AUSTRALIA

Department of Resources, Energy and Tourism,
Commonwealth Industrial Science and Research Organization

INTRODUCTION AND BACKGROUND

Australia is the world's ninth largest energy producer. It accounts for around 2.4% of world energy production. Australia is also the world's twentieth largest primary energy consumer.[1]

Australia possesses an abundance of high quality energy resources, with 47.5% of world uranium resources, 10.6% of world black coal resources, and 8.9% of world brown coal resources. As such, Australia is a net exporter of energy, with exports accounting for 68% of domestic energy production in 2008–09.[1] In 2009–10, energy exports accounted for 34% of Australia's total goods and services exports.[1]

Australia possesses only around 0.3% of world oil reserves, and is a net importer of crude oil and refined petroleum products.[1]

Australia's primary energy consumption is dominated by coal, petroleum products and gas. Renewable energy sources account for around 5% of Australia's primary energy consumption, and around 7% of electricity generation (4.7% from hydroelectricity). Wind energy now represents 1.5% of total electricity generation. However, many emerging renewable energy technologies, such as large-scale solar and geothermal, have the potential for commercial deployment in the context of appropriate market frameworks and support for research, development and demonstration.[1]

Recognizing the need to focus upon renewable and clean energy technologies, Australia has a Renewable Energy Target (RET) of 20% of electricity generation from renewable sources by 2020.

Australia is a member of the International Energy Agency Hydrogen Implementing Agreement and the International Partnership for the Hydrogen Economy.

ENERGY FRAMEWORK

The Australian Government is expected to announce its plan for a clean energy future (www.cleanenergyfuture.gov.au) in 2011. The vision is a future which will cut pollution and drive investment in new clean energy sources. This plan will be the primary driver for innovation in low-emission technologies, including hydrogen and fuel cells. The plan is expected to put a price on carbon, and will deliver new significant new initiatives to support investment and innovation in clean and renewable energy.

The $10 billion Clean Energy Finance Corporation is expected to drive innovative solutions to businesses seeking funds to launch clean energy and energy efficiency proposals and technologies.

The Australian Renewable Energy Agency (ARENA) will be an independent statutory body, managing $3.2 billion in funding in existing Australian Government renewable energy grants supporting research and development of renewable energy technologies and initiatives to bring them to market. Around $1.7 billion of this funding is currently

VITAL STATISTICS

Population

22,582,734

(Population clock, Australian Bureau of Statistics [ABS])

Territory

7,692,024 km²

Capital

Canberra, Australian Capital Territory

GDP/capita

AUD 57,827 (2009-10) (ABS)

GDP Growth

GDP percentage change from previous year

2007-08	3.8%
2008-09	1.4%
2009-10	2.2%

Australian Economic Indicators (March 2011) www.ausstats.abs.gov.au

Primary Energy Structure

Production

2008-2009

	PJ	%
Black coal	8,904.0	50.1
Brown coal	668.0	3.8
Renewables	303.0	1.7
Crude oil, condensate	1,132.0	6.4
Gas	1,916.0	10.8
Uranium	4,846.0	27.3
Total	17,769.0	

Energy in Australia 2011, www.abares.gov.au

Electricity Production

2008-2009

Generation capacity: *51.0 GW*

Generation (including off-grid electricity): *261.0 TWh*

Energy in Australia 2011
www.abares.gov.au

Electricity production by fuel 2008-2009

	TWh	%
Black coal	143.2	54.9
Brown coal	56.9	21.8
Oil	2.6	1.0
Gas	39.1	15.0
Hydro	12.3	4.7
Wind	3.8	1.5
Solar	0.3	0.1
Biomass	1.5	0.6
Biogas	1.3	0.5
Total	261.0	

Energy in Australia 2011, www.abares.gov.au

Consumption

Electricity consumption 2008-2009

Total electricity:	939.0 PJ
	of which
Hydro electricity:	44.0 PJ
Wind energy:	14.0 PJ
Solar electricity:	0.6 PJ

Energy in Australia 2011
www.abares.gov.au

uncommitted and will be available for ARENA to provide early-stage grants and financing assistance for projects that strengthen and drive down the costs of renewable energy technologies.

The Clean Technology Innovation Program will provide $200 million in grants to support business investment in renewable energy, low emissions technology and energy efficiency.

HYDROGEN RD&D SPECIFICS

PROGRAMS, PROJECTS AND INITIATIVES

Status and accomplishments

Australian hydrogen RD&D programs operating in Government research laboratories, industrial laboratories and universities are listed in the Australian Hydrogen Activity 2008 report. Many of these programs have international linkages.

In 2010, there was a strong level of activity in Australian research on photo-electrochemical hydrogen production and on hydrogen storage. The Maschmeyer/Masters group at the University of Sydney has investigated modification of the crystal structures of mixtures of the wideband-gap semiconductors ZnO and ZnS to produce hydrogen (H_2) by absorption of visible light. While the composites were not stable in the electrochemical cell, they did generate appreciable amounts of H_2 in the presence of a sacrificial solution under visible light irradiation and the synergistic effect between the two phases was elucidated in part.

The Maschmeyer/Masters group also investigated use of visible-light-absorbing dyes to increase the visible light performance of TiO_2. To limit leaching of the dye, a photocatalytic structure, constituted by a platinized TiO_2 membrane self assembled onto a dye-sensitized supporting structure, was designed. Anatase TiO_2 nanocrystals were deposited onto the surface of dye coated polystyrene spheres at low temperature using ionic liquids. The low temperature synthesis removed the need for calcinations, which would have destroyed the organic material in the structure. The structure showed improved stability under irradiation in aqueous solution, and comparable hydrogen evolution rates compared to structures in which the dye was deposited onto the surface of the TiO_2.

A third component of the University of Sydney research is in active site engineering, with emphasis on the synthesis of heterogeneous catalysts employing unconventional solvents, in particular, the use of ionic liquids. This class of solvents has the ability to passivate, and therefore stabilize, surfaces with high energy, which may also be the reactive surface of the catalyst solid. In this manner, a highly active MoS_2 was produced (maximizing edge sites and delamination) as HER electrocatalysts that also work in combination with CdS, where it replaces platinum as co-catalyst.

Research at the University of Western Sydney, led by Professor Janusz Nowotny, has continued work on titania-based photo-electrodes (photo-anodes and photo-cathodes) for photo-electrochemical hydrogen generation. The research established the effect of lattice imperfections of rutile (point defects) on its reactivity with oxygen and water. It was shown that titanium vacancies at the surface from the reactive sites lead to either partial or total water oxidation. The reactivity and the related semiconducting properties of rutile immersed in water must be considered in terms of the presence of protons in its lattice. Therefore, research has been carried out to understand the effect of protons in rutile on water oxidation.

A CSIRO group in Newcastle led by Dr Jim Hinkley, in collaboration with Associate Professor Scott Donne from the University of Newcastle, has been studying the electrochemistry of the Hybrid Sulfur cycle. This cycle is one of the most promising high temperature water splitting processes, because it involves an electrolysis step that consumes less than 40% of the power for conventional alkaline electrolysis. This power saving is possible because the electrolysis reaction involves the oxidation of sulfur dioxide to sulfuric acid. A thermochemical reaction at around 900°C – suitable for concentrated solar energy – is used to capture thermal energy and reduce the sulfuric acid to sulfur dioxide to complete the cycle.

The team has identified that many of the past inconsistencies of platinum catalyst performance can be explained by an understanding of the surface properties of the catalyst, and in particular the amount of reduced sulfur species. Dithionate anion is likely to be a key intermediate species. Current experiments are investigating the oxidation mechanism on gold and mixed metal catalyst surfaces.

CSIRO is developing two technologies for the separation and purification of hydrogen from mixed gas streams. One program aims to minimize the consumption of expensive and strategic metals (for example, palladium) by developing alloys for separation membranes formed primarily from Group IVb and Vb metals such as V, Nb, and Zr.

The main application of this technology is the separation of H_2 from CO_2-rich gas streams resulting from the conversion of carbon-based fuels. Alloys have been identified which meet international performance targets for hydrogen permeability (> 1 x 10-7 mol m^{-1} s^{-1} $Pa^{-0.5}$), cost (< \$1000 m^{-2}), temperature (up to 450°C) and hydrogen purity (> 99.999%). Research is presently focused on achieving the target membrane lifetime of five years and the development of membrane reactors with in-situ hydrogen separation. The process intensification achieved through the membrane reactor configuration allows hydrogen to be produced with greater efficiency than stand-alone conversion and separation processes, and allows for the integration of hydrogen production using concentrated solar-thermal energy.

The second technique employs Metal-Organic Frameworks (MOFs). MOFs provide a range of structures that could potentially separate hydrogen while blocking larger molecules in various mixtures. Computational modeling identified the most promising candidates. A particular framework, Zeolitic Imidazolate Framework-11 (ZIF-11), appears capable of achieving infinite selectivity of hydrogen at a reasonably high rate of 0.6 x 10^{-6} mol $m^{-2}s^{-1}Pa^{-1}$. This selective capability has been observed in another MOF based on Cu, where the pore geometry restricted gases other than hydrogen. The next step is to synthesize these structures within a membrane module to maximise the gas-framework contact, hence maximise efficiency.

Research is being conducted to find materials that can store more hydrogen than compressed cylinders; based on the material's porosity and surface area available. The materials of interest are known as metal organic frameworks (MOFs) and porous aromatic frameworks (PAFs). Some of the initial testing with CSIRO synthesized PAFs has identified key aspects for an effective storage material; how well hydrogen absorbs to the material (enthalpy of absorption) and charged metal sites. These two aspects have shown an increase of gas up take that are matching the current best performing MOFs in the literature. Performance improvements of the highly porous PAF, is a direct result of the inclusion of lithium metal.

Participation

Participants in Australian hydrogen RD&D are listed in the Australian Hydrogen Activity 2008 report.[2] In 2010, Australian researchers participated in IEA HIA Tasks 22 (Hydrogen Storage) and 25 (High Temperature Production). In addition, there is interest in participating in Tasks 28 (Hydrogen Delivery Infrastructure) and 30 (Global Hydrogen Systems Analysis) in 2011.

Funding

Australian university based research into Australian hydrogen RD&D is generally funded by:

- in-house funding;
- industrial funding;
- Australian Research Council grants; and
- specific Government programs.

ENDNOTES

1] Energy in Australia 2011, Australian Bureau of Agricultural and Resource Economics and Science, www.abare.gov.au

2] Australian Hydrogen Activity 2008, Department of Resources, Energy and Tourism (DRET), www.ret.gov.au

REFERENCES

DRET website: www.ret.gov.au

CSIRO website: www.csiro.au

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