Renewable Energy: Policy options & integration issues

Hugh Outhred
SP Powergrid, Singapore, 4/12/06

Outline

- Sustainability context
- Renewable energy generation: status & costs
- Renewable energy policy options
- Integration into competitive electricity industries
- Renewable energy case studies - wind & PV
- Key issues with high levels of renewable energy penetration
Sustainability context for the electricity industry (IPCC COP7)

Must also achieve resource adequacy:
Short & long-term system security (availability & quality of supply)

Climate change emissions
(Tonnes C per capita, Grubb 2006)

per-capita emissions vs population, 2000
Renewable energy barriers, challenges & opportunities, IEA, 2006

Figure 3. Development in oil prices since 1988 (www.oilenergy.com, 2006-02-13)

Renewable energy & coal comparison for Europe (IEA, 2006)

Aust. non-hydro RE market shares (%)

Coal-fired power station approx 35€/MWh
Low-emission generation cost trends for Australia (MMA, 2006)

Renewable Energy: Policy Options & Integration Issues

Status of RE technologies: hardware perspective (IEA, 2006)
The most effective policy options depend on the context (Grubb, 2006)

<table>
<thead>
<tr>
<th></th>
<th>Voluntary, regulatory and systemic instruments</th>
<th>Economic instruments</th>
<th>Innovation instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviour</td>
<td>![Symbol]</td>
<td>![Symbol]</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Substitution</td>
<td>![Symbol]</td>
<td>![Symbol]</td>
<td>![Symbol]</td>
</tr>
<tr>
<td>Technical innovation</td>
<td>![Symbol]</td>
<td>![Symbol]</td>
<td>![Symbol]</td>
</tr>
</tbody>
</table>

Successful innovation requires both technology push & market pull (Grubb, 2006)
Renewable energy support policy taxonomy
(Rivier, 2006; Enzesberger et al, 2002)

Policy instruments

Legislative measures
- Direct control
  - Supply push
  - Construction incentives
- Economic based
  - Demand-pull
  - Production incentives

Non-legislative measures
- Player-initiated (voluntary)
- Information
  - Green pricing (many countries)
  - Tradeable certificates (Australia, UK)
  - Feed-in tariffs (Germany)
  - Tender schemes (initial UK scheme)

Energy service delivery in the stationary energy sector

The electricity supply industry
- Generation
- Transmission
- Distribution

The natural gas supply industry
- Treatment
- Transmission
- Distribution

Equipment providers

Energy service companies focus on end-use options, e.g: efficiency, CHP, solar

Primary energy forms e.g: coal, gas, nuclear, renewable

Energy losses & external impacts

Hugh Outhred: Renewable Energy Policy & Integration Issues
Trading in electricity: an abstraction from reality

- Main commercial markets (humans; individual; abstract)
- Economic models (humans; collective; abstract)
- Engineering models (equipment; collective; abstract)
- Physical electricity industry (equipment; collective; concrete)

Decision making framework for the electricity industry

- Governance decision-makers
- Regulators
- System & market operator(s)
- Regulated industry participants
- Competitive industry participants

Underlying societal decision-making
Fig. 12 Decision-making interactions (Thorncraft, 2006)

- **Industry development**
  - laws & policy
  - rules, standards, operating procedures

- **Government (industry oversight)**
  - laws & policy
  - information

- **Industry monitoring & regulation**

- **Forward projections**
  - electricity spot market
  - price & dispatch
  - disturbances

- **Control actions**
  - physical system
  - centralised decision-making
  - physical disturbances

- **Assets**
  - operators
  - trades
  - derivative markets

- **Wholesale purchasers**
  - state information

- **Decentralised decision-making**

- **Energy conversion chain uncertainties & risks**
  - End-users could play a greater role in managing future uncertainty
  - Availability of fossil & fission fuels
  - Variable renewable energy fluxes
  - Climate change impacts
  - Generator decisions
  - Generator forced outages
  - Power system security
  - DNSP decisions
  - Distribution network outages
  - Power system security
  - TNSP decisions
  - Transmission forced outages
  - Power system security
  - End-use sector
  - (including distributed resources)
  - End-use services

- **Kinetic energy**
A restructured electricity industry must understand & efficiently manage, by centralised & decentralised decision-making, the location-dependent risks to the flow of end-use energy services.

• Wholesale & retail designs should be compatible, with spot & derivative markets that model flow constraints.

**Contributors to unavailability of electricity supply for small end-users (USA data, AEMC, 2006)**

<table>
<thead>
<tr>
<th>Contributor</th>
<th>Average unavailability per customer year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(minutes)</td>
</tr>
<tr>
<td>Generation/transmission</td>
<td>0.5</td>
</tr>
<tr>
<td>132 kV</td>
<td>2.3</td>
</tr>
<tr>
<td>66kV and 33kV</td>
<td>8.0</td>
</tr>
<tr>
<td>11kV and 6.6kV</td>
<td>58.8</td>
</tr>
<tr>
<td>Low voltage</td>
<td>11.5</td>
</tr>
<tr>
<td>Arranged shutdowns</td>
<td>15.7</td>
</tr>
<tr>
<td>Total</td>
<td>96.8 minutes</td>
</tr>
</tbody>
</table>
Renewable Energy: Policy Options & Integration Issues

Future state space managed by decentralised decisions

Security & commercial regimes (global & local)

- Unreachable or unacceptable futures
- Present state
- Secure operating limits (probabilistic)
- Emergency control

Renewable energy increases future uncertainty but forecasts can help

Commercial regime: Possible futures managed by decentralised decisions

Security regime: Possible futures managed by centralised decisions

5 min

Secure operating limits (probabilistic)

Emergency control

Growing uncertainty

Fig 5. Shared responsibility for risks to energy service flow (security & commercial regimes)

Security regime:
- SCADA & AMI
- On-line security assessment
- Central control
- Reliability policy

Commercial regime:
- Ancillary services, spot energy & derivatives
- Network access

End-use & distributed resources:
- Energy management systems (security)
- Nodal markets & network access

DNSPs, for radial distribution:
- Distribution system automation (security)
- Network access regime

TNSPs, for meshed transmission:
- Managed by ISO (security)
- Arbitrage in nodal markets

Large generators:
- Operation when directed by ISO (security)
- Nodal markets & network access
Dispatch, Pre-dispatch, PASA, SOO & ANTS to manage supply-demand balance

(source: NEMMCO)

- Medium Term PASA (2 yr, daily peak)
- Short Term PASA (7 days, 30 min res, 2hr update)

0  day 1  day 2  week 1  month 1  year 1  year 2

- ST & MT Projected Assessment of System Adequacy support reserve assessment & participant operating decisions. ST PASA projects region demand & reserve for 7 days @ 30 min resolution, updated every 2 hours. MT PASA projects daily peak demand & reserve for 2 yrs, updated weekly.
- Statement of Opportunities (SOO) & Annual National Transmission Statement (ANTS) are intended to inform generation, demand & network investment decisions (10 year horizon, issued annually).

These procedures all rely heavily on quality of forecasts

Managing supply-demand balance in NEM

- Spot market forecasts & derivative markets
- Energy markets
  - Ancillary services & security
  - Security projections & FCAS derivative markets
- Spots for period t & period t+1
- Frequency control ancillary service markets, period t
  - FCAS markets for period t+1
- Time
  - Increasing uncertainty looking forward
Enhanced industry structure

Generation Sector - large generators

Intentions, offers & payments

Multi-region five-minute energy & FCAS markets

Intentions, bids & payments

DR providers

Services

ESCO's

Commercial Physical

market & system operator

(eg NEMMCO)

End-users

ESCO's: the missing players in the restructured electricity industry

Commercial Physical

Energy flow

Energy flow

Energy flow

End-use sector (including DR)

Energy flow

ESCOs: the missing players in the restructured electricity industry

AMI: the missing interface in the restructured electricity industry

Australian wind resource

(Estimate of background wind (m/s) – Australian Greenhouse Office)

Approx. 4500 km
Wind farm response to varying wind conditions

Simulated dispatch with 500MW wind in SA
(Oakeshott, 2005)
NEMMCO Forecasting Timeframes

Now

Dispatch

5 Min Pre-dispatch

Pre-dispatch

STPASA

MTPASA

0 5 1 40 hrs 8 days 2 Years

Mins Hr

S1: Infra-red satellite map (BoM Aust, 1125 UTC 24/4/05)

Low-pressure cell over southern Australia (BoM, 2006)

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

Australian PV Concentrator Technology

- Each dish has 112 curved mirrors which focus sunlight onto a central receiver, 500x concentration, 25kW
- Dishes are cooled & independently track the sun
- Suited to end of grid applications & CHP
- Installed in 6 diesel grids
- Another 30 dishes (750kW) for 3 NT Power and Water Authority diesel grids
- 150MW now funded for rural Victoria

Solar Systems Pty Ltd: 220 kW PV Concentrator power plant at the Pitjantjara lands
Aust. Govt. Solar Cities program

- $75M over 5 years from 2006 to demonstrate high penetration uptake of solar technologies, energy efficiency, smart metering
- Aimed at improving the market for distributed generation and demand side energy solutions
- Tenders called 2005 – must include matching funds, PV, efficiency, monitoring, advanced tariffs, marketing and financing strategies
- Eleven consortia short-listed from 23 applications
- Funds so far awarded to Adelaide & Townsville

PV Case Study for NSW Dept of Planning: Newington Solar Village (PV+SWH)
Newington Solar Village

- 780 houses with 1kW PV; 199 houses with 0.5kW PV.
- Passive solar design, energy efficient appliances
  - Loads av 16 kWh/day cf 7.5 design
  - Load profile ‘peakier’ than for normal houses
- 30 houses monitored July 04-June 05
  - Ave daily PV output per house 3.2 kWh (~20% of load)
  - 2 systems faulty, when removed, 3.4 kWh/house ave, about 10% lower than expected (although 2005 may not be a typical year)
  - Average peak output for 30 houses, 13 kW

Relationship between electricity use and temperature, Newington
PV output variability (30 houses)

Average and percentile profile of total PV Output from 30 sites
July 2004 to June 2005

Household Load and PV Output
average over 30 houses

Average daily load and PV output per house

Hugh Outhred: Renewable Energy Policy & Integration Issues
PV Output, Homebush Bay Substation Load and Temperature - Peak Load Summer Day

1st Feb. 2005 for Homebush Bay, 10x Olympic PV output

Key technical issues for high-penetration renewable energy

- Design & demonstration of distributed resource systems (generation, storage, end-use response)
- Advanced metering, communication & control for distributed resources
- Improved power electronic devices
- Compact, high-capacity & cost-effective reversible energy storage
- Mathematical modelling & forecasting for renewable energy generation & distributed resources
Key regulatory & policy issues for high-penetration renewable energy

- **Institutional issues:**
  - Robust security regime with security-constrained dispatch
  - Efficient commercial regime (operation & investment)
  - Effective regulatory framework (network services)
  - Compatible arrangements for gas industry

- **Policy issues:**
  - Appropriate innovation in renewable energy technologies
  - Correct location & timing for investment in renewables
  - Forecasting for security & commercial regimes
  - Active end-user participation (value, timing, efficiency)
  - Skill development in all relevant areas

Key commercial issues for high RE

- **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

- **Efficient network access regimes:**
  - Availability & quality; active end-user participation

- **Renewable energy forecasting tools for:**
  - Renewable energy generators
  - Other generators and end-users
  - System operators & policy-makers

- **Efficient financial mechanisms to counter un-costed fossil fuel externalities**
Many of our publications are available at:
www.ceem.unsw.edu.au