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
**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

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**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 (artefacts)
- **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 (5 minutes 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

The physical potential of renewable energies (physical upper bound)

"Founding an International Renewable Energy Agency", IRENA, 2009

Note: solar & wind energy are non-storable energy fluxes

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

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
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
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Geothermal energy - grid connection

(Geodynamics, 2006)

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

(AEMO, AWEFS overview, Jan 10)
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)

electricity industry state

unacceptable states

unsatisfactory (insecure) states

satisfactory (secure) states

trajectory managed by commercial regime

Trajectory managed by security regime

Wind energy may increase future uncertainty but forecasts can help

The Renewable Energy Integration Challenge & International Experience
NEM security regime forward projections
(now incorporating wind forecasts at all timescales)

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 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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