AUSTRALIA

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INTRODUCTION AND BACKGROUND

Australia’s economy and prosperity are built on access to secure, affordable and reliable energy. Australia’s energy diversity is one of its natural strengths and a key competitive advantage. This diversity provides Australian homes and business access to the energy needed to build its industries and communities. Australia’s coal, gas and uranium exports supply global markets hungry for energy security. The depth of the Australian energy resource base will support continued energy production well into the future.

The energy sector plays a vital role in the Australian economy, accounting for 7% of GDP and $71.5 billion in export earnings in 2013–14. Australia is among the world’s largest exporters of LNG, coal and uranium, and its importance to global energy markets will continue to grow. Energy related industries also contributed 1.5% to total Australian employment in 2013–14, and provided significant infrastructure investments. In Australia, renewable energy sources are currently used for generating electricity, both on and off-grid, as well as for residential heating and cooling, transport fuels, and heat production in the manufacturing sector. Hydro and wind energy are used on a commercial scale for electricity generation. Solar energy use is growing for electricity generation, both on and off grid, and for heating and cooling. Bioenergy is used for small scale electricity generation, directly for heating and cooling in residential and industrial settings, as well as for transport fuels.

Australia has an abundance of renewable energy sources and there is significant potential for future development in large scale solar energy, geothermal energy and marine energy. Many of these renewable technologies are currently at the proof of concept stage, or in the early stages of commercialisation. Upfront costs continue to be relatively high for many renewable energy technologies. Additionally, some renewable energy sources are far from transmission and distribution infrastructure and markets, making development costly and difficult.

ENERGY FRAMEWORK

UPDATE ON RELEVANT POLICIES AND PROGRAMS (2010-2015)

Australia has a rich diversity of renewable energy resources (wind, solar, geothermal, hydro, wave, tidal, bioenergy). Greater use of many energy sources with lower greenhouse gas emissions (especially renewable energy sources) is currently limited by the immaturity of technologies and the cost of electricity production. Advances in technology supported by industry and government actions are expected to result in commercial electricity production by 2030 from sources that are currently only at the demonstration stage.

Australia’s energy usage in 2030 is expected to differ significantly from today’s usage under the influence of the 20% Renewable Energy Target and other government policies, such as the proposed emissions reduction target. Australia’s long-term energy projections show total energy production nearly doubling due to strong export demand. Primary energy

VITAL STATISTICS

If EU Member, so state

Population
22,751,014 (https://www.cia.gov/library/publications/the-world-factbook/geos/as.html)

Territory
- total: 7,741,220 sq km
- land: 7,682,300 sq km
- water: 58,920 sq km

Capital
Canberra

GDP/capita
$65,400 (2015 est.)

Average Annual GDP Growth
GDP - real growth rate: 2.4% (2015 est.)

Primary Energy Structure
- Primary energy production in Australia was 19,318 petajoules in 2012–13
- Production: Coal accounted for 59% of Australia’s energy production on an energy content basis in 2012–13, followed by uranium (22%).
- Natural gas accounted for 13% of energy production, oil a further 5%, while renewable energy—mostly bioenergy and hydro—contributed 2%.

Imports
Australia’s energy imports were valued at $40.8 billion in 2012–13. Crude oil and refined petroleum products were the predominant energy imports, which were valued at $20.4 billion and $17.9 billion respectively. Australia is a net

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importer of crude oil and refined petroleum products, with net imports accounting for 35 per cent of oil consumption in 2012–13, compared with 7 per cent a decade ago.

**Exports**

Australia’s net energy exports (exports minus imports) in 2012–13 were equivalent to 68 per cent of production. Energy exports accounted for 31 per cent of the value of Australia’s total commodity exports in 2013–14, and were valued at $71.5 billion. Coal was the largest energy export earner, with a value of around $40 billion in 2013–14, followed by LNG ($16.4 billion) and crude oil ($11.1 billion).

Earnings from energy exports fell by 12 per cent in 2012–13, largely as a result of lower coal prices. Earnings rose by 6 per cent in 2013–14, supported by higher LNG prices. Australia’s real energy export earnings have increased by 8 per cent a year on average over the past ten years.

**Electricity**

**Production**

- Total production: 235.2 billion kWh (2012 est.)
- Electricity - consumption: 222.6 billion kWh (2012 est.)
- Electricity - installed generating capacity: 63.25 million kW (2012 est.)

- Electricity - from fossil fuels: 78.5% of total installed capacity (2012 est.)
- Electricity - from nuclear fuels: 0% of total installed capacity (2012 est.)

Electricity consumption is expected to rise by 35% and electricity demand is expected to increase by nearly 50% by 2030. Whilst coal is expected to continue to dominate Australia’s electricity generation, a shift to lower-emissions fuels is expected to result in a significant reduction in coal’s market share and concomitant increases in gas and renewable energy, particularly wind.

Australia’s energy infrastructure is concentrated in areas where energy consumption is highest and major fossil fuel energy resources are located. Greater use of new energy resources, particularly renewable energy sources, will require expansion of Australia’s energy infrastructure, including augmentation of the electricity transmission grid.

The Australian Government has a target of 20% generation of electricity from renewable sources by 2020. The government is now considering its response to the Recommendations of the Climate Change Authority 2014 Renewable Energy Target (RET) Review.

The $5.1 billion Clean Energy Initiative (CEI) complements the Renewable Energy Target (RET) by supporting the research, development and demonstration of low emission energy technologies.

The $5.1 billion Clean Energy Initiative (CEI) consists of:

- The Solar Flagships Program, which supports the construction and demonstration of large-scale grid-connected solar power stations in Australia, may include solar, thermal, photovoltaic, and energy storage technologies. In addition, the Government has provided $100 million to the Australian Solar Institute (ASI), which aims to increase the cost-effectiveness of solar technologies and accelerate the capacity of solar industries in Australia; thereby assisting in meeting the Government’s expanded Renewable Energy Target of 20% by 2020.

- The Australian Centre for Renewable Energy (ACRE), which will promote the development, commercialization and deployment of renewable technologies through a commercial investment approach.

- The Renewable Energy Future Fund, which will support the development and deployment of large- and small-scale renewable energy projects and will enhance take-up of industrial, commercial, and residential energy efficiency.

- The Carbon Capture and Storage Flagships Program that supports the construction and demonstration of large-scale integrated carbon capture and storage projects in Australia, which may include gasification, post-combustion capture, oxy-firing, transport, and storage technologies. Complementing this program is the National Low Emissions Coal Initiative, which aims to accelerate the development and deployment of technologies that will reduce emissions from coal use.

**Funding**

In 2014, the Commonwealth Scientific and Industrial Research Organization (CSIRO) experienced a budget decrease.

**Hydrogen R,D&D specifics**

From 2010–2015, Australian hydrogen R,D&D programs have been operating in Universities, Government research laboratories and industrial laboratories. Many of these programs have international linkages. During this period there was a strong level of activity in Australian research on photo-electrochemical hydrogen production, hydrogen storage
and hydrogen fuel cells. Hydrogen production research was conducted at the following institutions: the University of Newcastle, Griffith University, the University of New South Wales (UNSW), the Australian National University, University of Queensland (UQ), Monash University, University of Western Sydney (UWS) and the University of Sydney.

Hydrogen storage research was conducted at the following institutions: Curtin University, Griffith University, UNSW, UQ, Monash University, University of Wollongong (UoW), University of Melbourne and the University of Sydney.

Hydrogen Fuel cell research was conducted at the following institutions: UQ, UoW, University of Technology Sydney and Curtin University. Some companies involved in hydrogen research include Ausnational Investments, Control Technologies International, Ningxia Searcher Heat-Superconducting Technology Co Ltd., Hydrexia and Aquahydrex Pty Ltd.

**PROGRAMS, PROJECTS AND INITIATIVES IN BRIEF**

**Some of the research projects that were awarded Australian Research Council (ARC):**

1. Nano-scale tuning: a path to functional materials for hydrogen storage (Aguey-Zinsou, UNSW)
2. Design of hollow nanoparticles of titania for the sustainable production of hydrogen from water using sunlight (Belova, University of Newcastle)
3. Solar water-splitting technology based on sustainable materials and the novel cell configuration to provide the needed stability and efficiency of solar cells as well as a reduction in manufacturing cost (Winther-Jenssen, Monash University)
4. Multifunctional Porous Nanospheres Engineered Composite Membranes for Hydrogen and Methanol Fuel Cells (Qiao, UQ)
5. Practical Hydrogen Storage for Fuel Cells Electrical Vehicles by Confined Ammonia Borane System (Yao, UQ)
6. Advanced solar powered hydrogen production systems based on green algal cells (Hanakamer, UQ)
7. Solar-driven massive hydrogen production from biomass and biomass/coal mixtures by supercritical water gasification (Yao, Griffith University)
8. Improving solar energy utilisation by splitting water with visible light (Sheppard, UWS)
9. Turning the electrolytes for high efficiency solar splitting of water (Zhao, Monash)
10. Renewable solar hydrogen generated from waste streams (Maschmeyer, University of Sydney)
11. Concentrating solar thermal energy storage using metal hydrides (Buckley, Curtin University, Ausnational Investments)
12. To identify and to understand highly reactive surfaces for solar hydrogen production (Sun, UQ)
13. Multifunctional nanoballs and variable length ligands (Batten, Monash University)
14. Designing metal-organic materials through a hierarchical self-assembly strategy (Clegg, UQ)
15. Highly-efficient, reversible fuel cell (Siwegers, UoW, Aquahydrex Pty Ltd.)
16. The design and synthesis of novel boron-nitrogen hydrides (Guo, UoW)
17. The production of a stable, hybrid heterogenous catalyst system for the oxidation of organic substrates derived from lignin biomass as an adjunct to visible light hydrogen generation from water (Maschmeyer, University of Sydney)
18. Bio-engineering highly efficient microalgae cell-lines that can drive solar powered hydrogen production from water (Hankamer, UQ)

19. Metal Hydride Reactors for High Temperature Thermochemical Heat Storage (Buckley, Curtin University, Ausnational Investments)

20. Mesoporous Metal Scaffolds: Reactive Containment Vessels for hydrogen storage (Buckley, Curtin University)

Hydrogen research projects with Australian Renewable Energy Agency (ARENA):

- Production of biofuels and hydrogen gasification of biomass (Li, Curtin University) Solar hydrogen production (University of South Australia)

- Hydrogen storage in magnesium alloys (Hydrexia – also funded by The Southern Cross Renewable Energy Fund). In late 2014, Hydrexia released its first commercial product (Metal hydride containing 18 kg of hydrogen) for customer evaluation

Excerpt of Research being done on Energy Storage using Metal Hydrides for Concentrated Solar Power Systems. - Lead Investigator: Professor Craig Buckley, Curtin University

A schematic of the concentrating solar thermal system coupled with metal hydrides as a thermal storage medium during (a) daytime and (b) night time operations appears below. This research at Curtin University led by Professor Craig Buckley aims at replacing molten salts with metal hydrides for heat storage in concentrated solar power systems (CSP). Metal hydrides are a class of thermochemical heat storage materials that are 5–30 times more energy dense than molten salts and have the potential to reduce the heat storage costs of next generation CSP. 3-5


Off-Grid Hydrogen Projects - Sir Samuel Griffith Centre: Off-Grid Building with Massive Hydrogen Storage

Griffith University is the site of the Sir Samuel Griffith Centre (SSGC). This is a 6000 square metre research and teaching building designed to be self-powered from within its own footprint and to operate independently of the electricity grid. Energy is captured by a photovoltaic array covering the roof and some window awnings of the building, consisting of 1124 20% efficient monocrystalline Si panels with a peak output of approximately 330 kW. Short-term energy storage is in a large Li-ion battery stack. Long-term energy storage is achieved by electrolysing water to produce hydrogen, which is stored as a metal hydride, with approximately 135 kg H₂ (1500 Nm³) capacity. A 60 kW PEM fuel cell bank is installed to provide the building baseload during dull weather. The SSGC is a realisation of the concept discussed by Gray, et al 6. The off-grid energy system has been part of the $47 million SSGC project from its inception; it is not retro-fitted. Professor Evan Gray has been instrumental in designing the hydrogen storage coupled with electrolyser and fuel cell.

STATUS AND ACCOMPLISHMENTS

The Hydrogen Technology Roadmap developed in 2008, identifies the potential role of Australian governments, industry, and researchers and recommends strategies in the possible development of a hydrogen economy. The Roadmap is complemented by the Australian Hydrogen Activity 2008 report, which outlines Australian research projects related to hydrogen and fuel cells.

A non-profit private company called the Australian Association for Hydrogen Energy (AAHE) has been set up to bring together organizations and individuals interested in the production, storage, transport, safety, distribution and end use of hydrogen.

The National Hydrogen Materials Alliance (NHMA) was a partnership between the Commonwealth Scientific and Industrial Research Organisation (CSIRO), 11 Australian universities, and the Australian Nuclear Science and Technology Organization (ANSTO).
The NHMA was launched in October 2006 to develop new materials that improve the efficiency and economics of hydrogen generation, storage and end use. It provided a focal point for hydrogen research in Australia and, through collaborative research programs between the partner organizations, facilitated the development of critical mass research programs. Several researchers from the Alliance participated and continue to participate in IEA/HIA tasks. The three-year term of the Alliance finished in June 2009.

In addition to the research in the NHMA, there are R&D programs in a number of universities, government research laboratories and industrial laboratories, as described in the *Australian Hydrogen Activity 2008 Report*. Some of these programs have international linkages either through the IEA HIA or otherwise.

**FUTURE PROJECTS**

Some examples of new projects that will commence shortly include:

- A Queensland Sustainable Energy Innovation Fund (QSEIF) grant awarded to Prof. Andrew Dicks (Queensland University of Technology) through LC Energy9 “Stationary sustainable power using advanced fuel processing technology.” This is a two-year project to develop micro-channel reactor systems for supplying hydrogen for small-scale (around 5kW) stationary power systems. The use of natural gas, LPG, bio-diesel and bio-gases will be investigated.

- An Australia/India Strategic Research Fund project on “A novel way to reduce Platinum metal loadings in a carbon nano-composite electrode to produce low cost-high efficiency commercially viable Polymer Electrolyte Membrane (PEM) fuel cells.” This two-year project is collaboration between Queensland University of Technology (Prof. Andrew Dicks) and the National Physical Laboratory, New Delhi, India.

- Prof Janusz Nowotny (University of Western Sydney) has obtained support through the bilateral Australia/Germany Agreement on Solar Fuels for research on photo-electrochemical hydrogen production.

**REFERENCES**


