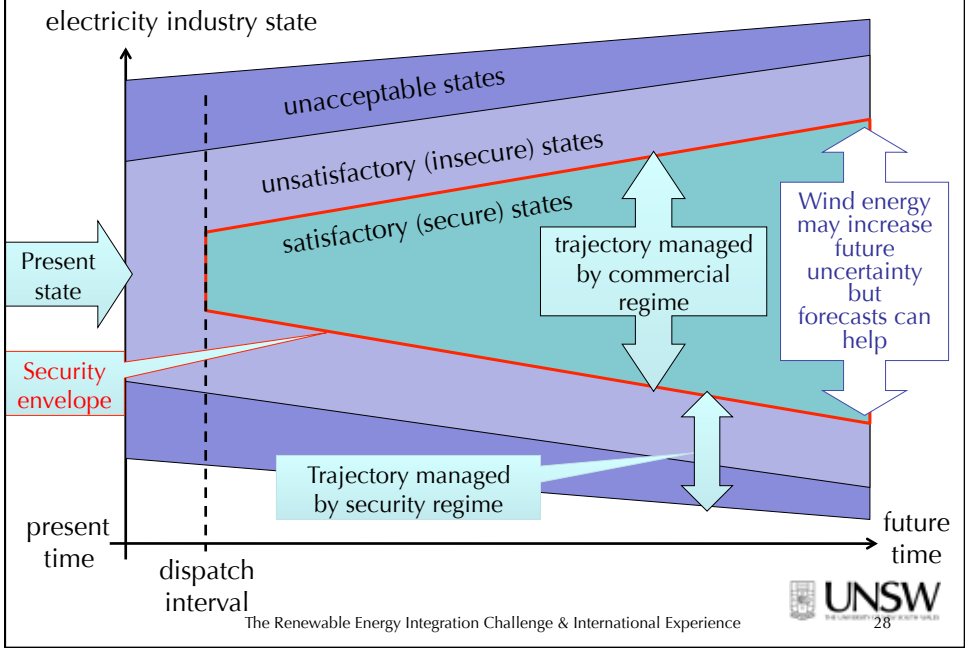


(Wiser & Bolinger, 2008)



Expected renewable energy penetration in South Australia (ESIPC-SA APR, 2008)

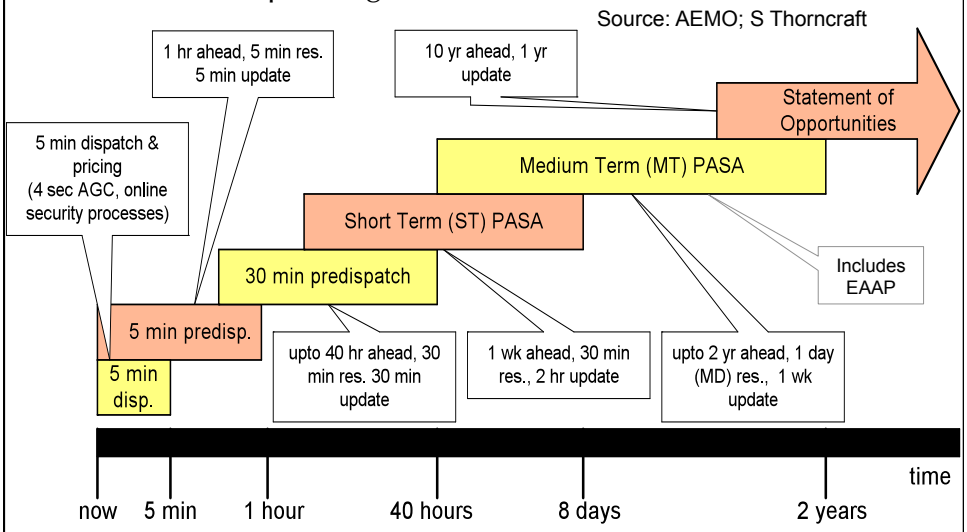
NEM security & commercial regimes (Thorncraft, 2009)



NEM security regime forward projections

(now incorporating wind forecasts at all timescales)

Source: AEMO; S Thorncraft



(PASA: Projected Assessment of System Adequacy)
(EAAP: Energy Adequacy Assessment Projection

Conclusions

- An electricity industry implements a complex technological system: *Need coherent innovation in orgware, software, hardware*
- RE integration needs careful planning:
  - Identify barriers to entry & characterise uncertainty
  - Provide incentives for complementary resources:
    - Flexible generation, demand & storage
  - Introduce "smart grid" features to maximise acceptable level of penetration (acculturation)
- Wind integration in the Australian National Electricity Market successful to date

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Hugh Outhred is a Professorial Visiting Fellow at the University of New South Wales, an Adjunct Professor at Murdoch University, *Guru Besar Luar Biasa* at STTNAS Jogjakarta, Indonesia and a Director of Ipen Pty Ltd, which provides advisory and educational services on energy, society and the environment.

Hugh retired in 2007 after a 35-year career at UNSW, most recently as Presiding Director, Centre for Energy and Environmental Markets and Head, Electrical Energy Research Group, School of Electrical Engineering and Telecommunications.

During his career, Hugh has been a Fulbright Senior Fellow at the University of California Berkeley, a Board Member of the Australian Cooperative Research Centre for Renewable Energy, an Associate Director of UNSW's Centre for Photovoltaic Devices and Systems, a Member of CSIRO's Energy Flagship Advisory Committee, a Member of the National Electricity Tribunal and a Member of the New South Wales Licence Compliance Advisory Board.

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