

Going for Gold - Racing toward Net Zero Emissions

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Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australia

1. Introduction

CSIRO is Australia's national science agency, solving the greatest challenges through innovative science and technology. In CSIRO we deliver science and technology solutions that enhance Australia's economic competitiveness and regional energy security - while enabling the energy transition to a net zero emissions target by 2050.

Our role is to drive research outcomes, foster collaboration and get technology to scale.

Australia has been reliant on fossil fuels both domestically and as an export market, sustaining our growth economy but has begun the transition to renewable sources.

Australia has the largest electricity grid in the world, spanning almost the entire continent. In 2016, severe weather disconnected the entire state of South Australia from the grid, impacting 800,000 people. This outage highlighted the need for greater interconnectivity, to diversify our energy sources, and the importance of energy storage. This event prompted Australia's first extensive whole-of-system review of the entire electricity system. The outcome is a renewed emphasis on the role of science and technology to predict weather, climate, energy usage and generation. We have the technology to transition to net zero emissions without sacrificing sustainability, reliability or affordability.

Australia is the sunniest continent on earth, and we have access to vast renewable resources. However, energy from these sources is intermittent and variable, only producing energy when the sun shines or wind blows. It is therefore critical to be able to store energy effectively.

As part of a global partnership, a battery system, UltraBattery, was developed by CSIRO in Australia, built by the Furukawa Battery Company of Japan and tested in the United Kingdom through the American-based Advanced Lead-Acid Battery Consortium. A true global collaboration.

The UltraBattery has turned the conventional lead-acid battery — a 150 year-old energy-storage system — into a dynamic technology for storing electricity and powering vehicles.

This is at the heart of what we do. We solve the greatest challenges through innovative science and technology and through our extensive collaborative network we can bring these solutions to the world.

2. R&D activities related to clean energy technology

We play a unique role in the ecosystem in Australia. We are more than 100 years old, and are one of Australia's most prominent research organisations addressing the energy transition.

We have a target of Net Zero emissions energy research by 2050. This transition is underway and will involve a shift to decentralised electricity generation with an increased share of renewable energy.

The world will be replacing coal-fired power by gas-fired generation, renewables and other low-carbon technologies. We will see greater integration of short term and long term storage into the grid. In addition to net zero emissions electricity, we will see decarbonisation of industry and transport, through electrification and increased energy productivity. Finally, we're planning for a new energy export industry that manages carbon impacts and associated risks and emerging hydrogen industry for domestic and export markets.

3. Specific research activities in hydrogen, CCUS, and related technologies

Australia has the resources and skills to build an economically sustainable domestic and export hydrogen industry which can help meet agreed emissions targets and address concerns around energy security.

While use of hydrogen across the energy and industrial sectors is one of a suite of technology options that can play a role in helping Australia meet the prescribed decarbonisation targets, there are a number of other domestic trends and characteristics that favour its widespread use. These include natural gas supply, changing electricity sector, liquid fuels security, skilled workforce, and others.

Export of hydrogen represents a key opportunity for Australia, given its vast energy resources across solar, wind, coal, and natural gas.

Investment in research by commercial partners allows further development of hydrogen technologies, steering us towards a significant export market which could supply the North Asian region. The partnership between CSIRO and Australian minerals company Fortescue Metals Group is a good example of this.

We created a unique membrane material that extracts pure hydrogen from ammonia, which is used as a carrier. This means the hydrogen can be transported and stored as ammonia, capitalising on existing infrastructure. The membrane allows pure hydrogen to be extracted at point of use, such as a car refuelling station.

In this case the big breakthrough came when the Fortescue Metals Group invested to commercialise this technology with the intention to produce hydrogen domestically.

CSIRO and Fortescue recognise that a hydrogen industry will require a collaborative approach, and that there will remain opportunities for other organisations to participate in this growing industry (for example, opening industry up via guaranteed funding, collaboration and clear path to market).

Japan and Korea, through Toyota and Hyundai saw cars refuelled last year for the first time using the purest hydrogen produced from our liquid Ammonia fuel, from our hydrogen membrane.

Related programs/projects conducted by the institute (further information on programs/projects are found in the template)

- Demonstrate the solar thermochemical production of hydrogen using a 200 kW beam down solar thermal concentrator / Fundamental research into new catalytic materials to improve the production of hydrogen via the two step redox process (2018-2022)
- Development of a techno economic feasibility study for the methanol pathway for transporting hydrogen from Australia to Japan (2018-2021)
- Development of PEM electrolysis technology and kW class systems for distributed and off-grid applications
- Development of solid oxide electrolysis for steam / CO₂ electrolysis for production of hydrogen, syngas and liquid fuels
- Basic R&D for electrochemical ammonia synthesis using renewable sources of electricity.
- Development of metal membrane-based reactor for ammonia production at low pressures by sourcing hydrogen directly from a PEM electrolyser
- Basic R&D for direct ammonia utilisation in a solid oxide fuel cell for power generation
- Development of solid state hydrogen compressor for domestic use (in-home re-fuelling of fuel cell electric vehicles) / Fundamental research into metal hydride materials capable of compressing H₂ using low grade heat sources (2018 - 2021)
- Commercialisation of CSIRO's metal membrane technology. This project aims to scale up the production of CSIRO's hydrogen separation membranes and construct two pilot plants each capable of producing 200kg/day of fuel cell quality hydrogen from decomposed ammonia.
- Development of solid oxide electrolysis for steam / CO₂ electrolysis for production of hydrogen, syngas and liquid fuels
- PICA Project: 5000 hour evaluation of an advanced Post-Combustion CO₂-capture process (PCC) with two advanced liquid absorbents for application in Victorian brown coal fired power
- The technology development in this project aims to convert hydrogen produced from renewable electricity together with CO₂ from the atmosphere into a methane product that seamlessly fits in with existing energy export chains and available infrastructure

4. International collaboration

4-1 International alliance/networking development

CSIRO's Global Strategy aims to connect Australia to the global science, technology and innovation frontier as well as access new markets for Australian innovation. CSIRO has extensive number of international activities and collaborations around the world.

For us, collaborations are fundamental way of how we work and find solutions to the greatest challenges we face on the planet. We have collaborations with research intuitions in the G20 members which include innovations in clean energy technologies.

4-2 International joint R&D activities

The Australian Solar Thermal Research Institute (ASTRI) is an \$87 million, eight-year global research initiative creating international collaboration with research institutions, industry bodies and universities transforming Australia into a global leader in concentrating solar thermal power technologies.

This has led to solar thermal partnerships with Japan's Mitsubishi Hitachi Power Systems, the Cyprus Institute, Thermal Focus in China and Heliostat SA in Australia.

This is another great example of our research in action; using excellent science to deliver breakthrough innovation, and through global collaboration, increasing renewable energy deliverables.

Related programs conducted in the institute (further information on programs/projects are found in the template)

- CSIRO began investigating barriers for EV adoption in Australia. Charging infrastructure was identified as being a key area where there could be improvements. Areas identified as problematic are charging in homes with multiple cars, large groups of vehicles and remote fast charges. (2014 – ongoing)
- CSIRO works with a wide range of industry partners to help them to understand how new technologies can be used within their current business model and to also allow them to hybridise technologies that they manufacture to create new products. We also work internally with groups in CSIRO to build prototypes using experimental CSIRO technology (2014-Ongoing)

5. Future perspectives

CSIRO is focused on supporting the energy transition and drive towards net zero emissions, increasing our capability in renewables and digital energy technologies, investing in more clean energy growth areas and taking on big projects with strategic partners both in Australia and around the world.

Dr. Larry Marshall

2015 – present Chief Executive CSIRO, Australia

2007 – 2014 Managing Director Southern Cross Ventures, Palo Alto, CA, Shanghai, China, Sydney, Aust.

2005 - 2007 Managing Director/co-Founder Arasor, Mountain View, CA (China, Japan, Australia)

2004 Executive Chairman, Intersymbol, Champaign, IL

1999 - 2004 Chairman then CEO/co-Founder, Translucent, Inc, Palo Alto, CA

2000 - 2003 CEO/co-founder, Lightbit Corp., Mountain View, CA

1999 - 2006 executive Chairman/co-founder AOC Technologies, Fremont, CA

1995–2000 Vice President/co-founder Iridex Corp., Mountain View, CA

1992–1995 CEO/co-founder, Light Solutions Corp., Mountain View, CA

1989 – 1992 Technical Program Manager/Laser Engineer Fibertek, Inc. Herndon, VA

1985-1988 Cadet Research Scientist, Defense Science & Technology Organization, Adelaide, SA, Aust.

1984 CSIRO Summer Intern, North Ryde, NSW, Australia

Research Biography

Patents

21 Patents protecting 9 Commercial Products.

Patent #	Issued	Title
7,211,821	05/01/2007	Devices with optical gain in silicon
7,023,011	04/04/2006	Devices with Optical Gain in Silicon
6,876,487	04/05/2005	Any-to-any all-optical wavelength converter
6,862,130	03/01/2005	Polarization-insensitive integrated wavelength converter
6,858,864	02/22/2005	Devices with optical gain in silicon
6,734,453	05/11/2004	Devices with optical gain in silicon
6,717,718	04/06/2004	Hybrid optical device
EP0783783	04/23/2003	Passively stabilized intracavity doubling laser
6,377,599	04/23/2002	Focusability enhancing optic for laser diode
EP0904615	09/05/2001	Pulsed laser with passive stabilization
6,327,291	12/04/2001	Fiber stub end-pumped laser
6,222,869	04/24/2001	Aspheric lensing control for high power butt-coupled end-pumped laser
6,144,484	11/7/2000	CW laser amplifier
6,141,143	10/31/2000	CW laser amplifier

EP0990283	04/05/2000	Fiber Stub End Pumped Laser
5,999,554	12/07/1999	Fiber stub end-pumped laser
5,982,789	11/09/1999	Pulsed laser with passive stabilization
5,663,979	09/02/1997	Fiber stub end-pumped laser
5,521,932	05/28/1996	Scalable side-pumped solid-state laser
5,511,085	04/23/1996	Passively stabilized intracavity doubling laser
5,181,211	01/19/1993	Eye-safe laser system

Pending:

20040056243A1	03/25/2004	Optical gain in silicon
EP1310001A2	05/14/2003	Devices with optical gain in silicon
20020171913A1	11/21/2002	Method and apparatus for achieving noiseless optical amplification

Publication List

Invited Popular Articles

- “Investing in Blue Chip Lasers”
Laser Focus World, Sep (2004)
- “The house of Blue Light”
Laser Focus World, Oct (2004)
- “Band Architecture Improves Performance”
Laser Focus World, Sep. (2002)
- “Any Color you Like”
Industrial Laser Solutions; pp. 11-14, April (2002)
- “The Processing power of light”
Optics & Photonics News, Mar. (2002)
- “Leaping into the void”
Laser Focus World, May (2001)
- “Solid –state lasers catch a lift at ASSL”
Laser Focus World, vol. 36, no. 4. (2000)
- “The Laser Razor”
Wired Magazine, Jan 2000
- “Diode-pumped lasers begin to fulfil promise”.
Laser Focus World, , vol. 34, no.6, pp. 63-77 (1998)
- “Eye doctors look to diode-pumped lasers”.
Laser Focus World, vol. 32, no.6 (1996)
- “Biologically monitoring foreseen with ultraviolet light source”
Laser Focus World, vol. 30, no. 4, pp. 83-87 (1994).
- “Optical parametric oscillators go commercial”
Photonics Spectra, vol. 27, no. 4, pp. 125-128 (1993).
- “Blue-green lasers plumb the mysteries of the deep”,
Laser Focus World, vol. 29, no. 4, pp. 185-197 (1993).

Invited Presentations

- “Silicon Photonics”, Wednesday, April 26, 2006, Charles Hotel, Boston (MA)

- “US Experts tour, Australia, Canberra, Melbourne, Sydney, Brisbane, Coolumb, Perth, Adelaide, (2005)”
- “Business Engineering vs. Laser Engineering”, LEOS 2005, 23 October 2005, Hilton Sydney, Sydney, Australia
- “Frequency Shifted Diode Lasers and their Applications”, Laser Focus World Marketplace '05 Seminar, San Jose CA (2005)
- “Commercializing Technology”
L.R. Marshall, ANZA Tech, Palo Alto, CA (2003).
- “Market Opportunities for Diode-pumped Solid-state Lasers” Laser Focus World Marketplace Seminar, San Jose CA (2000)
 - “Diode pumped Lasers & Nonlinear optics for Material Processing” L.R. Marshall, IMTS 2000, Chicago, IL (2000)
- “Advances in solid-state lasers in medicine”
L.R. Marshall, LEOS '99, San Francisco CA (1999)
- “Diode-Pumped Solid-State Laser Developments and Applications
L.R. Marshall, Laser'99 Market Seminar, Munich Germany (1999)
- “Diode-Pumped Solid-State Laser Developments and Applications
L.R. Marshall, Laser Focus World Marketplace '99 Seminar, San Jose CA (1999)
- “ Semiconductor-based Lasers in Medicine”
L.R. Marshall, LEOS '98 , Orlando FL (1998)
- “ High Brightness Pumping for Nonlinear Optics”
L.R. Marshall, David G. Matthews, Leonel Gonzalez, Rajan Bhatia, Klaus Kleine; CNOM, Stanford CA (1998)
- “Diode Pumped Solid-State Lasers in Ophthalmology”
L.R. Marshall, LEOS'97, San Francisco, CA (1997)
- “Medical Applications of Diode Pumped Solid State Lasers
LEAP Session, CLEO '97, Baltimore MD
- “Optical Parametric Oscillators : From 289 nm to 4000 nm”,
L.R. Marshall, Proceedings of LEOS '94, Boston, MA Oct 31- Nov3 (1994).
- “Tunable diode pumped sources : Towards 1kW”,
L.R. Marshall, Advances in Solid State Lasers, Plenary paper, International Physics Congress, Brighton, UK, April 12 (1994).
- “Laser Transmitters for Lidar and Submarine Communications”,
L. R. Marshall, Proceedings of ITEMS '93, Washington, DC (1993).
- High Efficiency Diode-Pumped Tunable Solid-State Lasers"
Proceeding of the IEEE Lasers and Electrooptics Society Annual Meeting, Nov 16-19, Boston, MA (1992).
- "New Generation All Solid-State Tunable Lasers"
L. R. Marshall, Proceedings of the Australian Conference on Lasers & Spectroscopy, ACOLS'91 (1991).
- "All-Solid-State, High Power, Diode-Pumped 455 nm Laser"
L. R. Marshall, Proceedings of Lasers '91, MD5 (Society for Optical & Quantum Electronics, 1991).
- "High-Power Pulsed & CW Diode-Pumped, Mode-Locked, Nd:YAG Lasers",
L. R. Marshall, Proceedings of the Topical Meeting on Advanced Solid State Lasers, OSA, vol. 7 (1991).

- "Recent Advances in Stimulated Raman and Brillouin Scattering",
L. R. Marshall, ACOLS '89, Adelaide University, August 23-27 (1989).

Invited Papers

- "Diode pumped lasers for the visible and ultraviolet".
L.R. Marshall, Leonel Gonzalez, Rajan Bhatia, Klaus Kleine, David G. Matthews; SOQUE proceedings, Lasers '98, Tuscon AZ (1998)
- "Frequency conversion using cw sources"
L.R. Marshall; Proceedings of SPIE Volume: 3263, Photonics West '98 (3263-33), San Jose, CA (1998)
- "Mid-infrared CW & Pulsed optical parametric oscillators"
L.R. Marshall; ILS-X1 OSA Annual Meeting, paper MBB2, Sept 10 - 15, Oregon Convention Center, Portland, Oregon (1995)
- "Diode-pumped Lasers : visible and UV"
L.R. Marshall; Proceedings of SPIE, (2380), Photonics West, San Jose, CA (1995).
- "Noncritically phase-matched Degenerate 4 μ m OPO",
A.Kaz & L.R. Marshall; OSA Proceedings on Advanced Solid State Lasers (1994)
Vol. 20 pp. 443-446, Advanced Solid State Lasers, Salt Lake City, UT, Feb 7-10 (1994).
- "Noncritically phase-matched 289nm Generation",
A. Kaz & L.R. Marshall; OSA Proceedings on Advanced Solid State Lasers (1994)
Vol. 20 pp.385-388
- "Scaling Optical Parametric Oscillators in Power, Energy and Beam Quality".
A.Kaz & L.R. Marshall; OSA Proceedings on Advanced Solid State Lasers (1994)
Vol. 20 pp.466-470
- "Diode pumped lasers : Past the kW Barrier"
L.R. Marshall; Innovative Laser Technologies in Nuclear Energy, Mito, Japan, March 23-25,
Paper IIIb-pp12-18 (1994).
- "Wavelength Agile Diode Pumped Lasers"
L.R. Marshall; SOQUE proceedings, THH. (1994), 2, Tunable Solid State Lasers I,
Lasers '94, Quebec, Canada, December 12-16 (1994)
- "New Generation Diode-Pumped Tunable Lasers",
L.R. Marshall; Advanced Solid State Lasers, OSA, vol. 8, pp. 338-342 (1992).
- "High-Power, All-Solid-State, Diode-Pumped Eyesafe Lasers",
L.R. Marshall; Proceedings of SPIE Symposium on High-Power Lasers, Conf. 1415, pp. 1-11
(1992).
- "Highly Efficient Optical Parametric Oscillators",
Proceedings of SPIE Symposium on High Power Lasers, Conf. 1419, pp. 202-214
(1991).

Academic Background

Ph.D. Physics, 1989 (Macquarie University, Commonwealth Centre of Excellence : Lasers & Applications)
B.Sc. Honors, 1984
BS cum laude, 1983 (Macquarie University)