ATSE

ELECTRICITY GENERATION: ACCELERATING TECHNOLOGICAL CHANGE

INTERNATIONAL WORKSHOP

A REPORT BY THE AUSTRALIAN ACADEMY OF TECHNOLOGICAL SCIENCES AND ENGINEERING (ATSE) 2009

ELECTRICITY GENERATION: ACCELERATING TECHNOLOGICAL CHANGE

International Workshop
Melbourne, 31 March – 2 April 2009

The key findings from a three-day International Workshop in Melbourne convened by The Australian Academy for Technological Sciences and Engineering (ATSE) are:

1 Australia's energy security requires a major increase in baseload electric power generation capacity to meet the expected growth in demand – which growth will emerge independent of climate change and despite a much greater current focus on energy efficiency and conservation measures

2 Carbon pricing uncertainty makes new coal generating capacity problematic. The technology for both carbon capture and storage (CCS) and geothermal is not ready, water for hydro expansion is not available and current government policy prohibits consideration of nuclear power. Intermittent renewable energy sources provide no short-term solution to baseload power security because of their intrinsic variability but, in the longer term, storage solutions may help overcome some of the variability of intermittent renewables.

3 There is a high level of urgency to accelerate the introduction of new technologies, given the need to meet the greenhouse gas (GHG) targets and timelines established by government.

ELECTRICITY GENERATION: ACCELERATING TECHNOLOGICAL CHANGE – International Workshop

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Cover: Tarong Power station at dusk

Photo: Tarong Energy

Communiqué

The Australian Academy for Technological Sciences and Engineering (ATSE) organised a three-day International Workshop in Melbourne from 31 March to 2April 2009 that focused on the major challenges in accelerating technological change in electricity generation. ATSE invited to the Workshop representatives from four engineering academies – Japan, Germany, South Africa and the United Kingdom. Representatives from these Academies joined an invited group of Australian delegates who are experts in their fields to contribute to the Workshop and to develop the Workshop Communiqué that follows below.

ENERGY SECURITY

Energy security is a real issue for Australia

Energy security for Australia requires a major increase in baseload electric power generation capacity to meet the expected growth in demand. This growth is independent of climate change and will still occur even with a much greater focus made on energy efficiency and conservation measures. Rationing and blackouts are inevitable in future once economic growth picks up. Governments must establish the necessary long-term, stable policy settings now to ensure large-scale investments are made in new generating capacity.

The provision of baseload power is limited

The provision of baseload power is limited to a portfolio of a few technologies, all of which have particular challenges. CCS and geothermal technologies are still far from commercially proven. Remaining hydro resources are inadequate and current government policy prohibits nuclear. Intermittent renewables cannot yet provide economic baseload power due to their intrinsically poor capacity factors. Energy storage may in the longer term help overcome this problem, but costs are still very high.

ACCELERATING ENERGY TECHNOLOGY DEPLOYMENT

Urgency of intervention

Low-emission technologies need to be introduced urgently, given the need to meet government-established GHG targets and timelines. Moving new technologies from demonstration to full-scale commercial deployment can take 10 years or more.

Technology risk

Considerable technological and financial risks attach to power-generating technologies currently under development. Currently they remain uneconomic compared with proven baseload coal generation.

Carbon price

The expected CPRS carbon price is insufficient to encourage adequate investment of the magnitude required to demonstrate the commercial viability of new technologies in time. Novel solutions are needed to reduce capital investment and risk.

Public support

While significant RD&D funds have already been committed by governments these are insufficient for the challenges ahead. Low-emission technologies investments will generate public good (reducing CO_2 and other pollutants) as well as private returns. This justifies additional public RD&D support to the point at which promising technologies attract commercial finance.

■ Long-term policy stability

It is imperative that large-scale investments have long-term certainty in planning, regulation, and financial conditions. This demands clarity in the relative roles of governments, markets and regulators.

■ A strategic focus on technologies

New technologies need large-scale demonstration and back up R&D. Given their strategic importance, Australia must increasingly take leadership roles in major demonstrations of the following technologies: carbon capture and storage (CCS), geothermal power, solar thermal power, photovoltaics and brown coal drying. With other technologies Australia must engage internationally in large scale demonstrations.

OTHER ISSUES

Other issues requiring urgent attention include:

■ Grid expansion and stability

Electricity grid planning must provide for the long-term demands imposed by the diversity of power technologies, centralised baseload as well as distributed intermittent renewables, remote locations and the need for whole of system stability under variable supply and demand. Long-term national interest must play a key part in grid development planning.

■ Need for a fundamental analysis of options

There is a need for a bottom-up approach to analyse credible scenarios of the technology portfolio needed to deliver the required generation capacity by 2050 while meeting agreed emission reduction targets. This analysis must consider energy efficiency and conservation, generating-technology risk and financial risk, energy security, resource availability, price of electricity supplied and government and industry support. ATSE is prepared to undertake this project with appropriate support.

■ Support skills

Serious doubt exists as to Australia's skills adequacy to support massive scale introduction of new generating technologies. Education and training policies must ensure skills shortages do not impede essential investment acceleration.

■ Community awareness and support

The introduction of new technologies requires that there be community awareness and support. This should not be a matter solely for government. Many organisations have a role to play in this matter, including the Academy, in providing independent sources of factual information.

■ Nuclear energy

International Workshop contributors indicated that nuclear energy needs to be a part of the future baseload portfolio in their countries if deep cuts in greenhouse gas emissions are to be met. Concern was expressed that, by continuing to exclude consideration of domestic nuclear power, Australia is placing considerable baseload reliance on the technological and financial viability of as yet unproven CCS and geothermal energy technologies. It would be prudent to undertake further work on the reduction of technological, regulatory and other risks, including an understanding of the formation of community attitudes to nuclear power generation.

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- the International Workshop was funded by the Department of Innovation, Industry, Science and Research (DIISR) International Science Linkages – Science Academies Programme, established under the Australian Government's Innovation Statement, Backing Australia's Ability;
- contributions from the representatives from four engineering academies; namely: Engineering Academy of Japan (EAJ), German Academy of Science and Engineering (acatech), South African Academy of Engineering (SAAE) and The Royal Academy of Engineering (RAEng);
- the authors of papers and PowerPoint presentations at the Workshop;
- those ATSE Fellows who were the Workshop Moderator, Session Breakout Chairs, Reporters and Rapporteurs;
- the ATSE Workshop Organising Committee comprising: Mr Martin Thomas AM FTSE, Dr Vaughan Beck FTSE, Dr John Burgess FTSE, Mr Peter Laver AM FTSE and Dr John Sligar FTSE;
- arrangement of the Workshop by Elizabeth Meier and Meg Caffin from the ATSE International Office; and
- production of this publication was overseen by Mr Bill Mackey, Deputy CEO and Communications Director, ATSE.

Australian Government

Department of Innovation
Industry, Science and Research

Contents

1 Introduction

Energy technologies are faced with the twin challenges of security and climate change. The need to reduce emissions and to enhance energy security is accepted internationally, as is recognition of the need to accelerate the introduction of new and enhanced electricity generating and consuming technologies. Security means the assurance of reliable energy for all purposes – industrial, commercial, domestic and for transport. Regardless of individual views on the causes of climate change, governments are imposing increasingly stringent limits on emissions. It is essential that plans are implemented to ensure that these targets are achieved. Our society's challenge is to identify those policy and other mechanisms through which the commercial deployment of new technologies of choice can be accelerated to attract investor confidence, both private and public, against this background. While technology can deliver these needs, market forces alone will not be enough for its sufficiently rapid development and deployment.

Against this background, the Australian Academy for Technological Sciences and Engineering (ATSE) organised a three-day International Workshop in Melbourne from 31 March to 2 April 2009 to focus on the major challenges in accelerating technological change in electricity generation. ATSE invited contributing representatives from four engineering academies:

- Engineering Academy of Japan (EAJ);
- German Academy of Science and Engineering (acatech);
- South African Academy of Engineering (SAAE); and
- The Royal Academy of Engineering (RAEng).

Representatives from these Academies joined an invited group of Australian delegates, experts in their fields, to contribute to the Workshop and the outcomes Communiqué.

The Workshop followed an ATSE proposal to the International Council of Academies of Engineering and Technological Sciences (CAETS) in Tokyo 2007 on the need to examine how to accelerate technological change for electricity generation in response to the challenges of climate change and energy security, and how international collaboration may more effectively initiate such acceleration.

Following the CAETS meeting in Tokyo, ATSE initiated a project to investigate the issue of acceleration of technological change in response to climate change. ATSE's report[1] noted that industry and government must invest some $6 billion by 2020 in RD&D on new power generation technologies, while around $250 billion must be invested by 2050 in new and upgraded capacity if declared targets are to be met.

It was acknowledged that governments are making significant commitments to modify the electricity generation resource mix dramatically. Ambitious pollution reduction targets have been set which are clearly very challenging although, with appropriate drivers, the Academies believe that deployment of the appropriate technologies can meet these targets. Nevertheless market forces alone will not be enough; policy instruments in which investors can be confident will be essential.

The Workshop focused upon workable realistic strategies to accelerate technology deployment against the background of known technology and investment risks. Energy technologies are capital intensive and a plethora of risks attach to new entrants.

1 *Energy Technology for Climate Change: accelerating the technological response*, ATSE, December 2008

The International Workshop was organised broadly as follows:

1. Country overview reports were circulated to delegates in advance of the Workshop. These Country Overview reports contained a description of the current energy supply mix and some of the issues and challenges ahead.

2. Day One of the Workshop had a focus on Energy Technology Demonstration and Deployment Issues. Following power point presentations from several speakers, the Workshop broke into two parallel breakout sessions:
   a. Nuclear and Fossil Fuels
   b. Natural and Secure Renewables.

Reports on the Breakout sessions are contained in this report.

A plenary reporting session was held following the breakout sessions (see the Rapporteur report).

3. Day Two of the Workshop had a focus on Investment Risks for Deployment Issues. Following power point presentations from several speakers, the workshop broke into two parallel breakout sessions:
   c. Deployment Investment Risk Reduction
   d. Strategies for Major Demonstrations.

Reports on the Breakout sessions are contained in this report.

A plenary reporting session was held following the breakout sessions (see the Rapporteur report).

4. Day Three of the Workshop comprised:
   a. Presentation on a draft discussion paper 'Maximising Value of Technology in the Energy Sector' as part of the Australian Government White Paper on Energy.
   b. Development of the Workshop Communiqué (based on the Rapporteurs' reports and the supporting Breakout Group reports.

PowerPoint presentations delivered at the Workshop do not form part of this report.

2 Rapporteur and Breakout Group Reports

2.1 TECHNOLOGY DEMONSTRATION AND DEPLOYMENT ISSUES

2.1.1 Rapporteur Report

Mike Sargent AM FTSE

- Energy is the key competitive input to the nation's economy, future supply, regulatory and taxation structures need to be positioned in an international context with economies similar in structure to Australia's and with our major trading partners.
- Technology to meet our target aspirations is available now, but technology which may be relevant to achieving Australia's goals have maturity ranges from some at immediately deployable level, some at development stage, to some still at the research stage.

- The cycle of technology adoption from idea (research) to widespread adoption is several decades
  - Australia therefore needs policies which facilitate acceleration of its potential for deployment of these technologies.

- It is essential to recognise that
  - the cycle to achieve this follows the pattern research → development → demonstration → deployment; and
  - deployment may be at a project or a product level.

- Each of these phases represents a retirement of risks for potential investors.

- In a regulated privatised energy industry, the predisposition of financiers or energy companies is to invest at the deployment phase in which the risk is mainly market risk (that is technology and cost risks have been mainly retired).

- The real need is therefore to enhance the need to accelerate the development/demonstration phase.

- The national policy position should, at this stage, encourage this investment in accelerating development and deployment of technology, rather than subsidise investment in mature technologies. This will include:
  - clear and stable investment (including explicit or implicit subsidy) environment;
  - clear and stable industry policy;
  - clear and stable regulatory environment;
  - providing equitable international competitiveness environment; and
  - providing clear and equitable inter-sector competitiveness.

- Thus the required Government intervention is at the development and demonstration stages; this intervention needs to provide for a stable environment for decision making by participants, with an assurance of continuity of Government policy over the activity duration.

- This Government intervention needs to be founded on an energy strategy that encompasses short term, medium term and long term considerations
  - This strategy needs to be based on rigorous engineering analysis of the maturity, costs and risks of options rather than simply on economic modelling which does not identify the risks of different options.
  - This strategy needs to encompass:
    - an energy supply technology mix which balances technology which is capable of providing an assured supply of energy throughout the day, with those technologies which provide energy at a lower marginal cost; and
    - an energy use mix which provides both an improved efficiency of usage and a capacity to move usage to lower emission technologies but with a lower capacity to provide an assured supply of energy.

- The electricity grid provides a medium to not only integrate new technologies into the energy supply structure, but also to provide mutual support to those technologies capable of providing assured supply and those technologies providing lower marginal costs but with higher risk of not being able to provide an assured sup[ply of energy: however there need to be development of new concepts of provision of connection to energy source, and of the management and operation of the grid, including intelligent grid concepts.

- The societal issues, including acceptance of new technologies , needs to be addressed through the development and demonstration phases.

- Attention needs to be given to the development of the skills necessary to implement the new technologies, as well as to capture future benefits from the knowledge of how to implement these technologies.

- The need for, and benefits of, international collaboration in these new technologies must be an active element of Australia's international relationship development.

- Australian policies must clearly distinguish between the policy positioning and the technologies which are relevant to companies which may need to retrofit technology compared with those who are implementing technology in a green-field situation.

- ATSE should:
  - seek to promote its position as providing reliable, independent and comprehensive information in respect of energy policy;
  - promote the need to establish for Australia the need for both a short term and a long term policy position in respect of energy strategy;
  - propose a cohesive structure of the Government's programs to give effect to this policy;
  - propose a regulatory environment which would support this policy position; and
  - encourage bipartisan support for this.

2.1.2 Breakout Group Reports

Breakout Group 1: Nuclear and Fossil Fuels

Key Points

CARBON CAPTURE AND STORAGE

- Capture.
- Transport.
- Sequestration.
- Society acceptance overlays them all.
- Challenges and risk in each.

- Capture:
  - technology;
  - scale up; and
  - costs.
- Transport:
  - access;
  - range of models;
  - pipeline; and
  - demonstration scale.
- Sequestration:
  - location specific;
  - science/geology; and
  - underground, biological mineral transformation.

- Academy's role: demonstration, education function, convey technology risks and upscale, time frames, understand realistic costs of demonstration and implementation.

NUCLEAR

- Nuclear: baseload power option.
- Promote reliable nuclear information within community.
- Academy to promote open debate in community on waste processing and product stewardship.
- An Australian engineering education program and students to undertake exchange to nuclear facilities overseas.
- Regulations and laws in place to pave the way forward for nuclear inclusion.

Chair: David Brockway FTSE

Recorder: Ron Hardwick FTSE

Breakout Group 2: Natural & Secure Renewables

Key Points

RENEWABLE ENERGY TARGETS – 20 PER CENT BY 2020

Renewable energy targets – 20 per cent by 2020 can be met technically – however all sorts of non-technical issues make it a challenge – for example: access of capital, human resources (including training).

MATRIX/MAP OF RENEWBLE TECHNOLOGIES

Advantages and disadvantages.

NETWORK ISSUES

Smart networks, storage, appropriate policy

- Microgrids.
- Remove barriers to connect ion.
- National planning for zones and hubs.
- Modelling.
- Australian federation (example for Europe).

CONTINUTY OF FUNDING FOR THE FULL CYCLE TO EARLY DEPLOYMENT

- Policy stability.
- Bipartisan support.
- Governments needs to be involved in early stage research and deployment.
- Where it starts to fund a technology it needs to fund it properly.
- World-scale research versus world-class.

STORAGE

- Grid is storage mechanism for all renewables.
- Car batteries can be a storage mechanism.

BREAKTHROUGH TECHNOLOGIES – WE HAVE TO ALLOW FOR THEM

INTEGRATION OF ENERGY POLICY WITH INDUSTRY POLICY

- Equipment and services issues.

Chair: Mary O'Kane FTSE

Recorder: Vaughan Beck FTSE

2.2 INVESTMENTS RISKS FOR DEPLOYMENT

2.2.1 Rapporteur Report

Tim Besley AC FTSE

- Governments need to provide policy clarity on energy matters with a significant degree of bipartisanship as an objective. It was noted if nuclear is in the mix the development of a nuclear generating facility will span five to six electoral cycles.
- The key test for the regulatory regime must be that it is in the national interest.
- In a multi-sourced energy system there will inevitably be a large number of low-voltage intermittent renewable units and complex electronics will be needed for system stability.
- Frequency control to compensate for numerous intermittent renewables would require operating some (baseload) plant at less than optimal efficiency and some financial incentive to undertake this role should be provided.
- Consideration should be given to duplicating the Bass Strait link with the objective of making Tasmanian Hydro primarily a pumped storage resource.
- The possibility of making use of the significant hydro electric resources in Indonesia should be considered.
- The example of the South African long-term energy strategy, which was built from the bottom up, was seen as a useful model.
- Care needs to be taken to minimise the risk of politics and regulation driving engineering principles off the table.
- Carbon mitigation should be based on engineering and science, not economic modelling.
- The United Kingdom's system of renewable obligation certificates (ROCs) should be further investigated. ROCs are issued to generators who sell them to suppliers who have an obligation to source a defined percentage of energy from renewables . This must be covered by holding a sufficient number of ROC's to cover the amount supplied. Generally 1 ROC equals 1 MWh.
- It was noted the UK has a system of grants for renewables – up to 40 per cent of capital for offshore a wind energy and 25 per cent for marine energy.
- The UK also imposes a tax on energy use by business – at present £4.30 per MWh.
- A House of Lords Report, which concluded that wind generation doesn't add to energy security, was cited.
- Large demonstration projects are needed relating to:
  - coal – carbon capture and storage including algae sequestration and large scale dewatering or lignite;
  - solar – solar thermal and solar cells including research on energy storage; and
  - geothermal – including long distance transmission.

- The pathway to such projects should be made clear and it needs to be accepted that government support will be needed.
- Large scale demonstration projects should be one step off fully commercial projects which in light of the demonstration projects outcomes could go ahead without further government support.
- Debt and equity markets are tight and governments need to make Australia an attractive investment destination. A comparison was made with Thailand which is currently much more favourable.
- Outreach programs are needed to educate the public on carbon capture and storage and the nuclear cycle including storage of waste taking advantage of Australia's favourable geology and utilising Australia's Synroc technology.

2.2.2 Breakout Group Reports

Breakout Group 3: Deployment Investment Risk Reduction

Key Points

- The predominant issue is government policy risk – either government policy must remain static over long periods or, if it changes, then companies affected must be compensated.
- Each technology follows a development cycle through a number of stages – there are influences, risk, costs and benefits for each stage and we can define these for each technology – we can feed back to Government the consequences of not doing certain things at each stage (both Government policy and actions).
- The Australian community needs to decide what it wants – an environment where others will invest or one where tax monies are used for investment.
- A suggestion for ATSE is to provide a set of Principles on the issues that were raised – much like the National Electricity Market Objective.
- ATSE should provide information that we have but that others don't have – and keep emphasising the facts in a non political manner.
- However, we may not be heard as a result of this passive role.
- ATSE could take more of a stand and be a passionate advocate around the risks that have been identified and the consequences of not addressing those risks.

Chair: Else Shepherd AM FTSE
Recorder: John Burgess FTSE

Breakout Group 4: Strategies for Major Demonstrations
Key Points

WHAT CRITERIA DEFINE A 'MAJOR DEMONSTRATION' PROJECT?

Scale : approx one-fifth of commercial
Should lead to commercial-ready technology without further subsidy.

WHAT ARE THE AUSTRALIAN PRIORITIES FOR SUCH PROJECTS?

- Baseload projects.
- Must do – International flagship projects:
  - CCS – 2 or 3 sites;
  - solar – thermal/PV with storage;
  - geothermal – several sites; and
  - brown coal drying.
- Like to do:
  - energy storage;
  - carbon conversion – algae;
  - demand side technologies; and
  - intelligent grid.
- Must not do:
  - major equipment manufacture.

SHOULD ALL THE PROJECTS BE EXECUTED IN AUSTRALIA?

- No – black coal CC overseas.
- Solar devices.
- Smart transmission.

WHAT INITIATIVES/INCENTIVES ARE REQUIRED TO ACCELERATE IMPLEMENTATION?

- Shared investment.
- Clear regulatory environment.
- Customers involved to protect coal exports.

WHAT BENEFITS/BARRIERS ARE THERE FOR INTERNATIONAL INVESTORS?

- Need certainty for investment e:g. offtake certainty.
- Need assured access to commercial project/ IP knowledge.
- Need subsidy to mitigate technological risk and cost.

WHAT SHOULD BE THE TARGET OUTCOMES AND TIMELINES?

- Provides a pathway to a full commercial plant.
- Technologists are trained to support commercialisation projects.
- Create/protect employment in energy production/user sectors.
- Timeline to 2020 align with the EU program.
- Deliver long term energy security.
- Deliver clean sustainably energy solutions.

Chair: Frank Larkins AM FAA FTSE

Recorder: Ken Dredge FTSE

3 Country Overviews: Electricity Generation

3.1 AUSTRALIA: STATIONARY ENERGY TECHNOLOGY FOR CLIMATE CHANGE MITIGATION – THE AUSTRALIAN CONTEXT

Dr John Burgess FTSE

SUMMARY

The Academy of Technological Sciences and Engineering (ATSE) undertook a preliminary study in 2008 to addresses aspects of the stationary energy technology response required to address climate change. This report is summarised here, along with a summary of Australian Government policy and economic modelling on the topic. The key aspects are:

- Many challenges, both technological and financial, exist in replacing existing coal-fired CO_2 emissions in Australia.
- Several hundred billion dollars of investment in new technologies will be required ($2008) by 2050.
- The Australian Government has proposed significant emission targets by 2020 (−5 per cent actual or −27 per cent per-capita) and 2050 (−60 per cent actual), relative to 2000.
- An Australian "Carbon Pollution Reduction Scheme" has been proposed, commencing in 2010 with a relatively modest price of CO_2 and assistance for exposed industry and individuals.
- The Australian Government has put in place financial support for RD&D in the order $1.15 billion over several years. ATSE believes this should be significantly leveraged by other stakeholders (e.g. to $6B) and targeted at large-scale demonstration projects.
- Australian Government Policy does not support nuclear power as an option for future electricity generating technology.
- Government Treasury modelling assuming a global emissions trading scheme implies significant reductions in some Australian industries (e.g. coal and aluminium) and future major reliance on coal carbon capture and storage and geothermal technologies.

ATSE Report

The ATSE report *Energy Technology for Climate Change: Accelerating the Technology Response*[2] addressed:

- a qualitative description of the technologies and the issues associated with them;
- the probable investment costs required to achieve the cuts in carbon dioxide being suggested politically; and
- the probable research, development and demonstration (RD&D) effort that will be needed to achieve commercialisation of the technologies.

A number of technologies able to replace or ameliorate conventional coal-fired generation technologies were considered in the ATSE report. These included natural gas firing of turbines plus integrated gasification combined cycle steam generation (IGCC); large baseload gas firing; coal firing or gasification with capture and storage of carbon dioxide (CCS); renewable technologies such as solar photovoltaics (PV); solar thermal generation with steam; wind and wave generation; biomass combustion with IGCC; geothermal power generation from subsurface hot rocks; and nuclear energy. Each of these technologies

2 http://www.atse.org.au/index.php?sectionid=1261

was briefly reviewed qualitatively in terms of its current status and technology issues that need to be addressed to ensure its commercialisation. This assessment was undertaken using the combined expert experience of a number of Academy Fellows[3].

The qualitative analysis of the range of technologies showed that each technology has a number of issues associated with its adoption. For example, the renewable technologies are idle in terms of power generation for much of the time, which means that large renewable capacity must be installed in order to replace essentially continuous coal fired generation. This leads to large investment costs, especially for solar energy. Other technologies, such as carbon capture and storage from coal generators (CCS) and geothermal generation, have technical and size issues which have not yet been demonstrated on the commercial scale required. Fuel costs in the future may be significantly influence investment in gas firing capacity. Moreover, many of the technologies have environmental or political issues that remain unresolved. These issues include visual pollution and potential damage to wildlife (wind and wave power) and potential environmental and political factors (nuclear power).

Projected investment costs for each technology were developed in the ATSE study based on external authoritative sources and the opinion of Academy Fellows, including estimated future cost reductions based on "learning curves" as the technologies are commercialised from the International Energy Agency (IEA)[4]. Using this approach, calculation of the investment cost to replace 10 per cent of Australia's total fossil fuel emissions using stationary energy alone was undertaken based on replacement of coal fired generation of electricity. Scenarios for 2020 and 2050 were also examined in terms of fossil fuel CO_2 replacement.

The study showed that for some technologies large investment costs will be required to replace 10 per cent of Australia's total CO_2e emissions using different new stationary energy generating technologies. The investment costs for 10 per cent replacement range from around $30 billion (gas firing), $46 billion (wind power) to $174 billion (solar PV technology) based on projected 2020 investment costs (2008$). The investment costs decrease for some technologies by 2050 due to learning, but the costs generally remain high even then. In the case of most renewables, the high cost is related to the large capacity that must be installed to cover idle time and to thus generate sufficient energy to replace conventional coal firing.

Although not intended to be predictive of what will actually occur in the future, the scenarios for 2020 and 2050 developed in the study have been useful for teasing out some of the underlying challenges. The technology portfolio constraints adopted in the study for the 2020 case and the 2050 cases are, respectively, 20 per cent application of renewable energy and 50 per cent and 70 per cent replacement of fossil fuels relative to 2000.

The scenarios involve the specification of a feasible portfolio of new technologies to replace conventional coal fired generation, noting that no one new technology will be able to replace all the coal fired capacity to satisfy practical constraints. In the calculations for each scenario, a probabilistic approach has been adopted where several of the important parameters have been allocated probability distributions, including the growth rate in electricity consumption and the future investment costs of the technologies.

The results for 2020 showed that a feasible portfolio based on 20 per cent renewables and an assumed 1.4 per cent median growth rate in energy demand (with a range of 0.8 per cent to 2.2 per cent) would have an investment cost of $64 billion (range $55 billion to $74 billion) for the overall increase in

3 The involvement of a number of Academy Fellows in providing data and information for the study is gratefully acknowledged.

4 International Energy Agency, *Energy Technology Perspectives: scenarios and strategies to 2050*, OECD/ IEA, 2008.

electricity demand of 20 per cent by 2020. The portfolio of technologies to replace around 10 per cent of 2007 coal fired capacity (which includes an assumed 20 per cent gas, 6 per cent solar, 4 per cent wind and 4 per cent CCS plus other new technologies) is, however, not capable of reducing CO2e emissions to the level suggested politically, with a predicted increase in stationary energy emissions of +8 per cent (range 0 per cent to +15 per cent). Even so, the scenario is also by no means easy to achieve in the next 11 years. It would require, simultaneously, many challenging commercialisations of new technology. These would include for the portfolio assumed: large increases in new natural gas or coal bed methane power generation (to ~150 per cent of current gas firing capacity); very extensive new application of solar PV and solar thermal generation at high cost (comprising e.g. a 2kW system on 2.5 million house roofs for PV as well as 20 x 250MW appropriately located solar thermal systems); an order of magnitude increase in 2007 wind-power capacity (equivalent to an extra 4000 1MW wind turbines); geothermal generation at over 200MW scale operating commercially; 600 x 1MW wave- power generators, and three large (1GW) CCS-based coal-fired power stations sequestering more than 20Mt/a of CO_2. The study showed that, in all probability, new gas-fired capacity will be the technology of choice to reduce fossil fuel emissions from coal, this being the least expensive investment option with the lowest technology risk but financially dependent on future gas prices.

Clearly, different combinations of technologies could have been employed in the assumed scenario, but the conclusion that this represents a significant technological and investment challenge remains.

A scenario for 2020 has also been calculated in the ATSE study reducing CO_2e from coal firing by 5 per cent from 2000 (as declared by the Australian Government for total Australian emissions – see below). This scenario would require correspondingly larger application of renewables and CCS than the above case (~ 26 per cent) and higher investment cost (~ \$84 billion) by 2020, representing an even greater challenge.

The study showed, as outlined above, that significant investment cost savings and improved CO_2 reduction levels are calculated at the low range of electricity demand growth in the probabilistic model. Thus, effort will need to be focused on energy conservation as an effective measure for emissions reduction in a situation where population growth is occurring. Australian Government modelling has also shown an increasing carbon price associated with an emission trading scheme will reduce demand (see below).

The ATSE results for the first 2050 scenario show that a feasible portfolio with an assumed 1.4 per cent median growth rate in energy demand would have an investment cost of \$242 billion (range \$180 billion to \$305 billion) for the overall increase in electricity demand to 200 per cent of current level by 2050 (with capacity increasing to 300 per cent of current level due to the extensive application of renewables). The assumed portfolio of technologies (which includes 23 per cent gas, 25 per cent solar, 10 per cent wind and 20 per cent CCS plus other new technologies) is calculated to replace about 50 per cent of year 2000 CO_2 emissions, with a 75 per cent reduction in 2007 coal-fired capacity.

Several important key issues have been found to arise from the first 2050 scenario calculation. The first is that, for the median assumed energy supply growth rate of 1.4 per cent, around 20GW of CCS power capacity would be required and around 160Mt/a CO_2 will need to be sequestered. This is a significant development and commercialisation challenge. Under the same scenario, around 60GW of solar capacity would be needed, while about 16GW of wind power capacity would also be required. This wind power capacity requirement is approximately 50 times current levels and involves the installation of around further 16,000 1MW turbines, while the total solar capacity requirement is approximately six times higher than a 2kW PV unit on five million house roofs in Australia. This latter conclusion implies that, if solar energy is to make a substantial contribution to Australia's CO_2 reduction, it will need to be not only distributed but also include large centralised generation facilities at suitable sites which are likely to be remote (for example, around 70 solar thermal facilities with a capacity of 0.5MW for the scenario assumed). It is also likely that gas firing will provide a greater proportion of energy in 2050 than assumed in the scenario, this being the lowest technology risk option. However, gas still has around 50 per cent of the fossil fuel emissions of coal and for deep cuts in emissions may require gas plus CCS technology.

The second part of the assumed scenarios for 2050 involves substitution of nuclear power for the remaining conventional coal fired capacity with other minor adjustments to the technology portfolio. The investment cost in this second 2050 scenario has been found to not change appreciably from the first, the calculated median value being $252 billion (range $185 to $315 billion). However, the replacement of all conventional coal fired capacity with nuclear power has been shown to increase the replacement of coal-fired fossil fuels to 70 per cent relative to 2000, the balance being emitted by gas power generation. To achieve a similar 70 per cent reduction in 2050 using low-carbon and renewable technologies alone (without nuclear energy) would require increased investment if intermittent renewable technologies were employed, or very large application of CCS or geothermal energy generation.

In comparison to the ATSE study, the IEA[5] hasconsidered a scenario in which electricity is projected to grow at 1.9 per cent per annum and new technologies are required to achieve a global reduction of CO_2 emissions by 50 per cent from current levels by 2050 (to 14Gt CO_2 per annum). The IEA shows that under this scenario a global investment level of USD$16.5 trillion is required by the year 2050. Since Australia generates around 1.25 per cent of global electricity, this would imply an investment in Australia in the order of AU$215 billion; or approximately $AUD 5 billion per annum for the next 40 years, a result similar to that calculated in the ATSE study.

Figures 1 and 2 show a summary of the change in CO_2e emissions and the required investment costs for the new generating technologies under the assumed scenarios in Australia taken from the ATSE Report.

Figure 1 Change in CO_2e emissions under the business-as-usual and new technology scenario cases

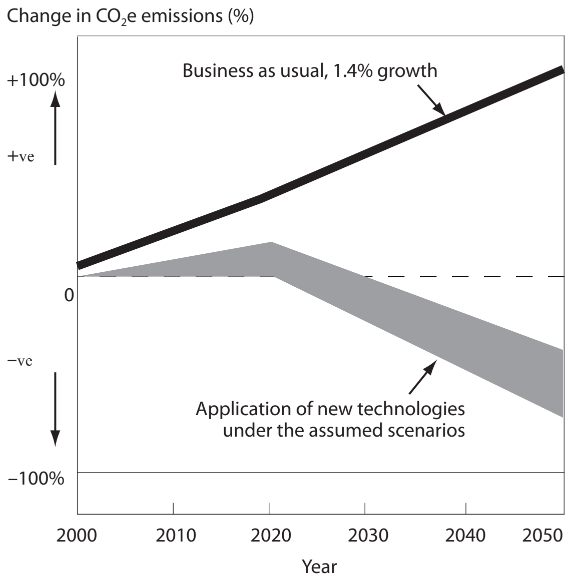
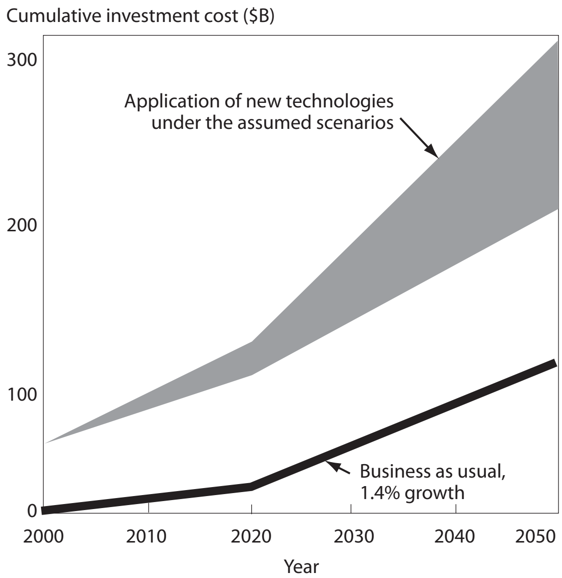


Figure 2 Summary of the results for the investment cost under the business-as-usual and new technology scenario cases



5 International Energy Agency, *Energy Technology Perspectives: scenarios and strategies to 2050*, OECD/ IEA, 2008

Australian Government Policy

An Australian Government White Paper on Energy is due for release in late 2009.

In mid-March 2009, the Australian Government tabled a draft parliamentary Act, following a White Paper on climate change in December 2008[6]. Key Points of the proposed Act are:

- a commitment to reduce CO_2e emission levels by 60 per cent relative to 2000 by 2050;
- a commitment to reduce CO_2e emissions by 5 to 15 per cent relative to 2000 by 2020, depending on international developments;
- an unconditional commitment to reduce CO_2e emissions by five per cent relative to 2000 by 2020. This is equivalent to a 27 per cent cut on a per capita basis, owing to population growth;
- a 'Carbon Pollution Reduction Scheme' commencing in 2010, with a probable starting carbon price of $25/t CO_2e and a capped price of $40/t CO_2e, with permits auctioned. The cap decreases over time with rolling five-year notice to achieve targets;
- once-and-for-all allocation of free permits for five years to the coal electricity generation industries, with safeguards against windfall gains;
- assistance to trade-exposed, emissions intensive industries in the form of proportionally lower priced permits; and
- financial assistance to Australian households of $6 billion ongoing per year focused on low to middle income earners through the taxation system.

Australian Government policy also specifically excludes nuclear energy as a technology option.

The Australian Government has also announced several R&D Funds as follows:

- $150 million Energy Innovation Fund (EIF);
- $500 million Renewable Energy Fund (REF); and
- $500 million National Clean Coal Fund (NCCF).

The Energy Innovation Fund has the following components:

- $100 million for the Australian Solar Institute; and
- $50 million for general clean energy research and development.

The Renewable Energy Fund, matched $2-for-$1 by private industry, is competitive and will be available for projects such as:

- $435 million for renewable energy demonstration;
- A $50 million geothermal drilling program; and
- A $15 million second-generation biofuels R&D program.

The National Clean Coal Fund involves support for leveraged investments of $1.5 billion in co-operation with industry's Coal21 initiative and support from other stakeholders, including state governments. Activities include:

- a pilot scale coal-gasification plant;
- demonstration of carbon capture and storage; and
- mapping and testing carbon-storage potential in Australia.

In addition, there is academic and applied research being undertaken in Australia for low-carbon technologies (e.g. the CO2CRC where applied research is being undertaken on the injection of CO_2 into rock strata in Victoria). Government Departments are also undertaking studies in this area (eg: the Department of Resources, Energy and Tourism Task Force on Carbon Capture and Storage).

6 See: http://www.climatechange.gov.au/whitepaper/
And: http://www.climatechange.gov.au/emissionstrading/legislation/index.html

Australian Government Treasury Report

The Australian Government Treasury published a recent Report[7] that undertook economic modelling using global equilibrium models to calculate how the Australian economy would be influenced over time by a global emissions trading scheme with increasing mitigation and a common carbon price. Technology portfolio modelling for Australia was included to 2050 under a range of global scenarios to stabilise atmospheric CO_2. In the model, global demand for Australia's energy intensive products such as coal and aluminium were calculated, and hence the future growth in electricity demand for their production determined.

The Treasury modelling showed:

- electricity generation is a key determinant of emissions in Australia under business-as-usual scenarios;
- electricity demand is lower in the Treasury modelling than with the constant growth scenario assumed in the ATSE report. In the Treasury report electricity supply is predicted to be about 70 per cent greater in 2050 than 2008 (compared with around 100 per cent greater in the ATSE report). The smaller demand in the Treasury case is caused by lower global demand for Australian coal and aluminium due to global emissions trading costs and the corresponding lower electricity demand in Australia;
- the scenarios for CO_2 trajectory require emissions in Australia to fall from 600 Mt/yr now to around 200 Mt/yr in 2050;
- global prices for CO_2e emissions are predicted to rise to around $125/t (2008$) by 2050;
- electricity generation emissions are predicted to fall by 70 per cent by 2050;
- wholesale electricity prices are predicted to more than treble by 2050; and
- Carbon Capture and Storage plus Geothermal energy technologies are calculated to be almost 60 per cent of electricity supply by 2050, the balance being provided by gas (almost 20 per cent) and other renewables (the other 20 per cent).

Conclusion

The ATSE study and the Government Treasury modelling showed that there are many challenges ahead for development of the technologies required to replace coal fired CO_2 emissions in Australia. The ATSE study concluded that R&D will be required in a range of areas as diverse as combustion science, chemical and reservoir engineering, electrical engineering, nuclear engineering, materials science, energy storage technology and mining engineering. Both studies showed that the scale of new technology commercialisation required, even in 2020, is very substantial and is massive by 2050 if the proposed targets are to be met. This will require billions of dollars funding for appropriate timely demonstration and deployment of the technologies at large scale, both in Australia and internationally. The estimate from the ATSE project for the cost of single demonstration of the required technologies (up to 1 GW scale) is ~A$6,000 million, primarily before 2020; this represents a rate of over $500 million per annum each year until then. By comparison, the International Energy Agency's (IEA) global deployment estimate of $US3,800 billion from now to 2050 would imply a deployment investment in Australia in the order of $1,400 million per annum for the next 40 years, on a pro-rata basis. This represents a significant technological and financial challenge.

7 *Australia's Low Pollution Future: The Economics of Climate Change Mitigation*, 2008, Australian Treasury, Commonwealth of Australia.
Copyright the Commonwealth of Australia, reproduced by permission. http://www.treasury.gov.au/lowpollutionfuture/report/default.asp

3.2 JAPAN: THE PRESENT NATIONAL ELECTRICITY GENERATION SCENE

Dr Tsuneo Nakahara, President, the Engineering Academy of Japan, and
Dr Yutaka Nagata, Senior Research Scientist, Socio-Economic Research Center, CRIEPI

Preface

At the 17th CAETS Convocation, hosted by the Engineering Academy of Japan in Tokyo from 23 to 26 October 2007, a wide range of global energy and environmental issues were reviewed and discussed by more than 230 attendees including CAETS academy representatives and specialists. The state-of-the-art of various technologies for improving energy efficiency, energy production with reduced carbon dioxide (CO_2) emissions, carbon-free electricity generation including nuclear power, and carbon dioxide capture and storage (CCS) were reviewed and discussed. Also discussed at the Convocation were global environment monitoring systems and various strategies and measures for foreseeable local and global energy and environmental challenges. And in the Statement, 9 action items have been recommended.

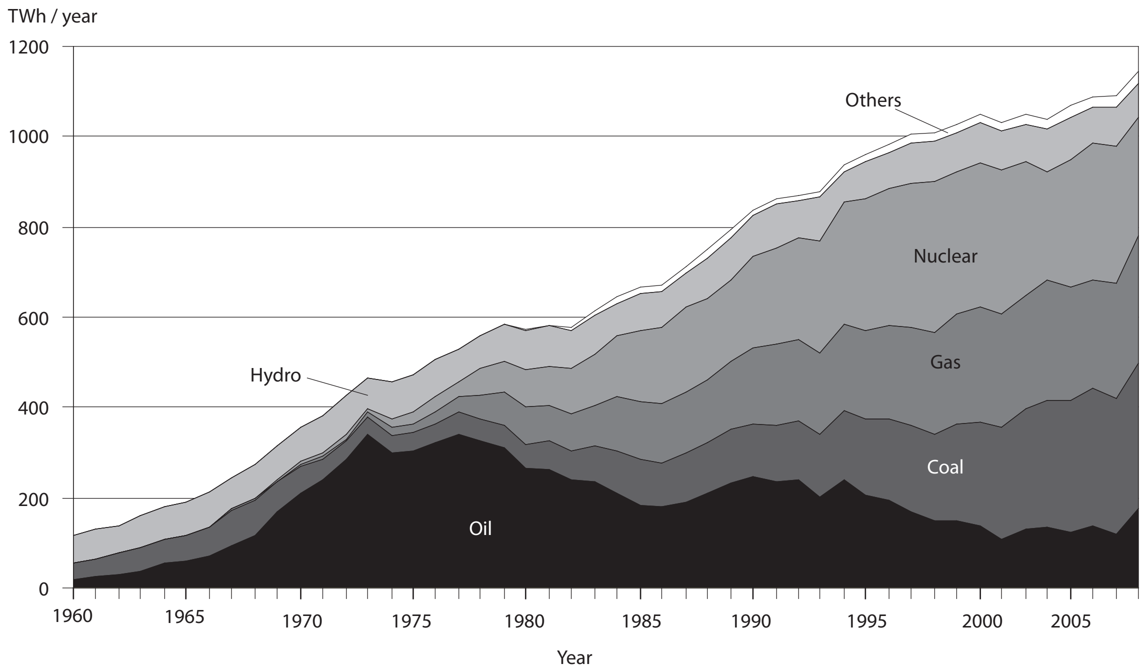
At that time the Kyoto Protocol was already ratified for the target in 2012, and the Nobel Prize was awarded to the former US Vice-President Al Gore and the IPCC team. Since the Hokkaido Toyako Summit in July 2008, 'Cool Earth 50', which sets the target of reducing global carbon dioxide to less than 50 per cent of today's level in 2050, has become popular among advanced countries. Consequently, in this workshop, a present and near-future plan should cover from present to 2012, a middle-range plan should cover from 2020 to 2030, and a long-range plan should cover from 2050 to 2100.

Present State-of-the-Art

Figure 1 shows power generation mix of Japan in the past and Figure 2 shows the implements in thermal efficiency and transmission/distribution loss factor.

Since the first oil crisis happened in 1973, decreasing the dependence on oil has been the top priority

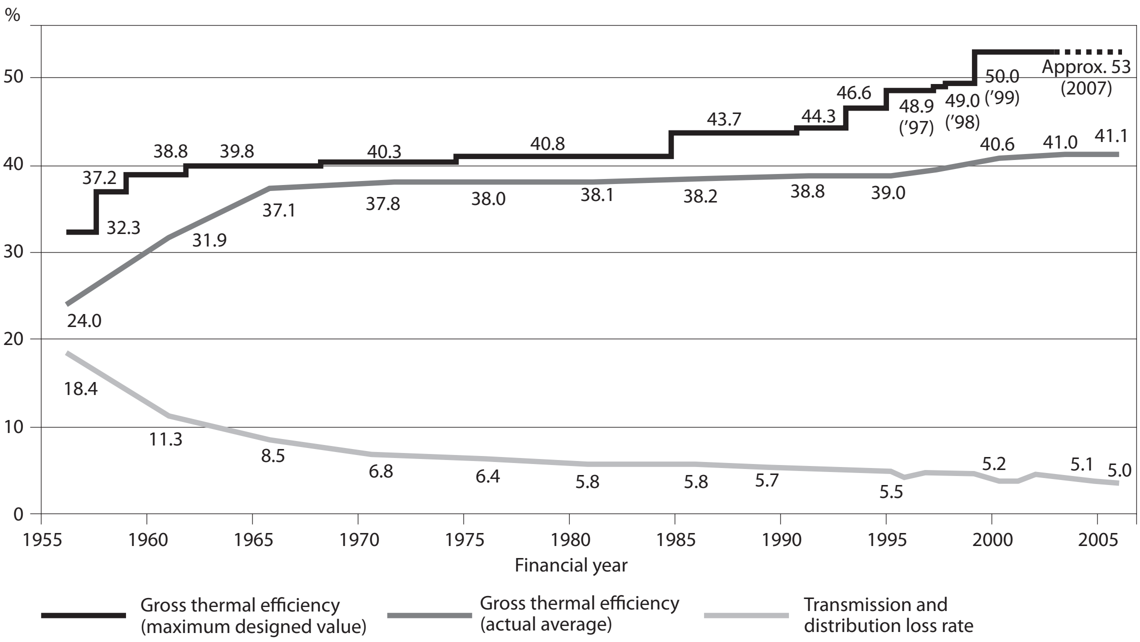
Figure 1 Power generation mix of Japan



Source: OECD/IEA (2008), Energy Balances of OECD Countries for energy policy in Japan. The Japanese government and electric utilities has been making efforts for diversifying the power sources and for improving the efficiency of power generation. As a result, the share of oil in power generation has drastically decreased from 73.2 per cent in 1973 to 11.1 per cent in 2006, and meanwhile, coal, gas, and nuclear have increased their shares by 20 per cent of each (Figure 1). The efficiency of thermal power plants has been improved by various methods, such as expanding plant capacity, raising steam temperature and pressure, adopting regenerative and reheat cycle, and using combined cycle power generation. The Kawasaki Thermal Power Plant, which started its operation in June 2007, achieved the highest gross thermal efficiency of 53 per cent (HHV[8], 59 per cent on LHV[9] base) with a 1,500°C class gas turbine (Figure 2). Average gross efficiency of all thermal power plants also achieved 41.0 per cent (LHV: 43.9 per cent) in actual operation, while reducing SO_x and NO_x emissions to several times smaller levels of other developed countries in 2007. Because energy security is another important issue of energy policy in Japan, the integrated coal gasification combined-cycle (IGCC) power plant is under development. A 250 MW, air-blown IGCC demonstration plant in Iwaki City, Fukushima Prefecture began its operation in 2007. It aims to achieve gross thermal efficiency of 46 per cent (LHV: 48 per cent) and net thermal efficiency of 40.5 per cent (LHV: 42 per cent), respectively (Clean Coal Power R&D Co. Ltd., http://www.ccpower.co.jp/english/index.html).

The Ministry of Economy, Trade and Industry (METI) formulates "Outlook for Long-Term Energy Supply and Demand" and this is reviewed roughly every three to five years with an aim to provide information about Japan's energy supply and demand structure in the future as a basis for considering and evaluating policies and measures. The latest outlook includes three scenarios over the year 2030, and among them, the "Maximum Introduction Case" assumed utmost dissemination of equipments, of which energy efficiency performance will significantly improve with cutting-edge technologies that are already at deployment stage, while not imposing obligatory measures on the people. Energy efficiency at final demand will be improved by 30 per cent in 2020 and by 40 per cent in 2030, respectively compared with the 2005 level. Moreover, next-generation automobiles including electric vehicles and plug-in

Figure 2 Improvements in thermal efficiency and transmission/distribution loss factor near and middle range future outlook and technology development

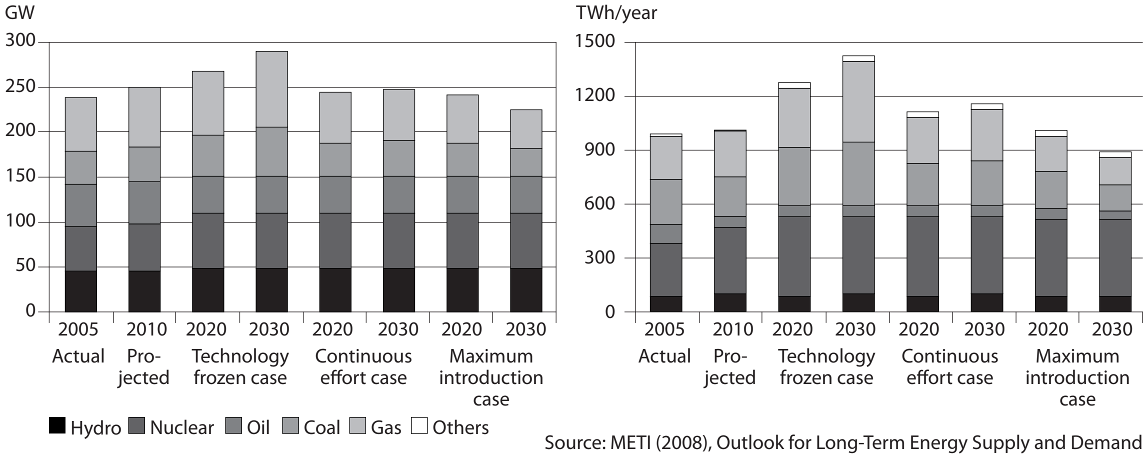


Source: The Federation of Electric Companies of Japan (www.fepc.or.jp)

8 HHV: higher heating value

9 LHV: lower heating value

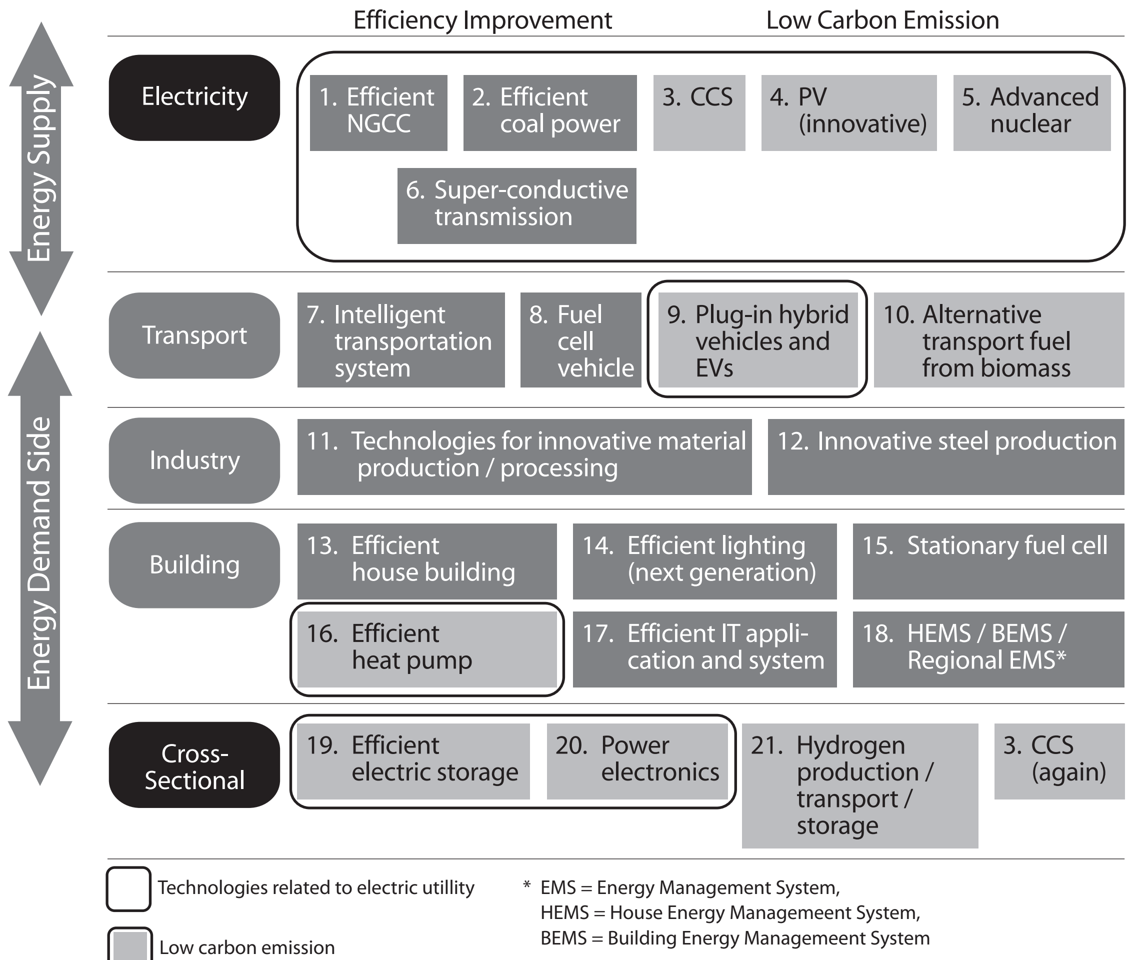
Figure 3 Outlook for the capacity (left) and the generated power (right) by plant type in Japan



Source: METI (2008), Outlook for Long-Term Energy Supply and Demand

hybrid vehicles will be disseminated up to 20 per cent in 2020 and 40 per cent in 2030 on stock base. According to these scenarios, capacity and generated power by plan t type are projected as in Figure 3. The amount of nationwide energy-related CO_2 emissions will decrease to 897 million t-CO_2 in the "Maximum Introduction Case", which is 13 per cent less than the 2005 level and three per cent less than the 1990 level.

Figure 4 Selected 21 technologies in the Cool Earth Energy Innovative Technology Plan



* EMS = Energy Management System,
HEMS = House Energy Managemeent System,
BEMS = Building Energy Managemeent System

Source: METI (2008), Cool Earth Energy Innovative Technology Plan

It is necessary to develop innovative energy technologies to achieve this CO_2 emission target. Therefore, METI established the Cool Earth Energy Innovative Technology Plan (Cool Earth 50) and selected 21 technologies as innovative technologies that should be given higher priority, and made a roadmap of development on these technologies (Figure 4). About a half of these technologies are directly related to electric utility, and it implies the importance of electric sector to achieve a large-scale reduction of CO_2 emissions. Table 1 shows the development roadmap of these technologies. Of course, not only developing technologies domestically but also promoting international cooperation is important while fully utilising existing frameworks, especially APP[10] and CSLF[11] for CCS, and GNEP[12] and GIF[13] for nuclear power.

Future Vision

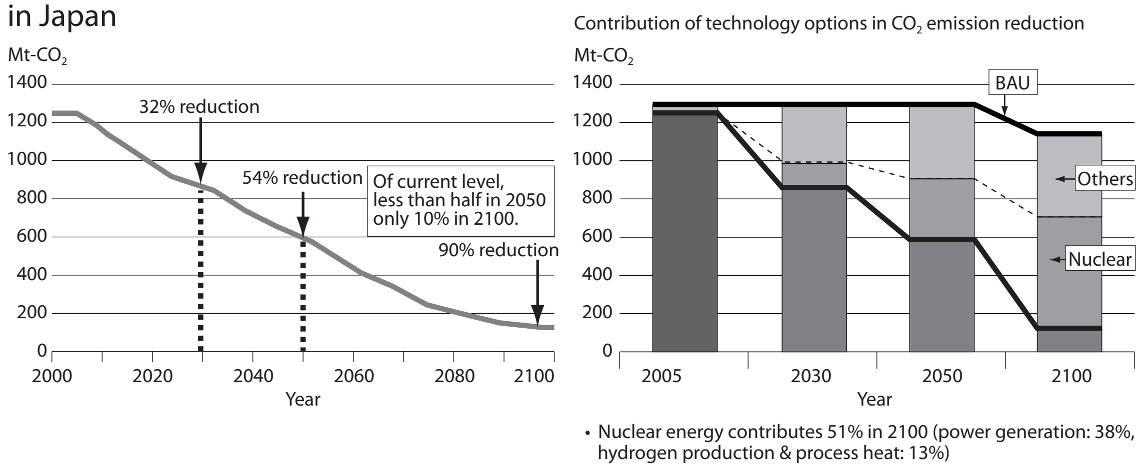
It seems now the consensus among the technically advanced countries is that the conventional energy sources will not be able to meet all the demands for sustainable economical growth without destructing

Table 1 Development Roadmap of Electricity-Related Technologies

Technology	Over 2020	Over 2030	Over 2050
Efficient Natural Gas CC Power	• Generating efficiency: 56% (with a 1700°C class gas turbine)	• Generating efficiency: 60% (FC/GT hybrid power generation)	
Efficient Coal Power	• Demonstration plant (1000 t/d class) of IGCC and 48% efficiency of A-USC	• 55% (600MW-class commercial generation)	• 65% (Next-generation IGFC)
Carbon Capture and Storage (CCS)	• Separation and capture of CO_2 • Geological storage of CO_2 • Capture cost: 2000s JPY/t-CO_2	• Cost: 1000s JPY/t-CO_2 (adoption of separation membrane on high-pressure gas) • Ocean sequestration of CO_2	
Innovative Photovoltaic	• High-efficiency compound semiconductor PV, 75 JPY/W of cost • Organic PV (dye-sensitised, thin-film organic)	• Ultra-thin crystalline Si PV • 50 JPY/W of cost, 22% of conversion efficiency	• PV with innovative structure/material
Advanced Nuclear Power	• Designing and construction of demonstration reactor	• Next-generation light-water reactor	• Commercialisation of fast reactor
Superconductive Transmission	• HTS Superconducting cable and associated technology	• HTS Superconducting cable network	
Plug-in Hybrid Vehicles and EVs	• Battery capacity: 3 times current level • 200km travelling distance on a full charge	• Battery capacity: 7 times current level • 500km travelling distance on a full charge	
Efficient Heat Pump	• Ultra high-efficiency heat exchange technology • Exhaust heat utilisation technology from ventilation and human sewage	• 25% cost reduction • 50% improvement in efficiency	• 50% cost reduction • 50% improvement in efficiency
Efficient Electric Storage	• Advanced Li ion battery • 200 Wh/kg energy density for vehicles	• Batteries with new concept/principle • 500 Wh/kg energy density for vehicles	
Power Electronics	• Diamond power device (3 inch, 10^2cm^2) • GaN-type power device (4 inch) • SiC power device ($50cm^2$)	• Diamond power device (4 inch, $10cm^2$) • GaN-type power device (5 inch, 10^3cm^2) • SiC power device ($10cm^2$)	

10 APP: Asia-Pacific Partnership on Clean Development and Climate
11 CSLF: Carbon Sequestration Leadership Forum
12 GNEP: Global Nuclear Energy Partnership
13 GIF: Generation IV International Forum

Figure 5 Target of CO_2 emission for 'Cool Earth 50' in Japan



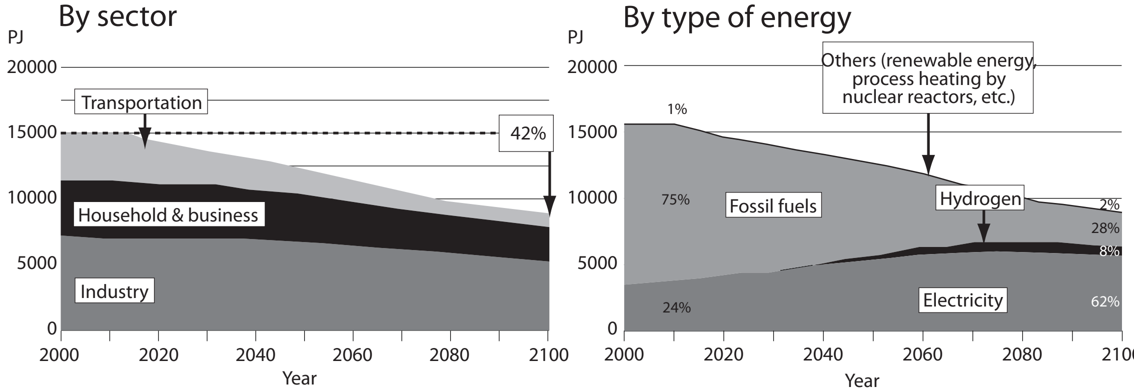
Source: JAEA

global environment and that nuclear power generation alone will not be able to afford enough energy unless safety concern by the public about its proliferation is reduced. Consequently combination use of all the possible technologies will be indispensable such as improved fossil fuel and coal power generation with CCS, renewable power generation using water, solar, wind, geothermal, bio etc. in addition to advanced nuclear power generation. The economical portfolio as a function of time will be very important and it might be dependent on the institution of each country. Japanese Government has not yet established basic policy for its long-range program.

The Engineering Academy of Japan has proposed the international cooperation of the Engineering Academies at the council meeting of the CAETS in Delft, Netherlands in June 2008 in order to find the pragmatic solutions for each country. Australia and Switzerland are also proposing the collaborations of the Engineering Academies for the related purposes. Here EAJ would like to present, for your reference, a future vision of nuclear power by Japan Atomic Energy Agency (JAEA) for long-range program although this is not the formally authorised plan of Japanese government. The left-hand side of Figure 5 shows the target of CO_2 reduction compared with 2000 for the 'Cool Earth 50' that requires more than 50 per cent in 2050 and the right-hand side of the same figure shows the contribution of technology options in reduction of CO_2 emission.

The left-hand side of Figure 6 shows the final energy consumption by sector and the right-hand side shows by type of energy. It should be noted that electricity is increasing while the total of final energy consumption is decreasing.

Figure 6 Final energy consumption for 'Cool Earth 50' in Japan



Source: JAEA

Figure 7 Primary energy supply mix for 'Cool Earth 50' in Japan

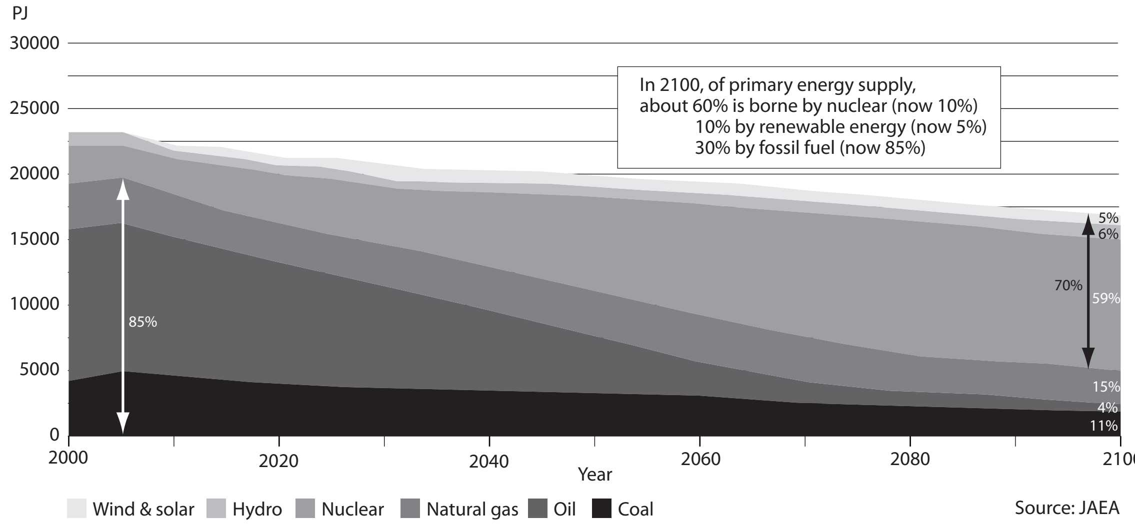


Figure 7 shows the portfolio mix ratio of primary energy supply in Japan for the case of Figure 6.

3.3 GERMANY: SOME ASPECTS OF THE ENERGY SUPPLY SITUATION IN GERMANY

Andreas Möller, acatech – German Academy of Science and Engineering

General conditions

As in other OECD countries, Germany is facing immense challenges in creating a future energy mix that will achieve all three targets in the energy policy triangle – security of supply, economic efficiency and environmental compatibility.

While energy requirements in Germany in recent years have remained almost constant, the conditions for producers and consumers have changed significantly. The global demand for energy has increased due to rapidly developing economies in other regions. The World Energy Outlook 2008 forecasts that the world energy demand will expand by 45 per cent between now and 2030 – an average rate of increase of 1.6 per cent per year.[1]

Due to the fact that about 58 per cent of primary energy consumption (PEC) is based on oil and gas, Germany's energy mix is strongly dependent on imports. (24 per cent lignite and hard coal, 11 per cent nuclear energy and 7 per cent others such as hydro, wind, and biomass make up the rest).[2] Germany is one of the biggest importers of gas, coal and oil worldwide, and has few domestic resources apart from lignite and renewables.[3]

Nuclear energy, which accounts for 22 per cent of electrical energy, has been a controversial public issue. The agreement between the four major electricity supply companies and the Federal Government in 2000 laid down the quantities of electricity in TWh which each of the 20 nuclear power plants then in operation would be allowed to supply ("Reststrommengen"). These "allowed quantities", or parts thereof, can be transferred from one power station to another power station if the latter is more economical to operate. This means in practice that all nuclear power stations will have been shut down about 25 years from the date of the agreement. At present, it appears that the last one will be shut down in 2023. Furthermore, Germany does not participate in the international G4 activities (R&D for fourth generation plants).

For these reasons, Germany is faced with the task of adjusting its energy policies in the light of changed conditions. This involves securing the supply of primary fossil fuel-based energy but – at the same time – achieving an energy base that relies less on fossil fuel.

Renewable Energies

The general desire to reduce carbon dioxide emissions has influenced German energy supply policy in the past two decades. The Federal Government has committed itself to cutting its greenhouse gas emissions by 40 per cent compared to the 1990 baseline levels by 2020, if other EU member states agree to a 30 per cent reduction of European emissions over the same time period. It is likely that Germany will reach this goal of a 40 per cent reduction.

When the former Social Democrat-Green coalition government decided to move out of nuclear energy, one of the solutions was to promote the renewable energy forms, thus combining energy demand and

1 IEA: World Energy Outlook 2008
2 Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety/AGBE 2009
3 In 2006, Germany was the second largest gas importer after the USA. Source: Federal Institute for Geosciences and Natural Resources, Annual Report 2006. www.bgr.bund.de

climate protection objectives. By 2020, renewables will contribute 20 per cent to electricity supply (14 per cent at present), and at least of 10 per cent of PEC.

Due to the feed-in tariffs of the 'Act Granting Priority to Renewable Energy Sources' (EEG – Erneuerbare Energien Gesetz) passed in 2000, wind power has become the most important renewable source of electricity production in Germany over the past decade, and now contributes seven percent (half of all renewables). The number of windmills has increased from 806 in 1991 to 19.460 in 2007 and is still rising.[4]

An amendment to the EEG in 2004 improved the financial incentives. In 2009, an updated version with changed support rules for various technologies was passed. In general, the EEG promotes all technologies aimed at generating electricity from renewable energy. However, capacity, location or other aspects may provide a reason for excluding certain types of plant from financial support.

Renewable electrical energy fed into the grid is paid for by the network operators at fixed tariffs (ct/kWh). The costs are passed on to electricity consumers, so that there are no subsidies by the government. The tariffs are different for specific technologies and subject to a reduction of about five per cent each year as an incentive for price reductions in new plant. The price is guaranteed for 20 years after completion of the plant, so that the operators have confidence in their planning criteria.

From 2000 to 2004, the amount of electricity generated from renewable energy forms supported by the Act increased from around 13.6 TWh to 34.9 TWh. During the same period the Act resulted in the amount of electricity generated from wind and biomass being more than doubled. With respect to photovoltaics a nine-fold increase in electricity generation in Germany was observed. 70 million tons of CO_2 were saved in 2004, with 33 millions tons being attributable directly to the EEG. These are the notable successes of the EEG.

Due to the structure of the EEG, a particularly high investment security is guaranteed while credit interest rates and risk mark-ups are low compared with other instruments. The EEG ensures high-quality installations which is an incentive for operators to run their plant efficiently (due to payments per kWh produced). This has helped to minimise the risks.

Apart from the increased costs for electricity for the consumer there are also other, less positive aspects associated with promoting the use of renewables in this way. By "subsidising" solar electricity, the solar industry has become an important industrial sector in Germany, although it would be completely non-competitive under free market conditions. This has become a sensitive political issue. One of the main challenges is thus to decrease the costs of manufacturing solar cells and to increase their efficiency.

In the case of wind energy, two of the major problems are the noise of the rotor blades and negative effect on the landscape. In the case of offshore wind farms, there are probably as yet unknown repercussions for the ecological system of the sea.

Biomass use can also promote a so-called monoculture in the form of a non-sustainable cultivation of energy crops. In Germany the land allocation problem has also been the subject of discussion because of the production of rape seed for bio-diesel ("food-or-fuel" debate), and because of the very high water consumption of energy crops. Depending on the region and the feedstock, about 4000 litres of water are needed for one litre of bioethanol.

4 Federal Ministry of Economics and Technology (2/2009)

Nevertheless, the bio-economy – which covers all sectors and services utilising biological resources (plants, animals, micro-organisms) – will play an important role in the wider German and European economies. It is a sector estimated to be worth more than €1.5 trillion per year.

Energy Efficiency and Energy Storage

An important part of the 2020 aim to reduce carbon emissions is the huge effort being made to enhance energy efficiency in industry, transport and housing, which are the three largest sectors of energy consumption.

Unlike the discussion on nuclear power plants or the competition between food and biofuel production, there has been political consensus on the need for energy efficiency measures. The utilisation of existing energy resources to their fullest extent is for Germany – as a centre of technological innovation – a promising field, and is an opportunity to assume a pioneering role while at the same time being economically attractive.

The greatest improvements in energy efficiency on a short timescale can be made in the areas of heating, hot water supply and larger domestic appliances. Apart from petrol or diesel for vehicles, almost 90 per cent of domestic energy consumption goes on heating and hot water production. Rational energy utilisation promises an enormous potential for saving energy, if new paradigms are applied with the necessary priority. Particularly the renovation of buildings with modest financial measures can save huge amounts of heating fuel. About a fifth of all greenhouse gas emissions are caused by private households, which is more than that produced by all kinds of road traffic in Germany. One has to bear in mind that three-quarters of all buildings were built before the first Heat Insulation Ordinance in 1978 and by far the largest number still needs to be renovated according to energy saving principles. In 2005, for example, 80 per cent of all private households (38 million dwelling units) were not yet thermally insulated. Overall, 150 million tons of carbon dioxide emissions could be saved annually.

Such renovation measures are in accordance with the target requirements of the European Union: The EU Council (Heads of State and/or Heads of Government) has decided not only on fixed targets for the percentage of renewable energy forms, but has also enacted the European guidelines 'Total Energy Efficiency of Buildings' (January 2003). EU member states are obliged to implement these guidelines and integrate them into national regulations. In Germany this is done via the technical norms DIN V 18599 "Energetic Estimation of Buildings" which form the basis for the regulation EnEV 2007 by the Federal Ministry of Transport, Building, and Urban Affairs in which these requirements have been further specified and to some extent strengthened.

Since it is clear that fossil fuel-based energy plays a large role in the German energy mix, Carbon Capture and Storage (CCS) technology is an important option to reduce green¬house gas emissions despite the high capital investment for providers and the need to study the safety issues associated carbon dioxide transport and storage. At present, there are only a few, small-scale demonstration projects, for instance in Hürth and Schwarze Pumpe (capture) and in Schleswig-Holstein and in the Altmark (storage). The Federal government currently plans to pass a CCS bill ('Gesetz zur Regelung von Abscheidung, Transport und dauerhafter Speicherung von Kohlendioxid') summer 2009.

Electricity seems to provide the key path to storing energy in a carbon-constrained world. In particular, in order to store energy from intermittent sources such as wind and sun, the development of more efficient batteries has become a vital necessity. Due to the short distances in urban transport and the need to reduce pollution dramatically, e-mobility has recently become a key word. Providers and engineers worldwide are searching for ways to make batteries more powerful, less expensive and less dangerous. Several cooperative projects between the Federal ministries and industry have been started, for example, the Innovation Alliance LIB 2015 (lithium ion battery).

Technology Transfer

The pressure for more efficient production, transmission, storage and utilisation of energy triggers the development of new technologies and methods. While battery projects focus on wind energy, there are also plans to link the Middle East/North Africa region with Europe by high-voltage cables, which is, of course, a solar energy vision. The current amount of electricity received from other countries via grid connection was in 2008 about 41 billion kWh (in comparison: Export to other European countries: about 62 billion kWh). The imports decreased by nine per cent. The main important countries for imports are: France (11 billion kWh), Denmark (nine billion Bio kWh)

The political will to combat climate change has become a success story for several branches of German industry. Germany today belongs to the world leaders in these fields, especially wind power. The promotion of clean technologies for energy generation has therefore not just reduced emissions, but also given incentives to providers, produced innovations in the renewables sector and given rise to new jobs. From 2004 to 2007, the number of jobs in the renewable energy sector increased by more than 50 per cent to nearly 250.000.[5]

This also has an impact on science. While the world's answer to the oil crisis in the 1970s was to save reserves, new technologies and breakthroughs in existing technologies seem to be the key response today. In most European countries, which are without their own reserves of raw materials, it is an absolute necessity to take this route. Under the responsibility of the various Federal ministries, the German government has started several programs to push research and development in future technologies within the framework of the "High Tech Strategy" – a national program (HighTechStrategie) with an amount of €15 billion has been running since 2006 and will end in 2009. An important part of publicly financed research is in the field of energy. In January 2009, the government confirmed the support of investments in innovations such as new energy saving technologies with a total amount of 50 billion Euro ("Konjunkturpaket II"). The Konjunkturpaket II runs in 2009 and 2010 – not all the money is for energy related measures but a significant part will be.

acatech, for example, is part of a group of three Academies studying the current energy research programme of the Federal Ministry of Education and Research, and identifying the research needs in key areas. Examples are energy storage technologies, CCS, superconductivity, optimisation of existing power grids as well as a wide range of bio-issues with emphasis on the economic and food security impacts of bio-fuels.

As far as nuclear fusion is concerned, Germany forms a part (actually a large part) of the European research program and therefore participates – via the EU – in the international fusion reactor project ITER. The 'fast track' scenario for the realisation of fusion power – following positive results from ITER and other experiments – foresees the beginning of construction of a demonstration fusion power station (DEMO) about 2030 to 2035. DEMO would actually deliver electricity to the grid but, on the basis of this timetable, commercial electricity generation would not occur before the middle of the century.

Energy research and the adoption of measures to combat climate change in Germany are under the jurisdiction of several Federal ministries. This fragmentation results occasionally in a parallel focus on several issues instead of an integrated, systematic approach to all aspects of energy supply from generation to consumer use. Although there are activities such as the Integrated Energy and Climate Programme of the Federal Government, a national policy for energy supply is still under discussion.

5 Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2009

3.4 UNITED KINGDOM: UK ELECTRICITY GENERATION OVERVIEW

John Loughhead FREng

1. Background

The UK electricity system is a tightly integrated network originating from a large build program in the three decades following World War II. This superseded a loosely connected distributed system based on municipal generation that had grown in an unplanned fashion in the first half of the 20th century. The system was developed and operated by a public utility, Central Electricity Generating Board (CEGB) until 1990, when it was privatised. The structure and ownership of the successor companies has changed continuously since then.

The National Grid provides a transmission capacity using up to 400kV systems, linking around 160 power stations of 200 MW or above, and feeding 13 regional distribution companies. Total installed generating capacity is around 82GW.

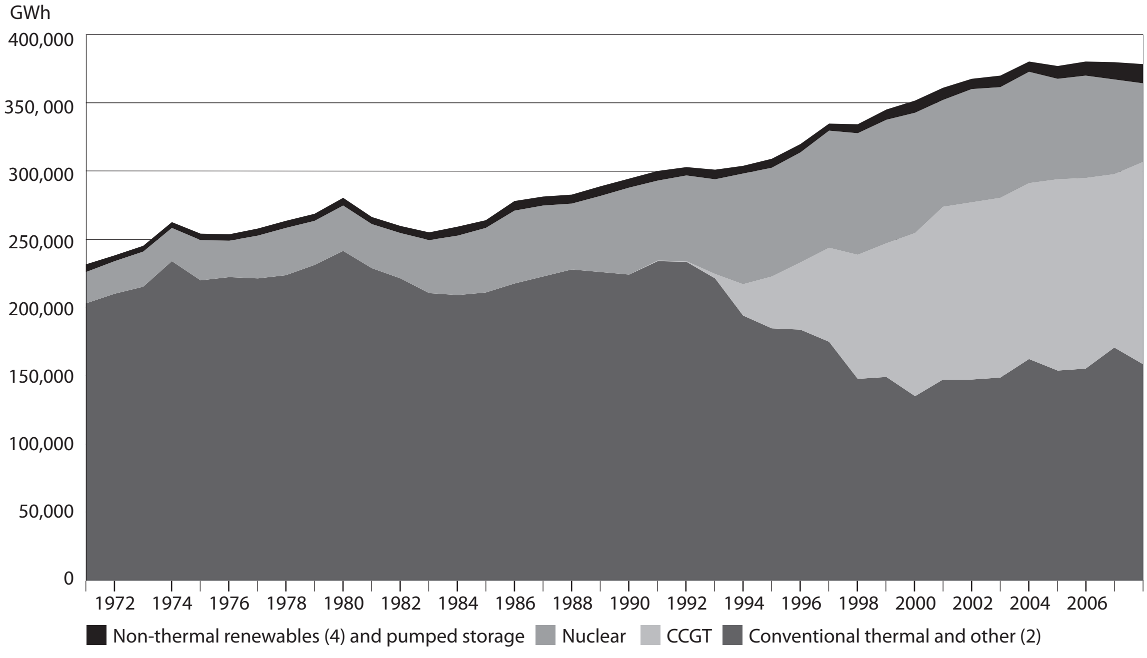
Generation assets are owned and operated by a number of private utilities, which sell power into a market system controlled by National Grid. Prices are bid and set for 30-minute intervals throughout the day, and so vary significantly over a 24-hour period. The Office of Gas and Electricity Markets (Ofgem) oversees the system operation as public regulator.

Historically the dominant fuel for electricity generation was coal. With the development of natural gas fields under the North Sea, and a politically desire remove the influence of mining unions, there was a progressive penetration of natural gas fuelled CCGT systems starting in the early 1990s.which now supply almost 50 per cent of all electricity. Nuclear power grew to around 27 per cent of supply in 1998, and is presently around 15 per cent due to closures of older stations. A sharp increase in installation of wind generators has occurred in the past few years, although their contribution to supply is still modest.

2. Generation Mix

This chart shows the historical level and mix of electrical supply in the UK:

UK Electricity Generation

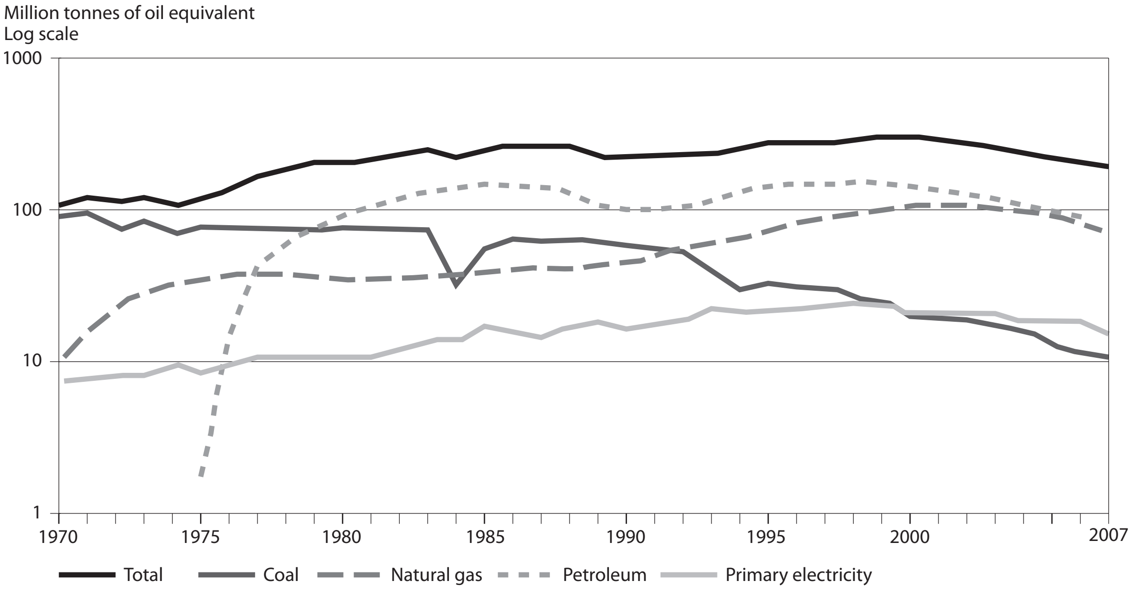


3. Fossil Fuel Production

The chart below shows the historical trend of fossil fuel production in the UK, using a logarithmic scale on the ordinate. It can be seen that coal has declined steadily over the past 35 years (the sharp dip in 1984 is the result of a prolonged miners' strike). Oil and gas production have both increased over the same period but are now in effective irreversible decline due to the exhaustion of the North Sea fields.

In response to this trend there has been an increase in provision for natural gas imports, both through construction of new pipelines from Norway and Europe, and in LNG termini, as well as additional storage facilities.

UK fossil fuel production

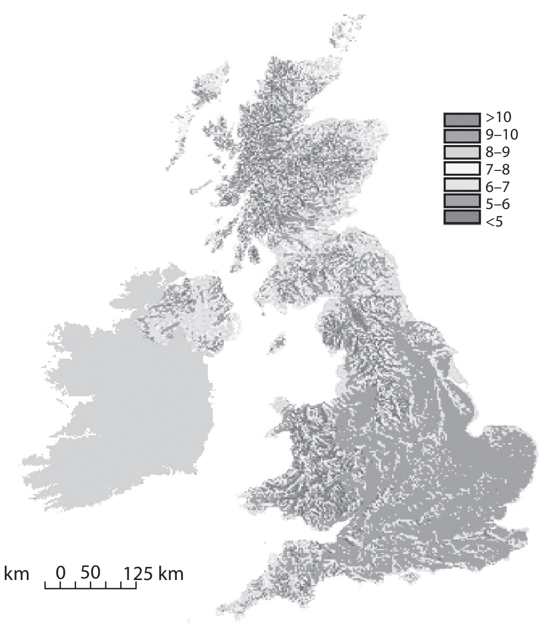


4. Renewables Development

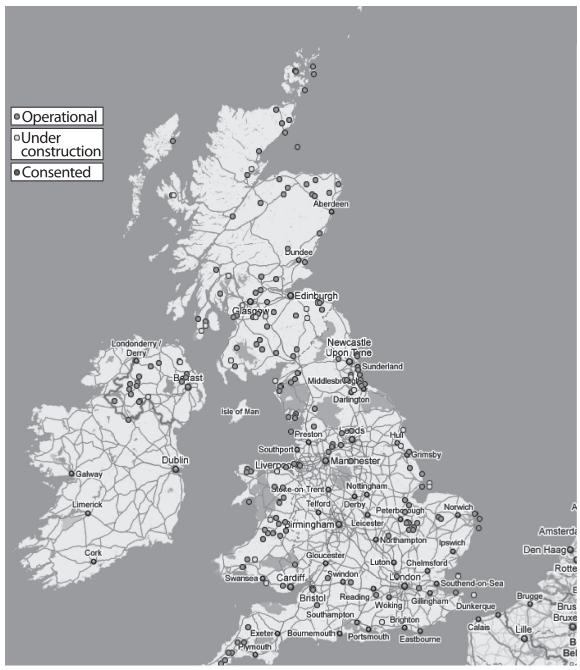
The primary renewables interest for the UK is on-shore and off-shore wind, due to the large available

Annual mean wind speed

at 25m above ground level (m/s)



Wind installations in the UK



resource in comparison to viable alternatives. The most attractive sites energetically are in the north of the UK, especially Scotland and in the seas to the north east. However, these are far from load centres which pose problems with both the current availability of suitable grid connections and the cost of constructing new infrastructure. Consequently the majority of current wind farms are found in the southern part of the UK. However, even here the rate of construction is impacted primarily by failure to obtain planning permissions for both on-shore and near-offshore wind farms due to objections by local residents to the perceived environmental impact, whether on scenery or concerns about noise.

The UK also enjoys a comparatively large marine energy potential, both wave and tidal. It is presently unexploited due to the technical challenge of producing commercially viable devices, although R&D continues and fairly large-scale demonstrators are being tested and monitored.

5. Policy Instruments

The UK has seen intense policy activity, related to energy supply, use, and innovation, over the past several years and electricity has been implicitly to the fore in much of this. An activity timeline is:

Timeline of key developments in the UK energy innovation framework. Major strategy and policy announcements with a significant implication for UK energy policy, as well as the creation of key institutions that fund energy research, are included. This is paralleled by developments in the regions and the devolved administrations: notably the creation of ITI Scotland in 2003.

The UK Energy Research Centre, a consortium of eight academic institutions was established in 2004. Among its aims are to coordinate a National Energy Research Network and create an atlas of energy research activity.

The Energy Research Partnership, which brings together key funders of energy innovation in government, industry, academia and other interested bodies, was established in 2006.

Year	Key policy and strategy reviews and publications	Creation of key energy innovations
2001		Carbon Trust
2002	Performance & Innovation Unit Energy Review	DTI New and Renewable Energy Programme
2003	Renewables innovation review Energy White Paper 2003	
2004	Science & Innovation Investment framework 2004–14	DTI Sustainable Energy Capital Grants programme DTI Energy Programme Research Councils Energy Programme
2005	Stem Review	
2006	Climate Change Programme Review	
2007	Energy White Paper 2007 Sinsbury Review of Science and Innovation	Technology Strategy Board (formerly technology programme) becomes an NDPB Energy Technologies Institute
2008	ETF Strategy 'Innovation Nation' white paper	Environmental Transformation Fund
2009	Renewable Energy Strategy	

And a summary of policy milestones:

Key energy innovation policy milestones

2000 – Climate Change: The UK Programme was launched – the original UK Climate Change programme aiming to reduce UK emissions by 20% by 2010.

2001 – The Carbon Trust was created with a mission to accelerate the move to a low carbon economy by working with business and the public sector to reduce carbon emissions and develop commercial low carbon technologies.

2002 – The 2002 Energy Review by the Performance and Innovation Unit examined the level and targeting of energy innovation spending and concluded that spending levels needed to increase; and in 2002 the first capital grants for energy technology were introduced as the DTI New and Renewable Energy Programme.

2003 – The DTI Renewables Innovation Review emphasised that low carbon technologies other than wind would be required to meet the UK's carbon emissions reduction targets, and made recommendations on the need for long-term support for innovation from Government as well as specific recommendations on investment in innovation and short-term actions.

2003 – The Energy White Paper 2003 defined a strategic vision for energy policy combining environmental, security of supply, competitiveness and social goals. It stresses the importance of energy innovation and committed the UK to investing more in energy innovation, as well as addressing a wide range of other factors such as the need for a suitable UK skills base.

2004 – The Science and Innovation Investment Framework set out a broad and long-term strategy for UK science and innovation policy.

2005 – The Energy Efficiency Innovation Review examined how a step-change in energy efficiency in the domestic, business and public sectors in the UK could be delivered cost effectively, and how energy efficiency improvement could be embedded into decision making across the economy.

2006 – The Government's report on the Energy Review, The Energy Challenge, sets out a package of proposals including banding the renewables obligation to provide enhanced support for emerging technologies.

2006 – The Stern Review[18] reviewed the complex innovation process to work out what policies may be required to encourage firms to deliver the low-emission technologies of the future.

2006 – The Review of the UK Climate Change Programme set out new measures to reduce emissions by 12 million tonnes of carbon by 200.

2007 – The Energy White Paper 2007 set out the benefits of developing low carbon technologies and introduced the Energy Technologies Institute and the Environmental Transformation Fund, as well as reviewing wider challenges such as the provision of skills.

2007 – The Commission in Environmental Markets and Economic Performance proposed actions that the Government, business and others should take to drive investment and innovation in environmental markets in the UK.

2007 – The Sainsbury Review of Science and Innovation examined the role of science and innovation in ensuring the UK remains competitive in our increasingly globalised economy.

2008 – Innovation Nation, the Innovation White Paper strengthened the focus of UK Innovation policy on demand side instruments – noting that the UK needs to complement the supply-side innovation measures with demand-side policies.

2008 – The UK Renewable Energy Strategy Consultation seeking views on how to drive up the use of renewable energy in the UK.

For electricity generation, the key incentives are:

- **Renewables Obligation Certificates (ROC)** – a statutory requirement on all generators to supply a stated percentage of electricity from renewable sources, the figure increasing each year to (presently) 15.4 per cent in 2015. A certificate is granted for each MWh generated, and the appropriate number must be surrendered at the end of the year or a penalty paid. A wind farm operator will thus have a surplus which can be sold to say a coal power plant operator, generating a financial support to the renewables. The system is presently being "banded" with fewer certificates granted for output from mature renewables technologies.
- **European Emission Trading Scheme (ETS)** – a cap-and-trade system for carbon emissions. The ambition was to provide incentives for investment in low-carbon electricity, but the price per tonne of carbon dioxide is around €10/tonne, considerably lower than needed to have the desired impact.
- **Climate Change Levy**– a consumer tax on business and public sector use of gas, coal, electricity and liquefied petroleum gas. The rate for electricity is presently 0.456p/kWh, but renewable electricity is exempt.

6. Future Developments

The UK Government has adopted an aggressive goal of 15 per cent of energy from renewable sources by 2020, which implies about 35 per cent of electrical energy from renewables. The primary source will be wind, with optimistic projections of increases in off-shore capacity driven by incentives through the ROC scheme.

If this is realised it will imply a large change in transmission topography and capacity (by up to 45GW) at an estimated cost of £4 billion. There are also unknown impacts of high levels of stochastic energy generation on the grid stability.

Additionally Government is seeking substantial cuts in carbon emissions, and aspires to fitting all new fossil fuel plants with carbon capture and storage by 2020. A demonstrator scheme will be subsidised in the coming year to justify the move, and the EU is likely to find a further such demonstrator as part of an EU-wide set of 12-15 such plants.

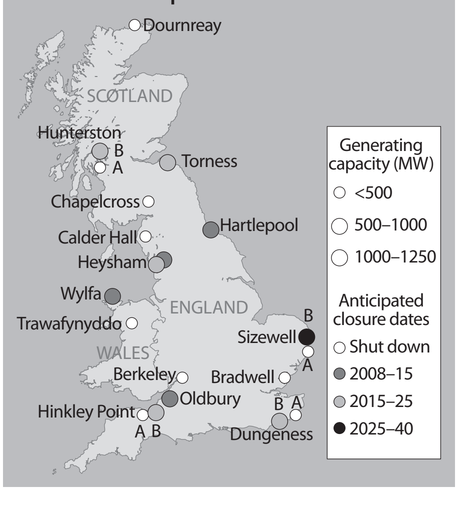
Underpinning R&D to support all these moves continues to be publicly funded, although the development of the technology and investment is regarded as the responsibility of private sector. The two come together in the new Energy technologies Institute, a public-private partnership engaged in development and demonstration of new energy technologies.

Policy has changed in respect of nuclear fission, which after two decades of policy rejection is now to be encouraged due to the projected impact of scheduled closures on carbon emissions if replaced by conventional plant. A fleet of new fission reactors (Gen-II and Gen-III) will be procured from international suppliers.

Another capacity driver will be the impact of the European Large Combustion Plant Directive which requires all plants above 50MW to meet stringent emissions standards by 2015.

Due to the age of a number of existing stations it is not always commercially realistic to upgrade them to the new standards, so they must 'opt out' and close by 2015. It is estimated this will cause 25GW of capacity to close prematurely, and in many cases it will (by owner preference) be replaced by gas or coal-fired plant. Lobby groups are pressuring Government

UK nuclear power stations



to refuse licences for any that are not zero-emission, which is not presently commercially available. There are growing concerns of a potential ‘energy gap’ if construction of replacement plant is not started soon.

To ease the pressure on generation, the development of intelligent demand-side measures is also progressing. It is likely that all homes will be fitted with smart meters over the next decade, and the distribution network adapted to more easily accept highly distributed generation, active load control, and similar measures.

A parallel move to reduce carbon emission from transport is presently favouring electrical vehicles, with an emphasis on battery-power for urban use. If adopted this could substantially increase the demand for electricity and require further generating capacity increases – some estimates are of a 50 per cent increase in **energy** demand, and more than 100 per cent increase in **power** demand on parts of the distribution network.

4 Workshop Program

INTERNATIONAL WORKSHOP, MELBOURNE 2009	
Electricity Generation: Accelerating Technological Change	
	TUESDAY 31 MARCH 2009 PROGRAMME
	Technology Deployment & Demonstration (D&D)
0930	Registration and morning tea.
1000	Workshop Opening/Welcome **Moderator – Peter Laver AM FTSE**
1020	**John Burgess FTSE** 'Stationary Energy Technology for Climate Change Mitigation – The Australian Context'
1100	**Engineering Academy of Japan (EAJ)** **Tsuneo Nakahara – President** 'Demonstration and Deployment Initiative in Japan - Future Grid, Superconductor and Nuclear Power'
1130	**The Royal Academy of Engineering (RAE)** **John Loughhead FREng – Executive Director UK Energy Research Council** 'UK initiatives for low emission generation demonstration and deployment'
1200	**acatech – German Academy of Science and Engineering** **Andreas Möller** 'Energy supply and demand situation in Germany'
1245	Lunch
1345	**Australian Academy of Technological Sciences and Engineering** **Robin Batterham AO FREng FAA FTSE – President** 'Deployment and Technology Learning'
1415	**Petroleum, Resource and Land Management Services (RLMS)** **Sue Slater – Senior Advisor** 'Overlapping tenures - Managing Underground Resources'
1445	**Break**
1500	***Group 1: Deployment & Demonstration Session*****: Nuclear and Fossil** Chair: David Brockway FTSE Recorder: Ron Hardwick FTSE ***Group 2: Deployment & Demonstration Session*****: Natural and Secure Renewables** Chair: Mary O'Kane FTSE Recorder: Vaughan Beck FTSE
1615	Networking Afternoon Tea
1645	**Summary Plenary Reporting Session** **Moderator: Peter Laver AM FTSE** Reporting back by Break Out Group Chairs Discussion on key points for inclusion in Communiqué **Rapporteur – Mike Sargent AM FTSE** Summary of all key points
1800 1815	Close of Workshop Day 1 **Moderator: Peter Laver AM FTSE** Networking Cocktail Party, Function Area East, First Floor, Crown Promenade Hotel
1845-2100	**Dinner**

INTERNATIONAL WORKSHOP, MELBOURNE 2009

Electricity Generation: Accelerating Technological Change

	WEDNESDAY 1 APRIL 2009 PROGRAMME
	Investment Risks For Deployment
0900	Report on progress to date on Communiqué. Moderator: Peter Laver AM FTSE
0930	**John Sligar FTSE** 'Linking with the Power System'
1000	**South African Academy of Engineering** **Dr Adi Paterson, Fellow and Chief Executive Officer, ANTO** 'South Africa: The future electricity generation in a resource-based economy'
1030	Morning tea
1100	**The Royal Academy of Engineering** **John Loughhead FREng- Executive Director UK Energy Research Council** 'Investment risk reduction for new UK large generation plant'
1130	**Japanese Central Research Institute of Electric Power Industry (CRIEPI)** **Yutaka Nagata** 'CO_2 Emissions Reduction from Electricity Sector in Japan for 2050: The Benefit of Technology R&D'
1200	Lunch
1300	**Ziggy Switkowski FTSE** 'Investment risk in energy technologies for climate change'
1330	**TRUenergy** **Carlo Botto Director – Portfolio Management** 'Facilitating Large Demonstration Generation Plants'
1400	Break
1415	***Group 3: Deployment Investment Risk Reduction*** Chair: Else Shepherd AM FTSE Recorder: John Burgess FTSE ***Group 4: Strategies for Major Demonstrations*** Chair: Frank Larkins AM FAA FTSE Recorder: Ken Dredge FTSE
1600	Networking Afternoon Tea
1630	**Summary Plenary Reporting Session** **Moderator: Peter Laver AM FTSE and Rapporteur – Tim Besley AC FTSE** Reporting back by Break Out Group Chairs Discussion on key points for inclusion in Communiqué **Rapporteur – Tim Besley AC FTSE – Summary of all key points**
1745	Close of Workshop Day 2 – **Moderator: Peter Laver AM FTSE**
1845 for 1915	**Dinner** Guest Speaker: **Drew Clarke, Deputy Secretary, Department of Resources, Energy and Tourism**

INTERNATIONAL WORKSHOP, MELBOURNE 2009

Electricity Generation: Accelerating Technological Change

	THURSDAY 2 APRIL 2009 PROGRAMME
0900–0955	Workshop participants to discuss draft discussion paper 'Maximising Value of Technology in the Energy Sector' as part of the Australian Government's White Paper on Energy – feedback facilitated by Chris Lloyd, Manager Policy Development, Department of Resources, Energy and Tourism.
1000	Morning Tea
1030	Discussion on Workshop Communiqué President, Australian Academy of Technological Sciences and Engineering **Robin Batterham AO FREng FAA FTSE**
1200	Lunch

5 People Profiles

The following were either presenters, facilitators at the breakout sessions or rapporteurs for the summary sessions. Brief biographical profiles on the following are given on subsequent pages.

Robin Batterham AO FREng FAA FTSE
Vaughan Beck FTSE
Tim Besley AC FTSE
Carlo Botto
David Brockway FTSE
John Burgess FTSE
Drew Clarke
Ken Dredge FTSE
Ron Hardwick FTSE
Frank Larkins AM FAA FTSE
Peter Laver AM FTSE
Chris Lloyd
John Loughhead FREng
Andreas Möller
Yutaka Nagata
Tsuneo Nakahara
Mary O'Kane FTSE
Adi Paterson FSAAE
Michael Sargent AM FTSE
Else Shepherd AM FTSE
Sue Slater
John Sligar FTSE
Ziggy Switkowski FTSE
Martin Thomas AM FTSE

BATTERHAM, Robin AO FREng FAA FTSE
President, Australian Academy of Technological Sciences and Engineering
Group Chief Scientist, Rio Tinto Limited
120 Collins Street, Melbourne 3000 AUSTRALIA
E: robin.batterham@riotinto.com

Presentation: 'Deployment and Technology Learning'

Robin Batterham is Group Chief Scientist, Rio Tinto Limited and a Professorial Fellow in the Department of Chemical and Biochemical Engineering at the University of Melbourne. As Group Chief Scientist, Professor Batterham is responsible for developing the Group's long term response to climate change and energy usage.

He has had a distinguished career in research and technology, in the public and private sectors. Robin has worked with CSIRO in areas such as mining, mineral processing, mineral agglomeration processes, and iron making. From 1988, Professor Batterham has held senior positions in Technology Development with CRA Limited. During this time, he led the development of a processing route for what is now recognised as the world's largest economic zinc mineralisation. He also contributed significantly to the HIsmelt process to develop a novel direct smelting technology for iron making. Professor Robin Batterham was Chief Scientist to the Australian Federal Government from 1999 to 2005.

Professor Robin Batterham is also an organist, holding a position at Scots Church in Melbourne.

BECK, Vaughan FTSE
Technical Director, ATSE
197 Royal Parade, Parkville, VIC 3052 AUSTRALIA
E: vaughan.beck@atse.org.au

Vaughan Beck is Technical Director with ATSE and is responsible for the Academy's research projects and the development of policy advice to government in areas such as climate change, energy and water. Dr Beck is the executive officer for ATSE's Energy Forum and he was actively involved in the development of the ATSE report *Energy Technology for Climate Change*, as well as the each of the Academy's other recent reports in the energy domain.

His background has been as a leader, both nationally and internationally, in conducting advanced research and the translation of research results into forms that have been widely adopted in industry. His research relates to the performance of the built environment and includes building performance under cyclonic conditions and building fire safety and protection. He has a diploma and a degree in mechanical engineering, a masters degree in structural engineering and a PhD in fire safety and risk engineering.

In 1989, Dr Beck was appointed as a Visiting Professorial Fellow at the Warren Centre of Advanced Engineering at the University of Sydney where he led a team of some 70 fire safety professionals. Professor Beck's research into building fire safety systems, and the program of reform that he led in Australia, was adopted in Australia and subsequently in a number of overseas countries. In 1991 Dr Beck was appointed as Professor and foundation Director of the Centre for Environmental Safety and Risk Engineering at Victoria University. He was subsequently appointed as Pro Vice-Chancellor (Research) at the University and was a board member of a number of companies including CRCs. Vaughan's awards include the W H Warren Medal awarded by The Institution of Engineers, Australia for outstanding contributions to the field of Civil Engineering, 1976 and the President's Award, Society of Fire Protection Engineers (North America), 1994.

BESLEY, Tim AC FTSE
Chairman, CO2CRC
PO Box 304, Cammeray NSW 2062
E: baroona@ozemail.com.au

Educated:
Bachelor of Engineering (Civil), University of New Zealand
Bachelor of Legal Studies, Macquarie University

Career Highlights:

Chairman of Leighton Holdings Limited	February 1990 to Nov 2001
Chairman Telecommunications Service enquiry	March 2000 to Sept 2000
Chairman of Commonwealth Bank	March 1988 to October 1999
Chairman of The CIG Group	July 1988 to May 1993
Managing Director of Monier Limited	1982 to 1988
Secretary, Commonwealth Department of Business and Consumer Affairs, and Comptroller General of Customs	1976 to 1981
First Assistant Secretary, Department of Treasury	1973 to 1976
Executive Member, Foreign Investment Review Board	1975 to 1976
First Assistant Secretary, Department of External Territories	1967 to 1973
Snowy Mountains Hydro-Electric Authority	1950 to 1967

Current Positions:
Chairman, CRC for Greenhouse Gas Technologies (CO2CRC)
Chairman, Science and Engineering Challenge Council, University of Newcastle
Board Member, The Australian Learning and Teaching Council for Higher Education
Director, IXC Australia Limited

BOTTO, Carlo

Director – Portfolio Management, TRUenergy
Level 33, 385 Bourke Street, Melbourne Victoria 3000 AUSTRALIA
E: jean.hart@truenergy.com.au

Presentation: 'Facilitating large demonstration generation plants'

Carlo Botto has extensive energy industry experience having worked in various roles in the electricity supply industry in Australia and North America over the past 25 years. These roles have included senior positions responsible for wholesale trading in generation, retail and trading sectors of the industry.

Carlo is currently Director – Portfolio Management in TRUenergy, a wholly owned subsidiary of CLP consisting of retail gas and electricity customers and generation assets in the Australian energy market. In this role he is responsible for managing the wholesale position of the gas and electricity assets in the market.

Originally from an electrical engineering background, Carlo gained significant operational experience while working in the New South Wales and Victorian industry where he held various positions in technical, production and commercial roles.

BROCKWAY, David FTSE

Chief, CSIRO Energy Technology
PO Box 330 Newcastle NSW 2300
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David Brockway was appointed Chief, CSIRO Energy Technology, in January 2004. In this role he has responsibility for a Division of about 220 people engaged in R&D on fossil fuels, renewables, energy storage, distributed generation, energy futures modelling and the environment. For the previous decade, David was the Chief Executive Officer of the Cooperative Research Centre (CRC) for Clean Power from Lignite and its predecessor, the CRC For New Technologies For Power Generation From Low-Rank Coal. David is currently a member of the Board of the CRC for Coal in Sustainable Development and of the Centre for Low Emissions Electricity in Queensland. David was previously a member of the Boards of the CRC for Clean Power From Lignite; Generation Technology Research Pty Ltd; and the Centre for Energy and Greenhouse Technologies Pty Ltd. David was also Chairman of Laser Analysis Technologies Pty Ltd, a spin-off company which is a joint venture of the CRC and another private company.

David is also a Fellow of the Australian Academy of Technological Sciences and Engineering, a Fellow of the Australian Institute of Energy and a Fellow of the Australian Institute of Company Directors. Before joining the CRC, David spent 13 years in the Research and Development Department of the State Electricity Commission of Victoria where he was variously Manager Scientific Investigations, Principal Materials Scientist and Head of Coal Science. In total, David has been involved in energy R&D for more than two decades.

BURGESS, John FTSE
Director, Scena Consulting Pty Ltd
P O Box 1215 Research 3095 AUSTRALIA
T: +61 419 379 167
E: burgess.john.jm@bigpond.com

Presentation: 'Stationary Energy Technology for Climate Change Mitigation – The Australian Context'

John Burgess has wide-ranging experience as a senior executive and R&D leader in industry, in strategy development and functional leadership in a global mining company and as an academic in chemical engineering. This experience includes:

- eight years as a prize-winning industrial researcher and three years as an academic undertaking basic, fundamental research;
- nine years as a manager of research, including executive leadership of the largest industrial research facility in Australia (BHP Research);
- five years experience as a senior executive of a major global company (BHP), including general management in safety, environment and sustainable development; and
- experience on Australian boards, including: Sugar Research Institute, Academy of Technological Sciences and Engineering Council, RMIT University Council, Australian Research Council Panels, CSIRO and university research institute Boards, Bilateral International Grants Scheme Panel, Higher Education Council Working Party, Australian Nuclear Science and Technology Organisation Advisory Committee, Australian Iron and Steel Technical Assessment Mission to China (in 1988).

CLARKE, Drew
Deputy Secretary, Department of Resources, Energy & Tourism
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Drew Clarke was appointed Deputy Secretary of the Commonwealth Department of Resources, Energy and Tourism in May 2008, with responsibilities across the three sectors. His previous position was Head of the Energy and Environment Division, where he was responsible for energy market reform, energy security and energy-related climate change policy. Drew's previous roles included head of AusIndustry, the business program delivery agency, and leadership of science agencies. He began his public sector career as a surveyor working in Australia and Antarctica.

DREDGE, Ken FTSE
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Ken Dredge, with degrees in chemical engineering and economics, was Chair of Tarong Energy Corporation Ltd from 1999 to mid-2007. His experience covers mining, energy and associated businesses at management and board levels. Within MIM Holdings Ltd he held positions including Executive General Manager – Mount Isa Operations and as an Executive Director. He was Managing Director of Dominion Mining Ltd from 1994–98. He is currently Chair of APS Consolidated Pty Ltd, a private company making GPS-based positioning systems for large mining equipment, and a director of listed junior mining development company, Queensland Ores Ltd.

HARDWICK, Ron FTSE
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Current
Group Technical Consultant – Visy Pulp and Paper (23 years)
Founder & Director – A.V.T. Services Pty Ltd (20 years) (Vacuum Industry)
Managing Director – Netra Holdings Pty Ltd (25 years) Automated Elec Houses)
Previous
Managing Director – Associated Minerals Pty Ltd (4 years)
Director and Chief Executive – Gases C.I.G. Ltd (now BOC Ltd) 25 years
Graduate
Mechanical and Electrical Engineering – Sydney University
Fellow – Academy Technological Sciences and Engineering
Member – Institute Engineers Australia
Member – Australian Institute Energy

LARKINS, Frank AM FAA FTSE
Chief Scientist for Energy, Victorian Government
Emeritus Professor, School of Chemistry, University of Melbourne
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Frank Larkins is Chief Scientist, Energy at the Department of Primary Industries, Victoria. He also holds an Emeritus Professorship in the School of Chemistry at the University of Melbourne. He previously held the position of Deputy Vice-Chancellor for 18 years at the University of Melbourne with portfolio responsibilities for research, international and global relations at various times. His research interests have been in energy chemistry, synchrotron science, atomic and molecular theory and in science and education policy.

Professor Larkins has been elected to Fellowships of the Australian Academy of Science, the Australian Academy of Technological Sciences and Engineering, the Royal Australian Chemical Institute, the Australian Institute of Physics and the Australian Institute of Energy. Frank has served as President of the Federation of Australian Scientific and Technological Societies, President of the RACI and Honorary Secretary and Vice-President of ATSE.

LAVER, Peter AM FTSE
Vice-President, Australian Academy of Technological Sciences and Engineering
c/- 197 Royal Parade Parkville VIC 3052 AUSTRALIA
E: plaver@ozemail.com.au

Peter Laver holds a range of appointments including memberships of the Climate Ready Committee of Innovation Australia, the Gambling Research Peer Review Panel, and the Appraisal Panel for the CRC Program. He is a director of the Australian Centre for Innovation and the Strategic Industry Research Foundation; Judge for a range of prizes and awards including –Engineering Excellence Awards, Business-Higher Education Roundtable Awards and the National Employment Services Awards. His working career was spent with BHP (now BHP Billiton) in a range of senior management positions in steel, minerals, transport, research and external affairs. Other past positions included Chairman –

Australian Building Codes Board, Chair – Victorian Learning and Employment Skills Commission, Chairman – Energy Research and Development Corporation, Chairman – CSIRO Energy Sectoral Advisory Committee, Chair – Community Advisory Council for the Community Support Fund, Chairman – Ceramic Fuel Cells Limited, Chancellor – Victoria University of Technology, Deputy Chair Australian Science and Technology Council (ASTEC), Chairman – Koppers (Australia), AUQA Auditor and Chair - National Board of Employment, Education and Training (NBEET).

- Fellow of the Australian Academy of Technological Sciences and Engineering
- Honorary Fellow of the Institution of Engineers Australia
- Fellow Australasian Institute of Mining and Metallurgy
- Advanced Management Program – Harvard University
- Centennial Medal
- Member Order of Australia (AM)

LLOYD, Chris
Manager – Policy Development Energy White Paper, Department of Resources, Energy and Tourism
GPO Box 1564, Canberra ACT 2601 AUSTRALIA
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Chris Lloyd is an adviser on public policy for the Australian Government, Department of Resources Energy and Tourism. He is a Manager, Policy Development, for the Energy White Paper, a process to identify a comprehensive public policy framework for energy, durable through to at least 2030. Previously he has been involved in a range of policy development and advising roles including: seconded to the Department of Prime Minister and Cabinet, and Department of Climate Change, to advise on coverage issues in preparation of the Carbon Pollution Reduction Scheme, Green Paper; and nearly two decades experience as a senior policy adviser in a number of resources and energy industry roles including, major resources investments, coal seam gas, GTL/CTL, technology research and development, environment and oceans policy, gas reform and pipeline access. He has an honours degree in economics and masters in environmental law and administration.

LOUGHHEAD, John FREng
Executive Director, UK Energy Research Council
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Presentation: 'UK initiatives for low emission generation demonstration and deployment'

John Loughhead is Executive Director of the UK Energy Research Centre and was previously Vice-President of Technology and Intellectual Property for the Alstom group in Paris.

For several years John has been extensively involved in UK and European public sector technology programs, as a member of various advisory committees and chair of policy reviews in the area of future electric power systems. He is a non-executive Director of the UK Ministry of Defence R&D Board, member of the UK Energy Research Partnership, Assessor for the UK Technology Strategy Board, member of the European Commission Advisory Group on Energy, and was previously a member of the Engineering & Physical Sciences Research Council.

John is a graduate in Mechanical Engineering from Imperial College, London, where he also spent five years in computational fluid dynamics research. His professional career has been predominantly in industrial research and development for the electronics, power and transport industries. He led the teams that initiated high temperature fuel cell research in the UK and formed the consortium that built the world's largest high temperature superconducting motor.

John is a Chartered Engineer, a Fellow of the Royal Academy of Engineering, Past-President of the Institution of Engineering and Technology (IET), and Fellow of the Institution of Mechanical Engineers, the City & Guilds of London Institute and of the Royal Society of Arts. He was Co-Chair of the Implementation Panel for the European Fuel Cell & Hydrogen Technology Platform and is presently Co-Chair of the Implementation & Liaison Committee, International Partnership for the Hydrogen Economy.

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Presentation: 'Energy supply & demand situation in Germany'

Andreas Möller has been with acatech in Berlin since 2005 coordinating the Academy's external activities in the fields of energy supply and climate change. He has also been involved in the acatech energy supply and its mobility interior networks. Previous to this he worked for Deutschlandradio as a news and politics journalist and was a speechwriter for DaimlerChrsyler's CEO.

Andreas obtained his PhD at Humboldt University on the topic of the influence of modern physics on Philosophy, Literature, and Media in Weimar Germany. His Masters also from Humboldt was taken in History and German.

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Presentation: 'CO_2 Emissions Reduction from Electricity sector in Japan for 2050: The Benefit of Technology R&D'

Field of Interest
Systematising the measures to assess the energy and electricity technologies from various sides and on the desirable future systems of energy supply, especially to build a less CO_2 and energy-secure society.
Professional Career
Visiting Associate Professor, Tokyo Institute of Technology (April 2000 – present)
Senior Research Scientist, Socio-Economic Research Center, Central Research Institute of Electric Power Industry (1999 – present)
Associate Professor, Kyoto University (May 1996 – March 1999)
Research Scientist, Economic Research Center, Central Research Institute of Electric Power Industry (1987–96)
Education
Tokyo Institute of Technology, Japan, Received Bachelor of Science (1981–85)
Tokyo Institute of Technology, Japan, Received Master of Engineering (1985–87)
Kyoto University, Japan, Received Doctor of Energy Science (March 1999)

NAKAHARA, Tsuneo
President, Engineering Academy Japan
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Presentation: 'The Demonstration and Deployment Initiative in Japan – Future Grid, Superconductor and Nuclear Power'

Tsuneo Nakahara has been President of the Engineering Academy of Japan since May 2006 and was President of the Japan Society for Science Policy and Research Management (JSSPRM) from October 2005 to October 2006. He is also Co-Chair of Japan Society for Technology, Inspector General of Japan Society for the Promotion Science and Vice-President of Japan Technology and Economy Society.

He received a BS degree and a PhD degree of engineering from University of Tokyo in 1953 and in 1961 respectively. He joined Sumitomo Electric Industries, Ltd. in 1953 and worked on a wide range of topics in the microwave, cybernetics, electronics and communication fields at R&D Laboratories, and related business Divisions. He later played a role of Executive Vice President from 1985–91 and Vice Chairman from 1991–97 as well as adviser to the CEO until 2005.

His outstanding achievements include the conception, design and manufacturing of optical fibre and cables from the late 1950s to 1980s, his leadership of important research and developments such as the HIOVIS project, the world first fibre to the home, the leaky coaxial cables communication system for the bullet train of the JR, the world largest vehicular traffic control system by computer for Metropolitan Tokyo, Intelligent Transportation Systems including the car navigation system today as well as the world first high temperature superconductivity power cable for NY in the US.

O'KANE, Mary FTSE
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Mary O'Kane is NSW Chief Scientist and Scientific Engineer. She is a specialist in technology, national and international research strategy and higher education policy and is Executive Chairman of Mary O'Kane & Associates Pty Ltd, a Sydney-based company that advises governments, universities and the private sector on innovation, research, education and development.

Professor O'Kane was Vice-Chancellor of the University of Adelaide from 1996 to 2001 and Deputy Vice-Chancellor (Research) from 1994–96. She was also Professor of Electrical and Electronic Engineering within the University.

Professor O'Kane serves on a number of boards and committees in the public and private sectors. She is Vice-Chair of the Development Gateway Foundation, Chair of the Cooperative Research Centre (CRC) for Spatial Information, Chair of the Australasian CRC for Interaction Design, and a director of ipernica Ltd and PSMA Ltd. She is a member of the Tax Concession Committee and of the board of the Australian Business Foundation. She was formerly a director of FH Faulding & Co Ltd and a member of the Australian Research Council, the Cooperative Research Centres Committee and the board of CSIRO. Professor O'Kane was a member of the Review of the National Innovation System and Chair of the Review of the Cooperative Research Centres Program.

PATERSON, Dr Adrian FSAAE
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Adrian (Adi) Paterson is the Chief Executive of the Australian Nuclear Science & Technology Organisation (ANSTO).

Previously he was general manager, Business Development and Operations, at the Pebble Bed Modular Reactor Company in South Africa. He has a BSc in Chemistry and a PhD in Engineering from the University of Cape Town. From 2001 to 2006, Dr Paterson worked at the Department of Science and Technology in various science policy roles including the development of national innovation instruments and Research and Development strategy. From 1984 to 2001, he worked at the Council for Scientific and Industrial Research in South Africa, rising through a number of assignments to the position of Executive Vice President and Chief Information Officer.

SARGENT, Michael AM FTSE
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Mike Sargent is a Director of M.A.Sargent & Associates, providing strategic corporate consulting services to industry, with a particular focus on the information technology, research, energy, environment and utilities sectors. Prior to this he was Chief Executive of Transfield Energy Group, and before that was Chief Executive Officer of ACTEW Corporation from November 1991. Dr Sargent has 45 years' experience in the utility industry in Australia, USA and Canada. Dr Sargent is a Director of the National Electricity Market Management Company, of the Australian Energy Market Operator, and of National ICT Australia. He is Chair of the eResearch Coordinating Committee and of the National Collaborative Research Infrastructure Committee. He is Chairman of Lighthouse Innovation Centre limited, a high technology seed fund and incubator. He is an Adjunct Professor of the University of Technology Sydney and of the University of Queensland.

Mike has a degree in electrical engineering and a Doctor of Philosophy from the University of Queensland.

He is active in professional and community matters. He is a Fellow of the Australian Institute of Company Directors, a Fellow of the Australian Academy of Technological Sciences and Engineering, Academician of the International Academy for Quality, and was President of The Institution of Engineers Australia in 1990. In recognition of his service to engineering he was made a Member of the Order of Australia in 1993 and was awarded a Centenary Medal in 2003.

SHEPHERD, Else AM FTSE
Chairman, Powerlink Queensland
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Present Positions

- Founder/Executive Director, Mosaic Information Technology Pty Ltd
- Chairman, Powerlink Queensland (1994 –)
- Director, National Electricity Market Management Company Pty Ltd (NEMMCO) (1995 –)
- Member, Council Board, International Electrotechnical Commission (IEC) (2004 –)
- Board of Trustees, Brisbane Girls Grammar School (2002 –)
- Chairman, Queensland Government Smart Women Smart State Task Force (2005 –)
- Member, Brisbane CityWorks and CityDesign Advisory Boards (2007 –)
- Deputy Chairman, International River Foundation (2007 –)
- Member, QUT Faculty of Science Advisory Committee (2007 –)

Qualifications

- 1965 B.E. (Hons, Elec), The University of Queensland, CPEng, RPEQ
- 1984 Grad. Dip. Mus., Queensland Conservatorium of Music, A.Mus.A

SLATER, Sue
Senior Advisor – Petroleum, Resource and Land Management Services
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Presentation: 'Overlapping tenures – Managing Underground Resources'

Sue Slater is currently a full-time staff member of RLMS with responsibility for various aspects of tenure management for several client companies; pipeline approvals, and landowner liaison. Sue graduated from the Australian National University with a Bachelor of Science majoring in geology in 1980. Since then she has completed further study at the University of Queensland and a Graduate Diploma in Business Administration from QUT. She has previously worked for the Geological Survey of Queensland, Department of Mines and Energy and Tipperary Oil & Gas (Australia) Pty Ltd. In these roles she has variously been responsible for technical assessment of petroleum tenure applications, preparation of annual reports, well completion reports, preparation of applications for various petroleum tenures, environmental reporting and compliance, tenure compliance, land management, well site assessment, well logging and geological evaluation. She is currently a member of PESA and QUPEX, and has been on the Queensland/Northern Territory PESA committee since 2007.

SLIGAR, John FTSE
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Presentation: 'Linking with the Power System'

John Sligar, BE(Chem), MEngSc, PhD, is well recognised for his significant and continuing contribution to the technical advancement of the electricity generation industry in Australia and to engineering education in the field of energy. His interests cover Chemical Engineering, Power Engineering and the development of sustainable technology for the competitive energy industry. He is a Director of Sligar and Associates, an energy consulting organisation focusing on the development of sustainable electricity generation for the next 30 years, since his retirement from Pacific Power in 1995.

He was formerly Chief Scientist, Pacific Power, the then largest electric utility in Australia, leading a team seeking an economic mix of energy generation capacity for the future. During this time a subsidiary, Pacific Solar was created to manufacture thin film solar cells. Dr Sligar has also served on a wide range of national and international committees dedicated to the advancement and transfer of technology for power generation, to engineering education and to the promotion overseas, particularly in the Asia Pacific region, of Australian energy resources and appropriate technology for electricity generation. He has made a substantial contribution to UNDP and Australian Government projects through the provision of structural and technical content as well as major lecturing content for a series of power technology courses delivered to more than 1500 personnel over 20 years from more than 30 economies. Dr Sligar has participated in numerous Missions and Workshops, as a part of Australian Government delegations, covering many aspects of power generation. He has undertaken numerous overseas visits to inspect plant, negotiate contracts and present technical papers at International Conferences and APEC Meetings on energy matters.

Dr Sligar is a Fellow of the Australian Academy of Technological Sciences and Engineering, the Institution of Chemical Engineers, London, Engineers Australia and the Australian Institute of Energy. In 1994 he was awarded an Honorary Doctorate of Engineering by the University of Newcastle.

SWITKOWSKI, Ziggy FTSE
Chairman, Australia Nuclear Science and Technology Organisation
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Presentation: 'Investment Risk in new technologies for energy generation'

Ziggy Switkowski is the chairman of the Australian Nuclear Science and Technology Organisation. He is also a non-executive director of Suncorp, Tabcorp, Healthscope and Opera Australia. In 2006 he chaired the Prime Minister's Review of Uranium Mining, Processing and Nuclear Energy which returned nuclear power to the country's national debate on energy strategy.

Dr Switkowski is a graduate of the University of Melbourne with a PhD in nuclear physics and he is a Fellow of the Australian Academy of Technological Sciences and Engineering.

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Martin Thomas has had a lifetime career in energy consulting, concluding as a Principal of Sinclair Knight Merz. Later he was founding Managing Director of the Cooperative Research Centre for Renewable Energy, ACRE. Former external roles include Deputy Chairmanship of Australian Inland Energy, non-executive Directorships of the Tyree Group and EnviroMission, Chairmanships of industry association Austenergy; the NSW Electricity Council and the Sydney 2000 Olympic Energy Panel. He is currently Chairman of Dulhunty Power Limited (ASX:DUL) and Alecto Energy Plc; Chancellor of the Asia Pacific International College (APIC) and Advisor to the Board of ZBB Energy.

In 2006 Martin Thomas served as a member of the Prime Minister's Uranium Mining, Processing and Nuclear Energy Review taskforce known as UMPNER.

He is a past President of the Institution of Engineers, Australia and of the Australian Institute of Energy. He was awarded the 2008 Peter Nicol Russell Memorial Medal of the Institution of Engineers, Australia.

Martin was elected to ATSE in 1992, served on Council from 1994-2000 and was a Vice-President from 1996-2000, serving as Chairman of the Symposium Committee from 1999-2000. He is an active member of the NSW Division Committee, chairing its Membership Committee for many years. He served on Symposium Organising Committees in 1997, 2002 and 2006.

In 2007, with the founding of the Academy's Topic Forums, he was appointed Chairman of the Energy Forum. In that role he led the ATSE ARC funded project on Transport Biofuels, is on the Steering Committee of the Energy Externalities Project and is leading the President's project Accelerating Technological Response to Climate Change.

6 Delegate List

ALDOUS, Richard – Acting Deputy Secretary, Energy, Earth Resources, Major Projects, Victorian Department of Primary Industries

ANGWIN, Michael – Executive Director, Australian Uranium Association

BADWAL, Sukhvinder FTSE – Chief Research Scientist, CSIRO

BATTERHAM, Robin AO FREng FAA FTSE – President, ATSE, Group Chief Scientist, Rio Tinto Ltd

BECK, Vaughan FTSE – Technical Director, ATSE

BENSLEY, Stuart – Interim CEO, Oceanlinx Ltd

BESLEY, Tim AC FTSE – Chairman, CO2CRC

BOTTO, Carlo – Director Portfolio Management, TRUenergy

BROCKWAY, David – Chief, CSIRO Energy Technology

BUTLER, Paul – Principal Energy Advisor, NSW Dept of State &Regional Development

BURGESS, John FTSE – Director, Scena Consulting Pty Ltd

CHARTERS, Bill FTSE – Emeritus Professor, Mechanical and Manufacturing Engineering, University of Melbourne

COOK, Peter CBE FTSE – Chief Executive, CO2CRC

CLARKE, Drew – Deputy Secretary, Department of Resources, Energy & Tourism

CROFT, David AM FTSE – Board Member, NEMMCO

DAVEY, Brian – Manager Large Scale Demonstration Projects, ETI, Department of Primary Industries, Victoria

DREDGE, Ken FTSE – Formerley, Chair of Tarong Energy Corporation Limited

DUREAU, Mike FTSE – Chairman and Executive Director, The Warren Centre for Advanced Eng Ltd

GAY, Geoff – Business Development Manager, TRUenergy

GILLESPIE, Allan FTSE – Managing Director, AustAsia Management Services Pty Ltd

GODFREY, Bruce – Interim Executive Director, Australian Solar Institute

HARDWICK, Ron FTSE – Group Technical Consultant, Visy Pulp and Paper

HARRIS, David – CSIRO Energy Technology, QCAT

HARTLEY, Dr Margaret – CEO, ATSE

HOLLAND, Dave – Managing Director, Solar Systems

HUNWICK, Richard – Managing Director, Hunwick Consultants Pty Ltd, and Integrated Carbon Sequestration Pty Ltd

JACKSON, Murray FTSE – Managing Director, Westernport Water Corporation

JOHNSTON, Mark – Head of NEM Department, NEMMCO

LAVER, Peter AM FTSE – Vice President, ATSE

LOUGHHEAD, John FREng – Executive Director, UK Energy Research Centre

LA NAUZE, Rob FTSE – Director Technical Strategy Advisors Pty Ltd

LARKINS, Frank FAA FTSE – Chief Scientist for Energy, Victorian Government

LLOYD, Chris – Manager Policy Development Enery White Paper, Department of Resources, Energy and Tourism

MÖLLER, Andreas – Consultant, acatech

MacGILL, Iain – Joint Director (Engineering), Centre for Energy and Environmental Markets (CEEN, UNSW)

MANTON, Mike FTSE – Chair, ATSE International Strategy Group

NAGATA, Yutaka – Senior Research Scientist, Socio-Economic Research Centre, Central Research Institute of Electric Power Industry, Japan

NAKAHARA, Tsuneo – President, Engineering Academy of Japan

NUTT, John AM FTSE – Vice President, ATSE

O'KANE, Mary FTSE – NSW Chief Scientist and Scientific Engineer

PATERSON, Adi FSAAE – Chief Executive Officer, ANSTO

POOLE, Martin – Executive Director, EPURON Pty Ltd

PRATT, Kerry FTSE – Faculty of Engineering, Monash University

PRITCHARD, Bob – ResourcesLaw International

REDLICH, Peter – Director, Energy Technology Division, Department of Primary Industries, Victorian Government

SAITO, Takuya –First Secretary for Science, Technology and Environment, Embassy of Japan, Canberra

SARGENT, Mike AM FTSE – Director, MA Sargent and Associates

SCHUCK, Stephen – Manager Bioenergy Australia

SHEPHERD, Else AM FTSE – Chairman, Powerlink Queensland

SIMMONS, John FTSE – Vice President, ATSE

SLATER, Sue – Senior Advisor – Petroleum, RLMS

SLIGAR, John FTSE – Director, Sligar and Associates

SÖDERBAUM, John – Executive Director, ACIL Tasman

ST BAKER, Trevor – Executive Chairman, ERM Power Pty Ltd

STARK, Peter – Head of Carbon, ERM Power Pty Ltd

SWITKOWSKI, Ziggy FTSE – Chairman, ANSTO

TANNER, David FTSE – Design/Project Engineering Manager, AE&A Australia Pty Ltd

THOMAS, Martin AM FTSE – Chairman Dulhunty Power Ltd

TYREE, Peter FTSE – Immediate past Chairman, Tyree Group and Advisor Tyree Group

WIBBERLEY, Louis – Principal Technologist, CSIRO Energy Technology

WILLIAMS, Adrian – Vice President, Aust Geothermal Energy Association; Advisor, Geodynamics Ltd

ZHU, Joe – Professor of Electrical Engineering, Head, School of Electrical, Mechanical and Mechatronic Systems, Faculty of Engineering and IT, University of Technology, Sydney

ATSE – in brief

The Academy of Technological Sciences and Engineering (ATSE) is an independent, non-government organisation, promoting the development and adoption of existing and new technologies that will improve and sustain our society and economy.

ATSE consists of more than 770 eminent Australian Fellows and was founded in 1976 to recognise and promote the outstanding achievement of Australian scientists, engineers and technologists.

ATSE provides a national forum for discussion and debate of critical issues about Australia's future, especially the impact of science, engineering and technology on quality of life.

ATSE links Australia with leading international bodies and worldwide expertise in the technological sciences and engineering.

ATSE fosters excellence in science, engineering and technology research and the critical education systems that underpin Australia's capacity in these areas.

ATSE tackles many of the most difficult issues governing our future, by offering fresh ideas, practical solutions and sound policy advice – and putting them on the public record.

Tarong Power station at dusk.
Photo: Tarong Power

ELECTRICITY GENERATION: ACCELERATING TECHNOLOGICAL CHANGE – International Workshop

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