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Renewable energy: resources, technology, integration

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EGAT Training Program

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www.ceem.unsw.edu.au

Renewable energy resources

- Diverse
  - Solar, biomass, wind geothermal, ocean
- Globally distributed
  - However, always nationally specific circumstances
- Large
  - Economic? depends on alternatives
  - However great technical + theoretical potential

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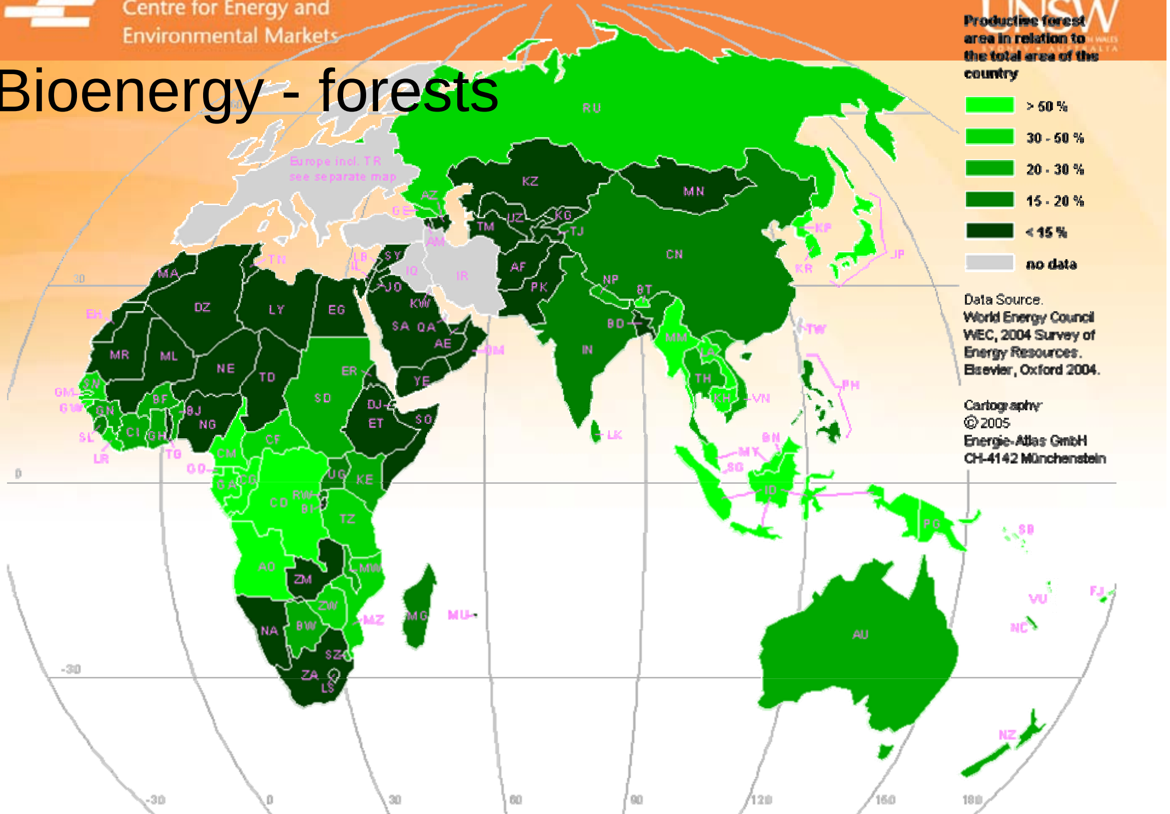
Bioenergy - forests



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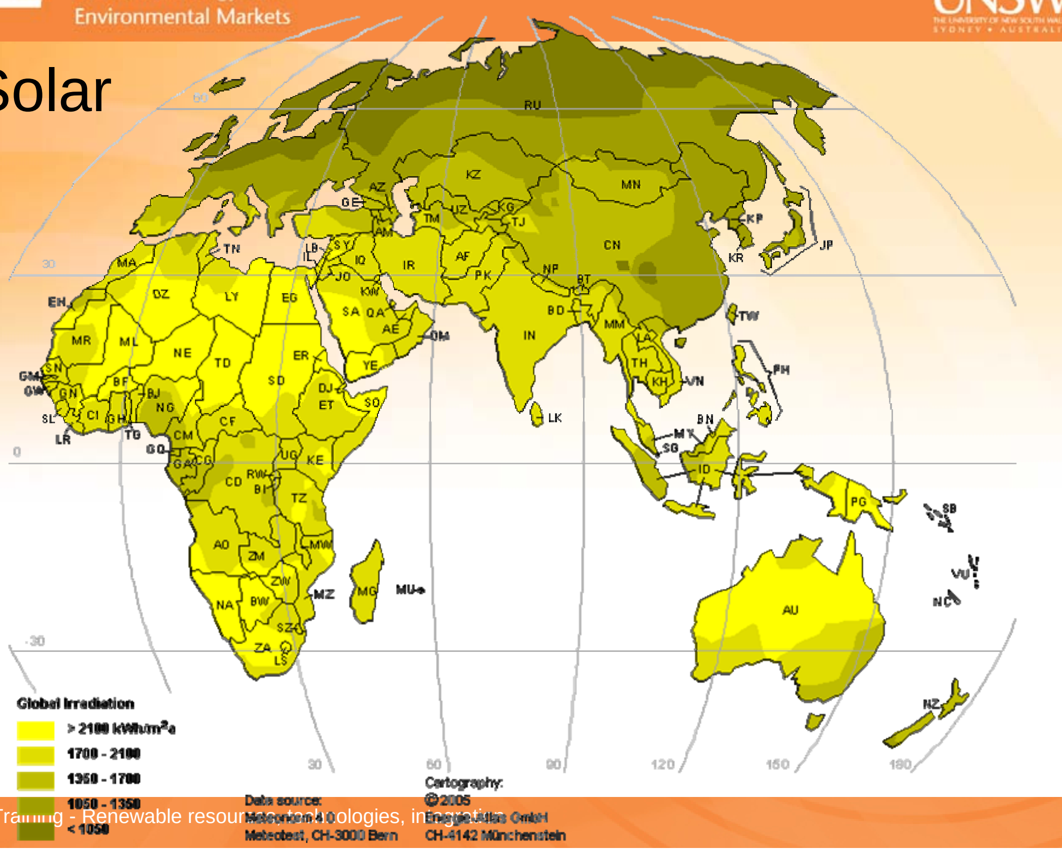
Solar



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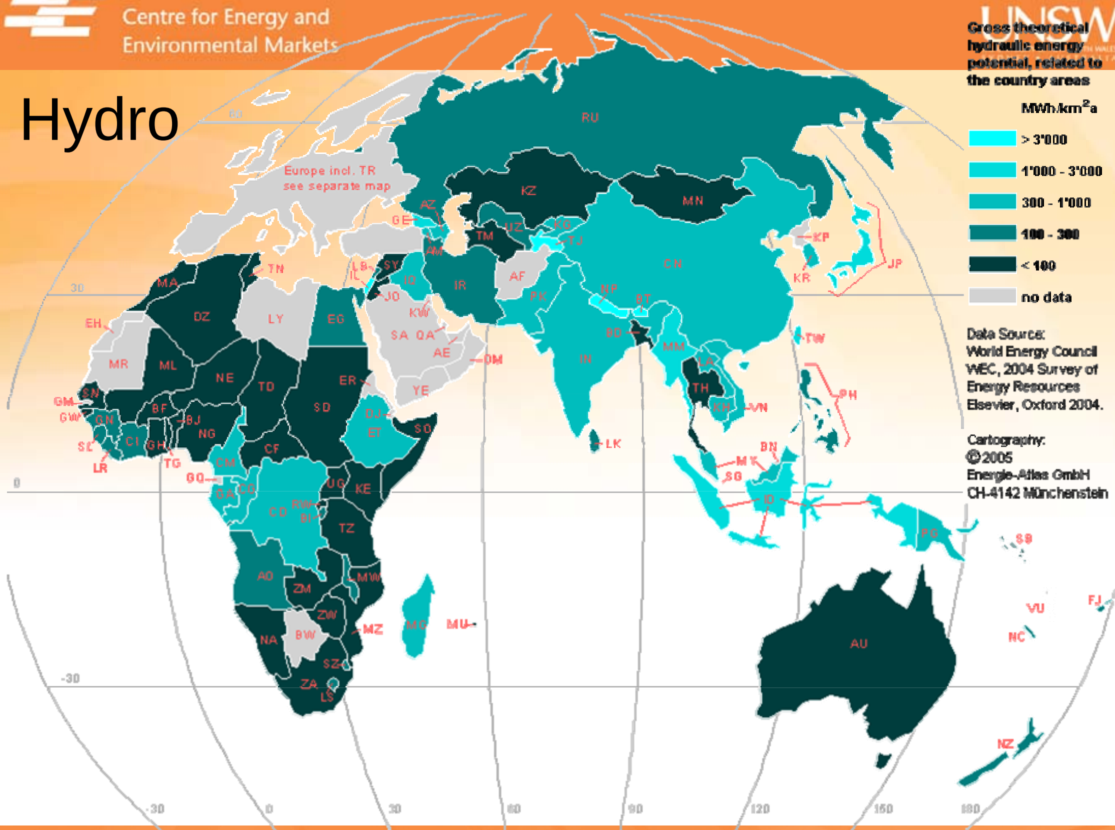
Hydro



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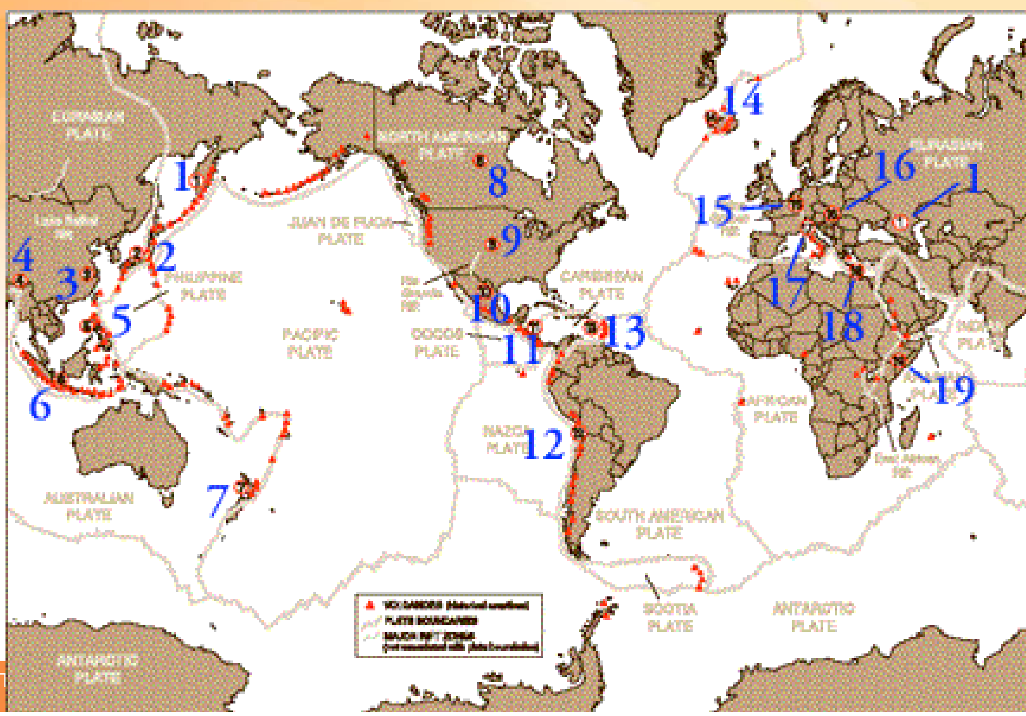
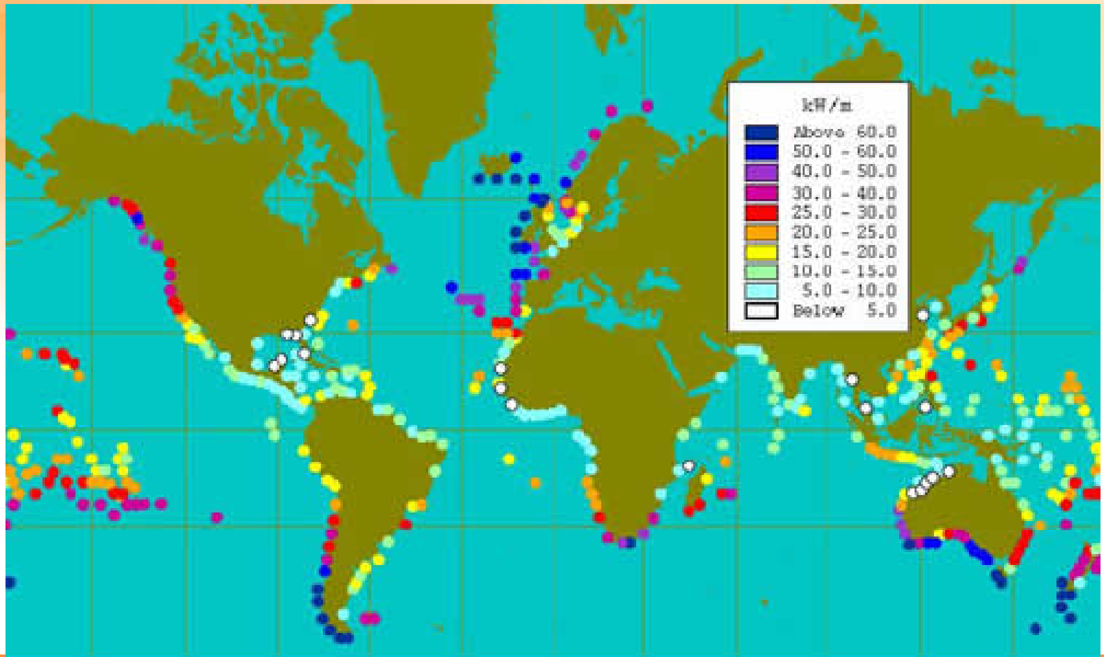
Geothermal



Wave energy



Wide range of RE technologies but varying technical status (IEA, 2006)

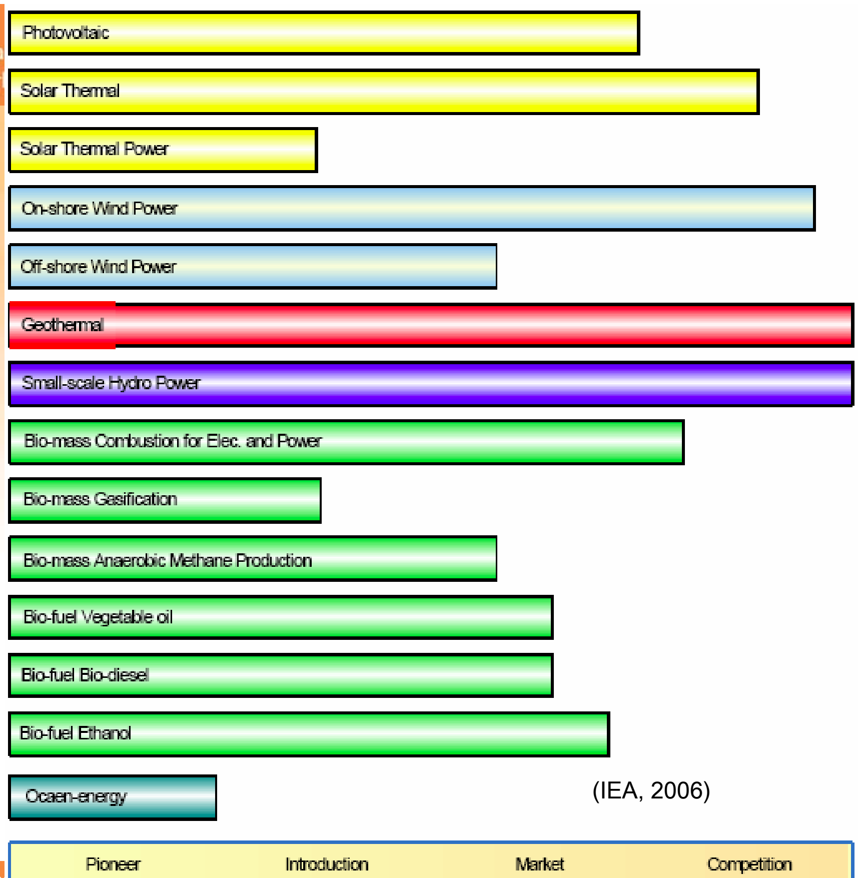
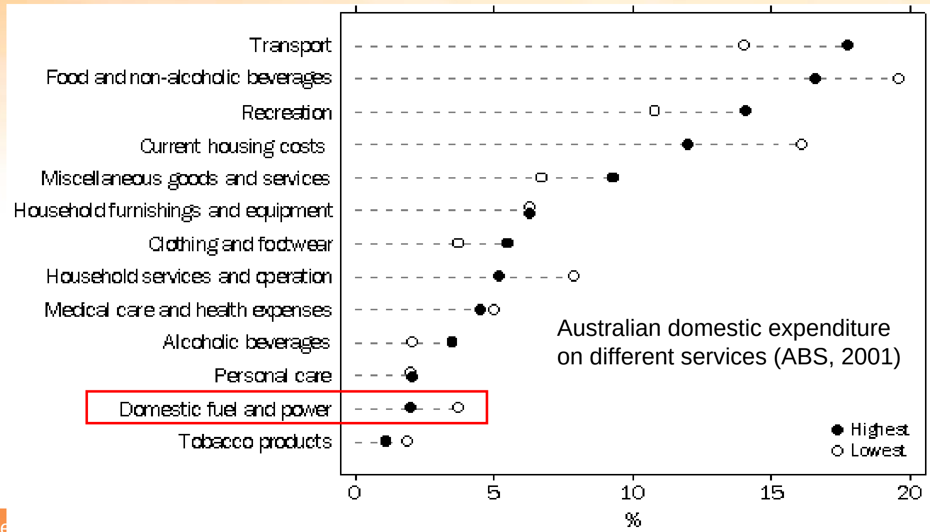


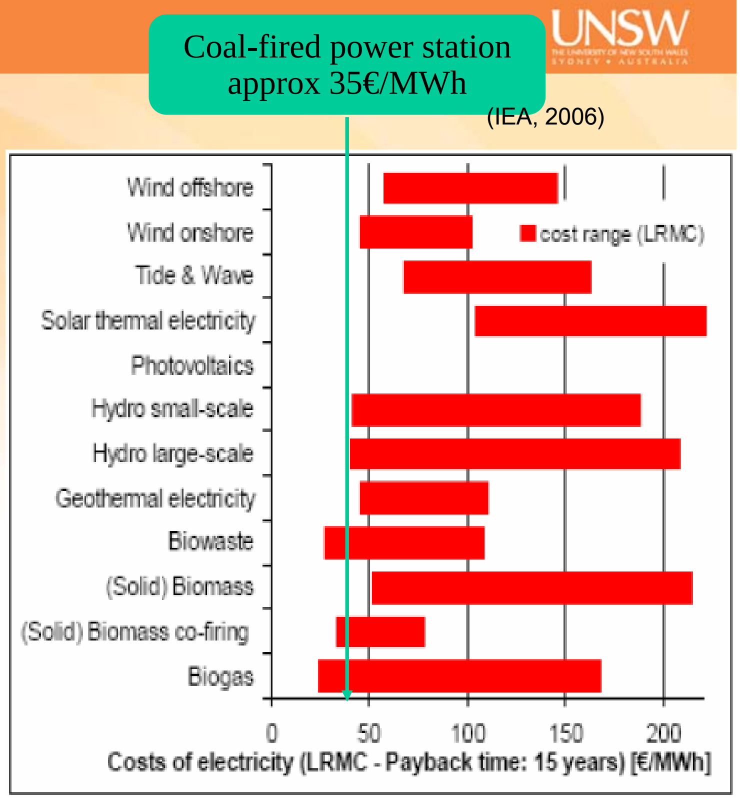
Figure 4: Development of renewable energy technologies – rough indication! [16]

However, fossil incumbents dominate for reason

- For the 'golden billions', never have so many had so much energy so cheaply
  finding fossil fuels equivalent to winning 'energy' lottery



- Renewable energy direct costs generally higher than fossil fuels
- Main drivers
  - Particular low-cost opportunities *eg. hydro, bagasse*
  - Energy security concerns
  - Climate change related policy
  - Industry development
  - Remote/rural areas



Some global renewable energy indicators

- Impressive growth of some technologies but from generally small base
- Growing policy efforts particularly in liquid fuels

Selected Indicators	2004		2005
Investment in new renewable capacity (annual)	$30	➧	$38 billion
Renewables power capacity (existing, excl. large hydro)	160	➧	182 GW
Renewables power capacity (existing, incl. large hydro)	895	➧	930 GW
Wind power capacity (existing)	48	➧	59 GW
Grid-connected solar PV capacity (existing)	2.0	➧	3.1 GW
Solar PV production (annual)	1150	➧	1700 MW
Solar hot water capacity (existing)	77	➧	88 GWth
Ethanol production (annual)	30.5	➧	33 billion liters
Biodiesel production (annual)	2.1	➧	3.9 billion liters
Countries with policy targets	45	➧	49
States/provinces/countries with feed-in policies	37	➧	41
States/provinces/countries with RPS policies	38	➧	38
States/provinces/countries with biofuels mandates	22	➧	38

(REN, *Renewable Energy Report, 2006*)

…and leading countries

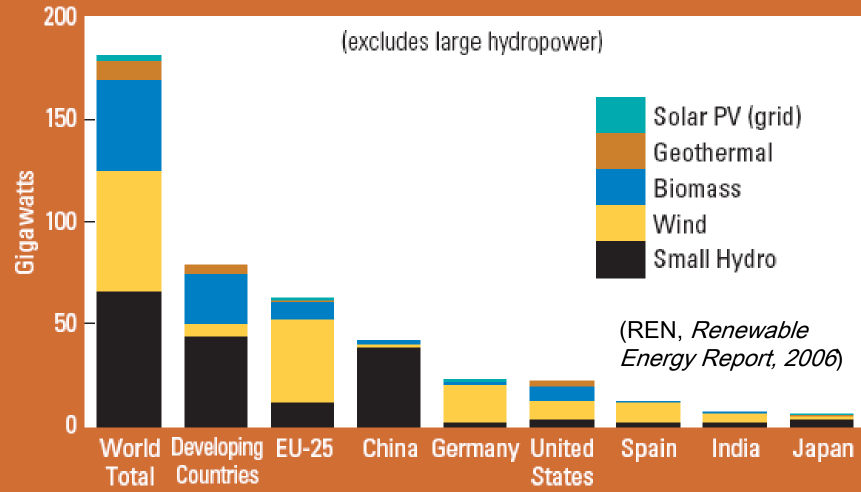
- Reflecting a combination of national endowments, national size, innovation *yet primarily policy*

Top Five Countries	#1	#2	#3	#4	#5
Annual amounts or capacity additions in 2005					
Annual investment	Germany/China (equal)		United States	Japan	Spain
Wind power	United States	Germany	Spain	India	China
Solar PV (grid-connected)	Germany	Japan	United States	Spain	France
Solar hot water	China	Turkey	Germany	India	Austria/Greece/ Japan/Australia
Ethanol production	Brazil/United States		China	Spain/India	
Biodiesel production	Germany	France	Italy	United States	Czech Republic
Existing capacity as of 2005					
Renewables power capacity (excl. large hydro)	China	Germany	United States	Spain	India
Large hydro	United States	China	Brazil	Canada	Japan/Russia
Small hydro	China	Japan	United States	Italy	Brazil
Wind power	Germany	Spain	United States	India	Denmark
Biomass power	United States	Brazil	Philippines	Germany/Sweden/Finland	
Geothermal power	United States	Philippines	Mexico	Indonesia/Italy	
Solar PV (grid-connected)	Germany	Japan	United States	Spain	Netherlands
Solar hot water	China	Turkey	Japan	Germany	Israel

(REN, *Renewable Energy Report, 2006*)

'new' renewable contributions for some key countries

Figure 4. Renewable Power Capacities for Developing Countries, EU, and Top 6 Individual Countries, 2005



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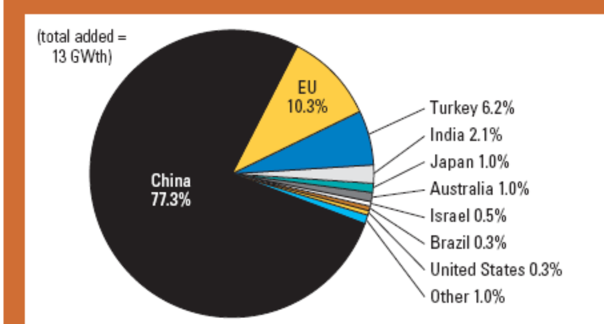
Solar Hot Water

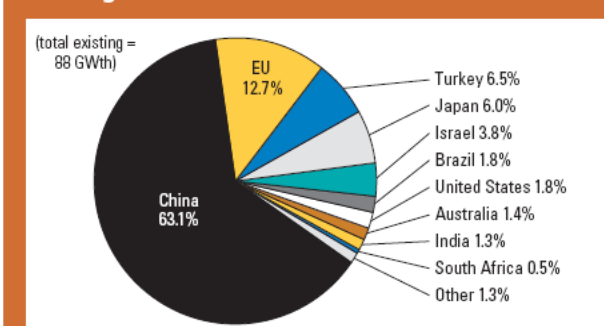
- China now dominates the world market
- Australia was formerly a key player

Figure 5. Solar Hot Water/Heating Capacity Added in 2005



(REN, *Renewable Energy Report, 2006*)

Figure 6. Solar Hot Water/Heating Capacity Existing in 2005



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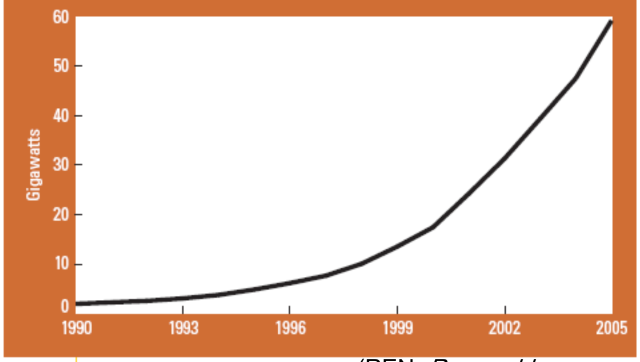
Wind power

- One of the energy success stories of the last decade

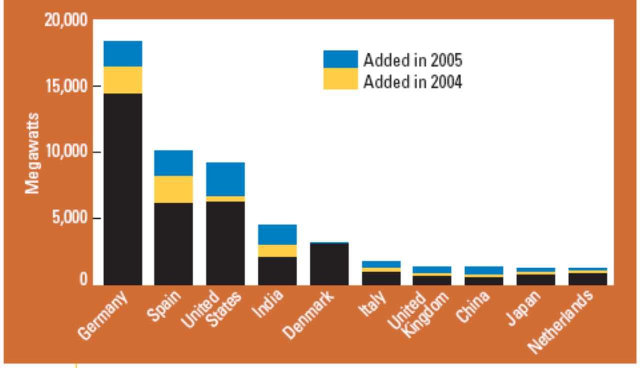
  Much more new wind than nuclear now being installed each year
- Australia has a very significant wind resource yet only limited industry development at present

Figure 1. Wind Power, Existing World Capacity, 1990–2005



(REN, *Renewable Energy Report, 2006*)

Figure 2. Wind Power Capacity, Top 10 Countries, 2005



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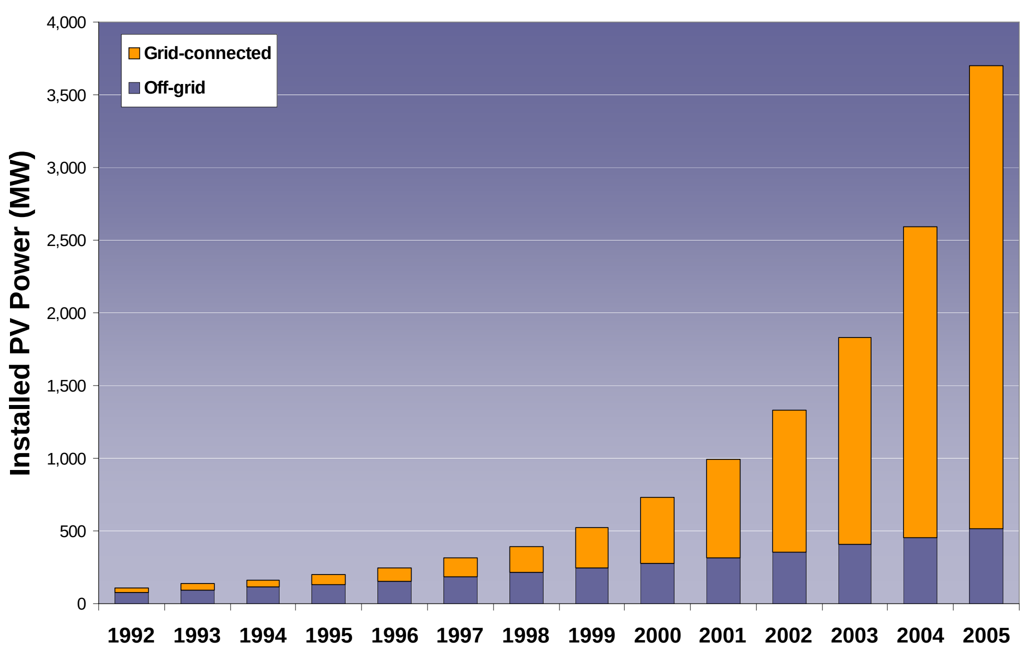
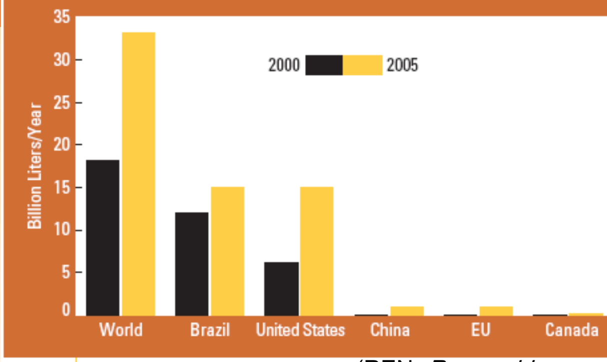
PV Market in IEA countries,1992-2005 (IEA PVPS, 2006)

Figure 1 Cumulative installed grid-connected and off-grid PV power in the reporting countries – Years 1992-2005



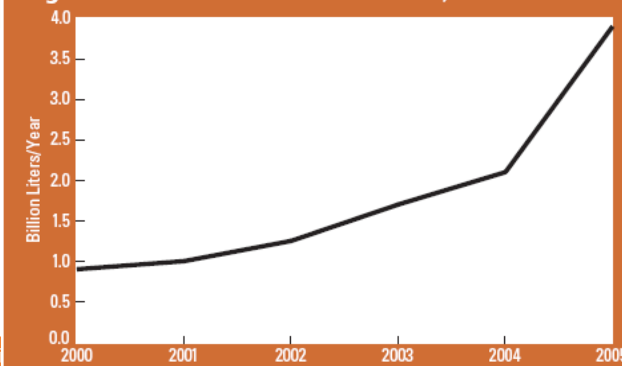
Liquid fuels

Figure 7. World Fuel Ethanol Production, 2000 and 2005



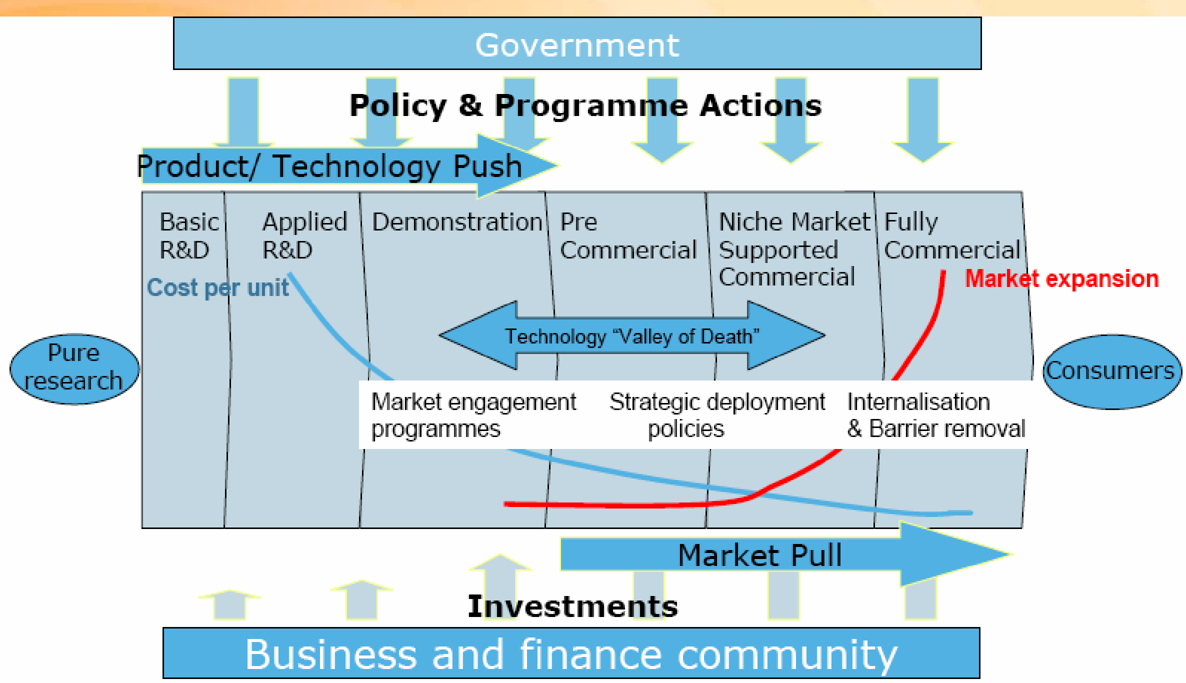
(REN, *Renewable Energy Report, 2006*)

Figure 8. World Biodiesel Production, 2000–2005



Renewable energy policy

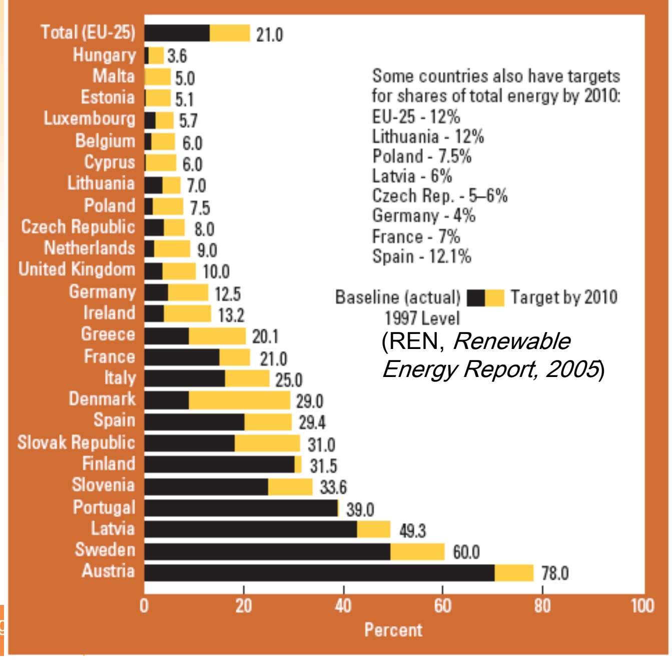
Successful innovation requires both technology push & market pull policies



Renewable energy targets

- A key driver for market deployment policies
- Major targets in many countries
  The EU in particular, but also a growing number of developing countries
- However, Australia has only a very modest target
  projected to be <1% for new renewables in 2020

Figure 10. EU Renewable Energy Targets— Share of Electricity by 2010



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Now strengthening targets in many countries

- "The European Council reaffirms the Community's long-term commitment to the EU-wide development of renewable energies beyond 2010, underlines that all types of renewable energies, when used in a cost-efficient way, contribute simultaneously to security of supply, competitiveness and sustainability, and is convinced of the paramount importance of giving a clear signal to industry, investors, innovators and researchers. … it endorses the following targets:
  – a binding target of a 20 % share of renewable energies in overall EU energy consumption by 2020;
  – a 10 % binding minimum target to be achieved by all Member States for the share of biofuels in overall EU transport petrol and diesel consumption by 2020, to be introduced in a cost-efficient way."
- China – 20% renewable electricity target for 2020 (currently ~8%)
- Growing number of US states with Renewable Energy Portfolio Standards (RPS)

Global sustainable energy investment

Figure 5. Global Investment in Sustainable Energy by Technology, 2006

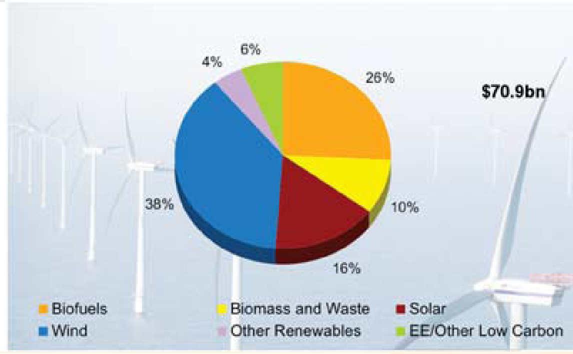
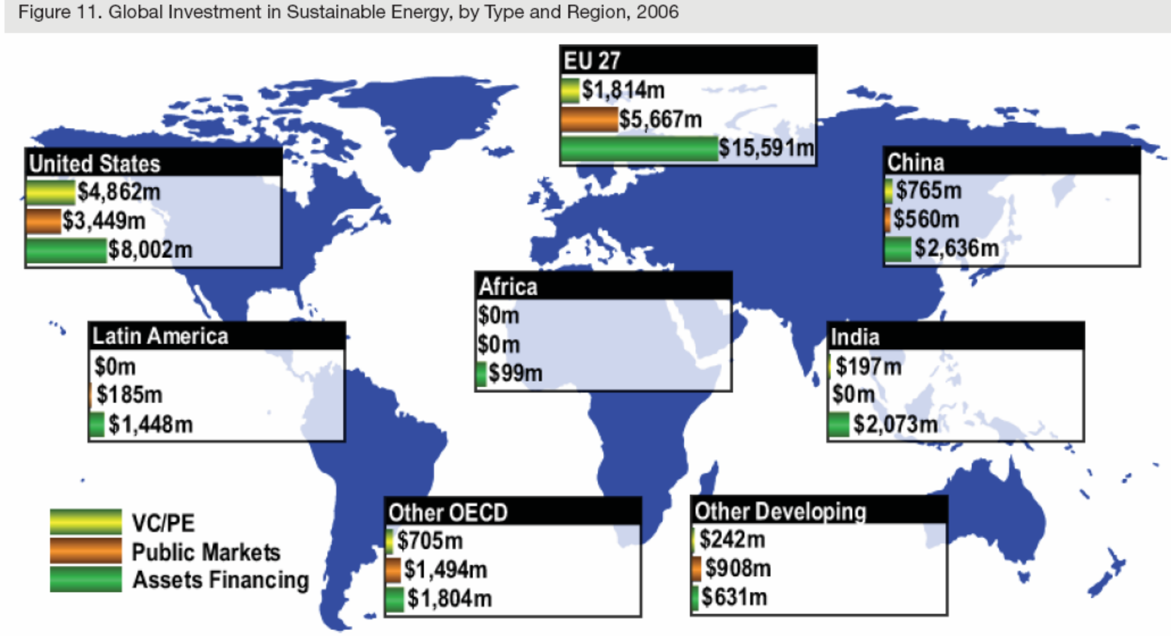


Figure 1. Global Investment in Sustainable Energy, 2006

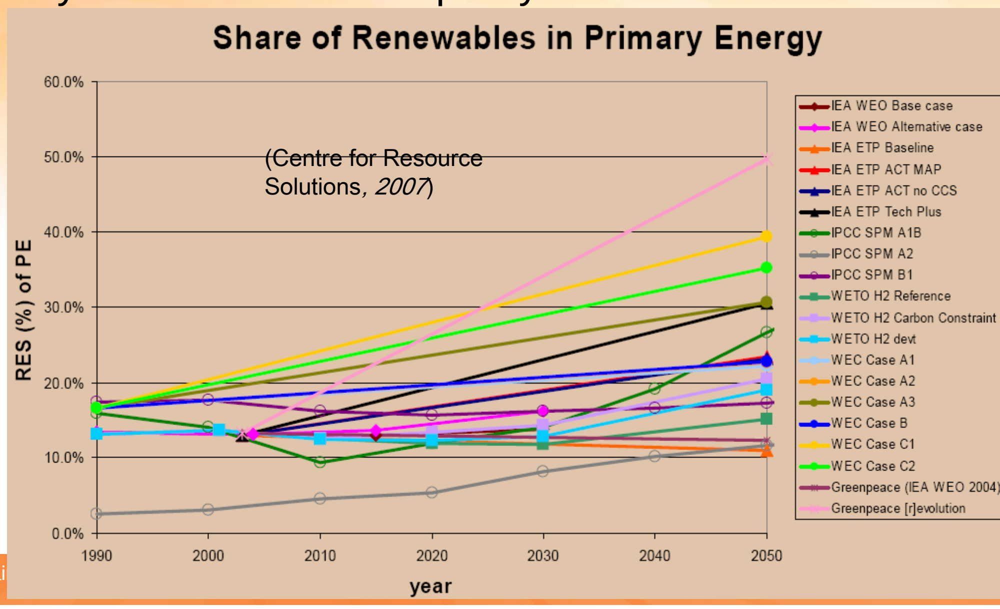
Where is what type of investment happening?

Figure 11. Global Investment in Sustainable Energy, by Type and Region, 2006

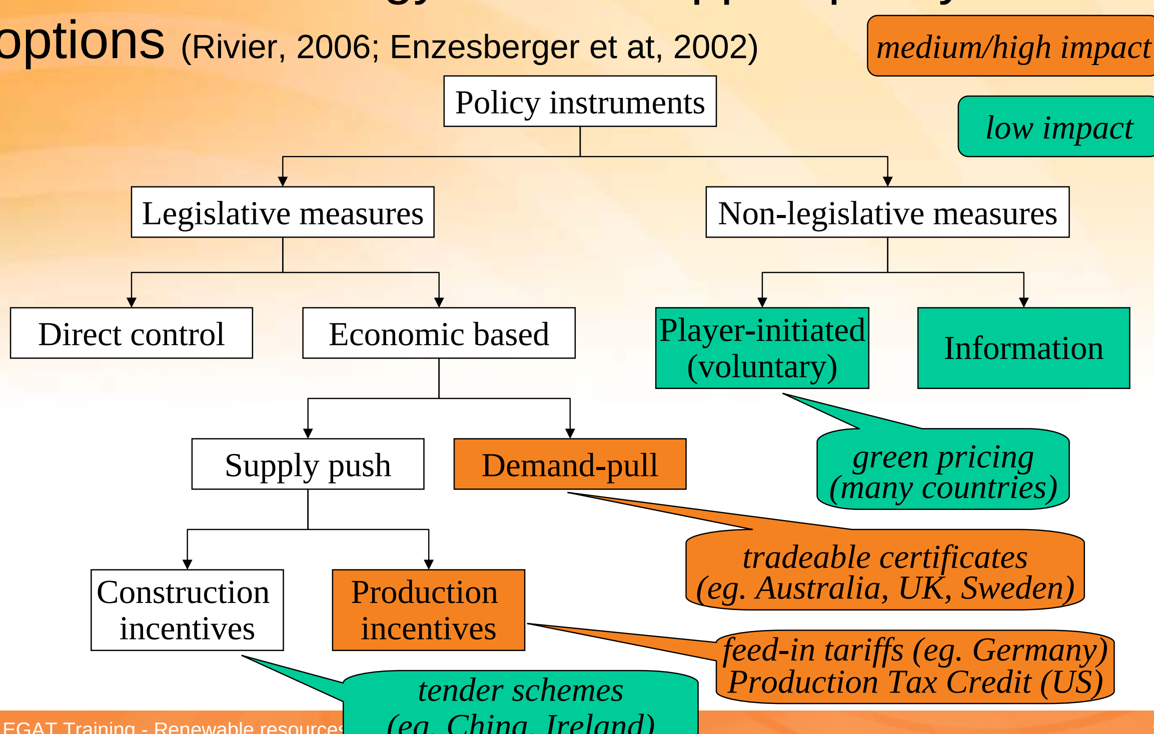


Possible renewable energy futures

- Wide range of scenarios depicting very different possible futures for renewable energy
- Key determinant will be policy efforts

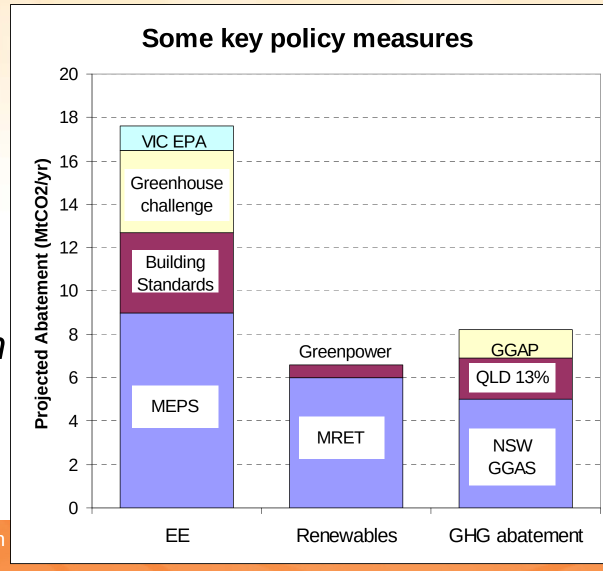


Renewable energy market support policy options (Rivier, 2006; Enzesberger et at, 2002)

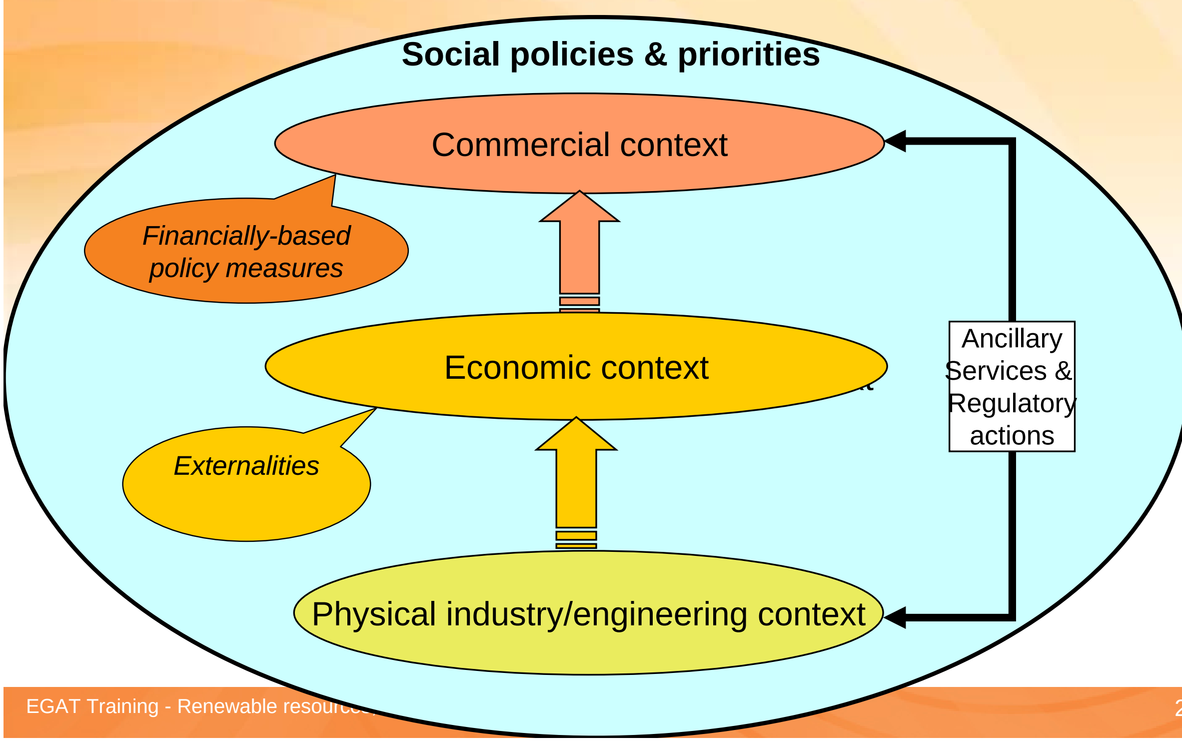


Current Australian Renewable Energy Policy

- Significant proportion of expected policy driven abatement from very modest Federal renewable energy target (MRET)
- State Govts now mandating additional renewable energy targets in absence of Federal action
- Some R&D & Demonstration 'technology push' support for emerging technologies
  but note very minor short-term emission reductions



Various contexts of renewable energy integration



Physical integration of significant renewables

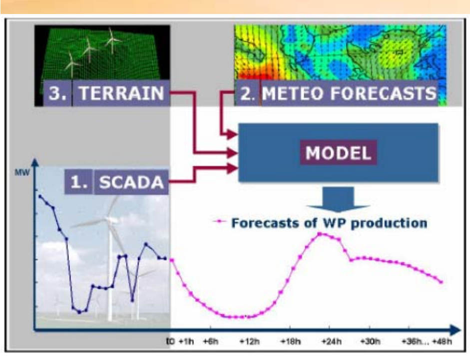
- All loads, generators + network elements have electrical flows that are variable, not completely controllable + somewhat unpredictable
  - *Major value of electrical networks is in aggregation of diverse variable, uncertain generation and demand*
- Renewables
  - Some renewables such as wind reliable but highly variable energy flux, only somewhat (downwardly) controllable + unpredictable
  - Generally smaller scale

The operational challenge for power systems

  - Attempting to maintain continuous flow of end-user energy services
  - manage small disturbances well but entire system put at risk by *large unexpected* changes
  - Require ‘plug and play’ technical regime for connection of equipment
- Australian NEM arrangements
  - Technical connection standards
  - Non-scheduled status for plant <30MW

Wind generation predictability

- Also depends on context
  - Prediction objectives? Expected value or extreme events
  - Scale – windfarm, region, NEM-wide



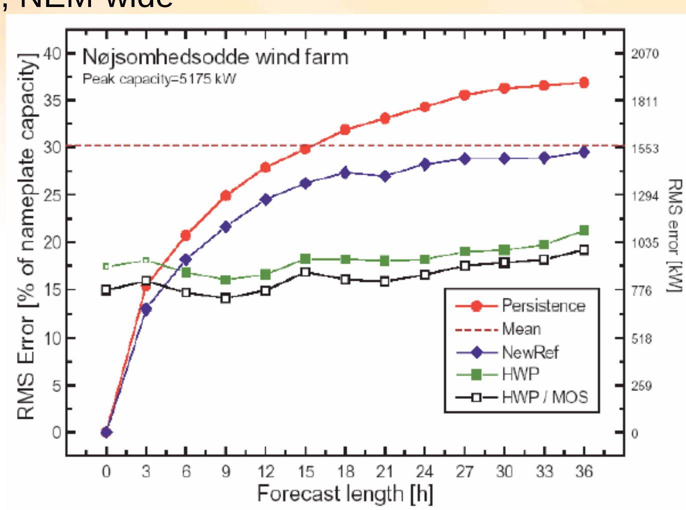


Figure 9 Root Mean Square (RMS) error for different forecast lengths and different prediction methods. Upper curves are statistically based systems, lower curves are weather forecast-based systems, from Giebel et al. (2003).

Economic integration of significant renewables

- All generation and loads have particular economic characteristics for integration
  - eg. large inflexible thermal plant imposes significant integration costs, as well as 'intermittent' renewables
- Objective is to maximise the value of renewables
  - Energy value: temporal, locational & contingency dependencies wrt rest of generation, network + loads
  - Environmental values: climate change, air, water, land-use
  - Other possible values… eg. industry development etc.
- Coordinated operation a key to maximising value
  - Challenges for scheduling of intermittent renewables, cogeneration + small scale systems
- Australian NEM arrangements
  - MRET provides separate environmental value to energy value
  - Current rule changes to incorporate large-scale intermittent renewables into security regime

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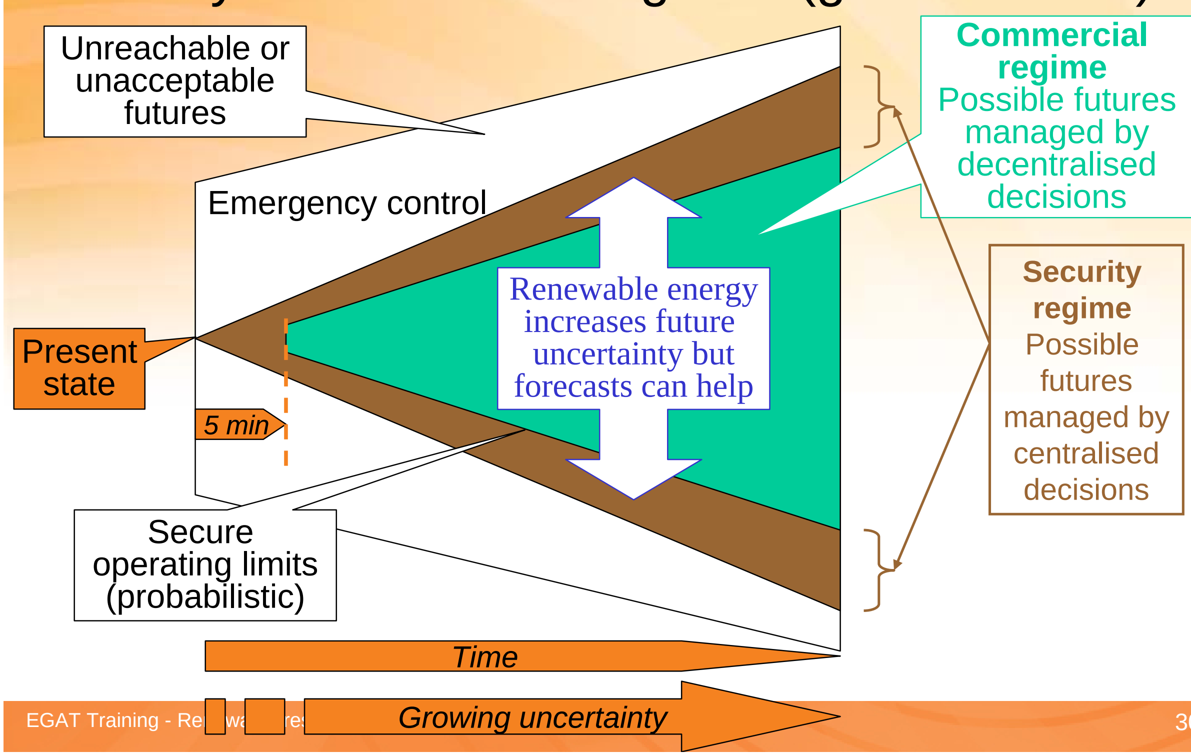
Security & commercial regimes (global & local)

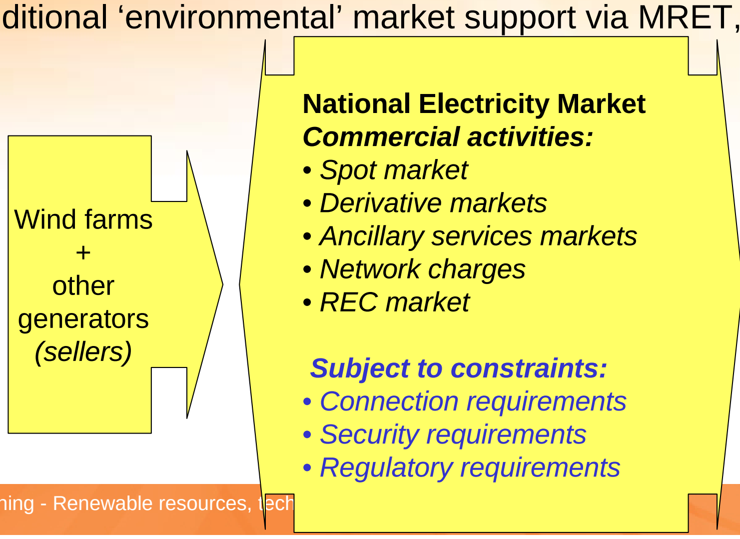


Commercial context for wind energy integration

- Electricity markets are ‘designer’ markets
- Key design challenges
  - Embracing + hence better managing inherent uncertainties within EI
    - allocate risk to those responsible + best placed to manage, however *EI infused with risks that are difficult to commercialise (allocate to players)*
  - Establish level playing field that doesn’t favour incumbent technologies + participants against ‘new entrants’ –*key part of competition*
  - Commercialise externalities as best possible
  - Appropriate centralised decision making where required
    - Short-term security, longer-term policy
- High renewable penetrations
  - *Now testing centralised power system control arrangements + adequacy of electricity industry restructuring*

Commercial context for wind integration in NEM

- Wind currently classified in NEL as Intermittent generation
  - “A generating unit whose output is not readily predictable, including, without limitation, solar generators, wave turbine generators, wind turbine generators and hydro generators without any material storage capability”
- Currently classified as non-scheduled, can be market or non-market
- Additional ‘environmental’ market support via MRET, *soon VRET, NRET?*



Wind in the NEM spot market

- Wind currently non-scheduled
  - Generate whenever wind is blowing (possibly s.t. to N/W constraints under NSP connection agreements)
  - Wind farms operate as "price takers" although high penetrations will impact spot market prices – *difficult to estimate*
  - Wind energy value in spot market depends on how regularly wind farms are producing when spot prices are high - *can be reasonably good correlation*
- Load will remain major source of variability + unpredictability until considerably higher wind penetrations (SA an exception)
  - NEMMCO has interim + progressing major wind forecasting sys
  - Other changes in progress….

Semi-Scheduled generation

- Scheduled
  - Submission of dispatch offers
  - Compliance with targets
  - Causer-pay for ancillary services
  - Ability to offer ancillary services
  - Publication of individual outputs:- forecast, offered & actual
  - Comply with technical standards

- Semi-Scheduled
  - Submission of dispatch offers
  - Causer-pay for ancillary services
  - Ability to offer ancillary services
  - Are treated as positive supply
- If involved in a constraint
  - Compliance with targets if less than forecast
- Publication of data
  - Not finalised yet

- Non-scheduled
  - Are treated as negative demand
  - Can only be curtailed (by NEMMCO) if system security is at risk

  NEW
  - Publication of grouped outputs forecast and real
  - New Technical Standards

Wind in derivative markets

- Wind farms may wish to participate in derivative markets:
  - Variable + somewhat unpredictable energy will normally have lower value that energy from other generators
  - Important to have good forecasts of average production plus seasonal & diurnal patterns
  - ‘Smoothing/firming’ contracts between wind + other generators are possible
- All market participants will be interested in predicting future wind power at local, regional + system-wide scale:
  - Important to develop high quality forecasting techniques available to all market participants

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Thank you… and questions?

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