






THE CALLIDE OXYFUEL PROJECT

Callide Oxyfuel Project air separation units. Each of the two units has a capacity to supply 330 tonnes of oxygen per day to the oxyfuel boiler

Callide
Oxyfuel Project

CONTENTS

FRONT COVER IMAGES (clockwise from left to right): Takahiro Goto and Ben Petty, Franco Montagner, the Callide A Power Station boiler in oxyfiring mode, the Callide Oxyfuel Project site, Dr Chris Spero, members of the Technical and Investment Advisory Committee, screens in the control room, part of the carbon capture plant

BACK COVER IMAGES (from left to right): Dr Chris Spero, Russell Rogers, Colin Garth and Ian Collard, Anne Marshall

FOREWORD

JOHN GALE

GENERAL MANAGER, INTERNATIONAL ENERGY AGENCY - GREENHOUSE GAS R&D PROGRAMME

Fossil fuels for electricity generation will remain an important part of the energy mix in the coming decades. However, they face a significant challenge in a carbon constrained world. Carbon Capture and Storage (CCS) technologies have a major role in significantly reducing the carbon dioxide (CO_2) emissions from their use.

Looking back to the time when the IPCC Special Report on CCS was published in 2005, oxyfuel combustion was considered the least mature among the main carbon capture technologies for the fossil fuel power sector. However, in the past 10 years, this technology went through a rapid development and is now fully recognised as an important option for capturing CO_2 from coal-fired power plants. Oxyfuel combustion is now ready for commercial scale demonstration.

The Callide Oxyfuel Project is one of the pillars that made this technology a success. I would like to congratulate the project on the important accomplishment they have made in demonstrating that this technology works not only for new-build but also for retrofit.

The partnership between the IEA Greenhouse Gas R&D Programme and the Callide Oxyfuel Project started in 2005. We have witnessed the development of the Callide Oxyfuel Project from its conception to its implementation. We are very proud to have held one of our world-renowned Oxyfuel Combustion Conferences with them in 2011 and to have visited the impressive site at Biloela in Queensland, Australia. It was a memorable experience for the hundreds of global experts to visit such an important milestone in the development of this technology.

After operating for more than 15,000 hours, it is sad to hear that the plant is now being decommissioned. Nonetheless, it has clearly achieved its goal. This book is a proof of that. It sets a gold-plate standard on how a collaboration by many stakeholders can succeed in operating the largest oxyfuel combustion power plant in the world.

The work done by Dr Chris Spero, Project Director of the Callide Oxyfuel Project, and his team is not only admirable, but most importantly will contribute substantially to the knowledge and experience in operating such a plant.

Finally, the next challenge to the oxyfuel combustion community is how to bring the wealth of expertise gained in this project to progress along the pathway to the commercialisation of this technology.

Looking towards the Callide A Power Station and the CO_2 storage tank (on the left), CO_2 coal box (centre) and liquid nitrogen tank (on the right)

BEFORE

2003

The Callide A Power Station prior to construction of the Callide Oxyfuel Project

AFTER

2015

TIMELINE

The Callide Oxyfuel Project is a world first project, successfully demonstrating how oxyfuel combustion and carbon capture technology can be applied to a coal-fired power station to generate electricity with low emissions.

The project has also further advanced global knowledge of carbon dioxide storage.

2003-04

NOVEMBER 2003
The Callide Oxyfuel Project concept is conceived as an initiative of the Australian Coal Association COAL21

MARCH 2004
Oxyfuel technology included in the COAL21 National Action Plan and a working group established

2006

MARCH 2006
Japanese partners sign the Memorandum of Understanding with CS Energy to commence the Callide Oxyfuel Project feasibility study

OCTOBER 2006
Callide Oxyfuel Project receives $63 million funding through the Australian Government's Low Emissions Technology Demonstration Fund

2008

MARCH 2008
Callide Oxyfuel Project partners finalise joint venture arrangements

NOVEMBER 2008
Official launch of the Callide Oxyfuel Project and the refurbishment of Callide A Power Station's Unit 4 commences

2009

JANUARY 2009
The Callide A Power Station Unit 4 refurbishment is complete and ready to be retrofitted for oxyfuel combustion

OCTOBER 2009
Earthworks for the construction of new oxygen and carbon capture plants start

The project becomes one of only a handful of carbon capture projects in the world to move beyond concept to construction

2011

MARCH 2011
Callide A Power Station's Unit 4 boiler modifications finished

COMMISSIONING COMMENCES

OCTOBER 2011
The new oxygen plant is completed, making Callide A Power Station oxyfuel-ready

2012

MARCH 2012
Unit 4 boiler operates in full oxyfiring mode for the first time

JUNE 2012
Oxyfuel demonstration phase begins

DECEMBER 2012
Carbon capture begins, making the Callide Oxyfuel Project one of the most advanced low emission projects in the world

2014

MAY 2014
Callide Oxyfuel Project passes halfway mark, achieving 6,000 hours of operation in oxyfuel combustion mode

OCTOBER 2014
The first of four test injections of Callide Oxyfuel carbon dioxide undertaken at the CO2CRC Otway Basin test site in Victoria

2015

MARCH 2015
The Callide Oxyfuel Project demonstration phase comes to a close after almost three years, successfully achieving 10,200 hours of oxyfuel combustion and 5,600 hours of carbon capture

THE VISION

A SUSTAINABLE ENERGY FUTURE

In a world in which more than 80 per cent of global energy production is derived from fossil fuels, and with demand expected to continue to rise, the Callide Oxyfuel Project was conceived in 2003 as an important step in developing a sustainable energy future.

> This project is a story about what can be achieved through good science, good engineering and international collaboration.
>
> **DR CHRIS SPERO,**
> **PROJECT DIRECTOR**

> The vision was laid down in 2003 arising from great thinking and communication among government, the coal industry, the electricity generation industry, coal researchers and universities.
>
> **DR CHRIS SPERO,**
> **PROJECT DIRECTOR**

The Technical and Investment Advisory Committee meets in Brisbane

The Australian Government announces funding for the Callide Oxyfuel Project. Keiji Makino from IHI, Tony Anderson from CS Energy, Barry Waining from IEA Engineering Australia and Frank van Schagen from CRC for Coal in Sustainable Development (CCSD)

Darren McGregor from GLP Plant and Keiji Makino from IHI discussing the conceptual plant layout

An aerial view of the Callide Oxyfuel Project

A WORLD FIRST

An international collaboration, the $245 million dollar project confirmed that carbon capture technology could be applied to a coal-fired power station to generate electricity with almost no emissions. By capturing carbon dioxide (CO_2), the project demonstrated that deep cuts could be made to power station emissions to help slow the process of climate change while maintaining the use of fossil fuels as a major energy source.

As one of only a handful of coal-fired low emission projects in the world to move beyond concept to construction, the project represented a number of firsts for Australia and the world.

KEY FACTS

- world's first industrial-scale demonstration of oxyfuel combustion and carbon capture technology
- world's first power station to be retrofitted with oxyfuel carbon capture technology
- first injection underground of CO_2 from an Australian power station
- world's first injection of CO_2 from an oxyfuel power station

OSAMU (SAM) GOUKON

SENIOR EXECUTIVE MANAGER ENERGY BUSINESS UNIT I & II
MITSUI & CO., LTD

As a member of the management committee, I was based at Mitsui's headquarters in Tokyo but I made up to 35 business trips to Australia during the project. Brisbane came to feel like my second home.

FINDING THE MONEY

Setting up the financial funding for the life of the project was challenging. But we needed to ensure we had continuity so we could achieve our primary aim of 10,000 hours of oxyfiring operation.

"I was so impressed by the very effective collaboration among all the participants from Australia and Japan, and the very strong support extended by both the Australian and Japanese governments."

NATURAL DISASTERS

I was really amazed that floods and cyclones hit the project more than once.

FUTURE OPPORTUNITIES

There is potential for future opportunities using this technology but it would need strong government support and suitable geographical conditions.

Sam was attracted to what he saw as the meaningful and beautiful goal of the project aimed at enhancing sustainable demand for coal and contributing to compliance with environmental protection through the reduction of greenhouse gas emissions.

DR CHRIS SPERO

PROJECT DIRECTOR
CALLIDE OXYFUEL PROJECT

As Project Director, I led the project from its conception in 2003. My role encompassed a vast array of responsibilities, including managing the joint venture and project companies (Oxyfuel Technologies Pty Ltd and Callide Oxyfuel Technologies Pty Ltd), leading the design, construction and operation of the plant, and overseeing research and development activities.

AIMING HIGH

Through the success of an industrial-scale demonstration, the Callide Oxyfuel Project made an important step forward in realising the ambition of sustainable and climate-friendly electricity generation from coal.

"Nature has provided a bountiful and low cost source of primary energy in the form of coal. However, the new challenge is to use our coal resources more efficiently and more cleanly."

KICKING GOALS

The project was about learning by doing, creating new knowledge, and achieving innovation. We demonstrated that oxyfuel technology works, is ready to be scaled up, and offers a realistic pathway for the sustainable use of coal for electricity production.

LEAVING A LEGACY

One of the important legacies of the project was the opportunity to train and develop younger people, including tradesman, engineers, scientists, and communications specialists. I would particularly like to acknowledge the way our younger project engineers - Franco Montagner, Toshihiko Yamada, Nobuhiro Misawa, David Schiefelbein, Takahiro Goto and others - rose to the challenges of the project. These people broadened their knowledge and skills in a truly professional way and I am sure they will be part of other important technological endeavours in the future.

As an engineer, and the leader of the project, Dr Chris Spero felt honoured to be part of something that could make an important contribution to society and to the environment.

DR TAKASHI KIGA

CHIEF ENGINEER ENERGY & PLANT OPERATIONS
IHI CORPORATION

Understanding the Australian spirit and dealing with cross-cultural communication was both exciting and challenging for me.

MANAGING RISK AND FORGING ALLIANCES

It was exciting to see the close relationship that was forged between the private sector and politicians in making this project happen and how the Australians and the Japanese were such good partners. Another thing that I was interested to learn was the focus on risk management and the need to carefully manage safety equipment and training. Due to CS Energy's rule that there was to be no alcohol on site, we even filled the sake barrel with water for the ceremony at the launch of the project's demonstration phase.

"So many things struck me as different about working in Australia: the wild animals, the diversity of people, the orange and yellow high visibility work uniforms people wore in airplanes on the way to Biloela, and the shifts in policies when governments changed."

FUTURE OPPORTUNITIES

Even if the power station was old, oxyfuel technology allowed us to make a coal-fired power plant carbon capture-ready and produce cleaner energy from coal. I would love the opportunity to work on a project like this again.

It was a dream come true for Takashi Kiga when he had the opportunity to work on the Callide Oxyfuel Project. Having begun his career in research and development on a small scale, the Callide project offered him the chance to work on a much larger scale and in a new country.

THE CONTEXT

FOSSIL FUEL DEMAND

Continued population growth and economic development are projected to drive increases in the demand for energy over the next half century, particularly in developing nations. It is clear that fossil fuels will continue to be a major energy source worldwide due to their abundance, low cost and suitability for use in base-load power stations.

> Coal, and indeed other fossil fuels, will remain a critical part of the global energy mix for decades to come. All the credible projections point to that. Coal is abundant, geographically widespread and among the lowest cost energy sources which makes it a highly desirable resource; especially for developing nations looking to grow their economies.
>
> **STEWART BUTEL, CHAIRMAN,**
> **AUSTRALIAN COAL ASSOCIATION LOW EMISSIONS TECHNOLOGY (ACALET)**

Coal production stockpile. Photo courtesy of Glencore

REDUCED EMISSIONS, CONTINUED COMPETIVENESS

Increasingly, there is a focus on reducing the energy sector's emissions footprint while maintaining competitiveness. The International Energy Agency's report, *CO_2 Emissions from Fuel Combustion Highlights (2014 Edition)*, shows that worldwide, electricity generation produces around 42 per cent of the total global CO_2 emissions, and that in the last decade, coal had replaced oil as the largest source of CO_2 emissions. While countries around the world canvass a range of solutions for reducing CO_2 emissions, the German Federal Institute for Geosciences and Natural Resources (BGR) has estimated that close to 900 billion tonnes of coal reserves remain, equivalent to 113 years of global coal output.

To enable developed and developing nations to continue to use coal as a cost-effective source of energy without harming the climate, carbon capture and storage needs to be part of the solution. Moreover, the need to gather hard data from industrial and commercial-scale demonstration projects across a diverse range of reliable and affordable clean coal pathways is broadly accepted.

The low concentration of CO_2 in power station flue gases is the major barrier to capturing CO_2, as the combination of gases makes the CO_2 very expensive to separate and process. Oxyfiring involves burning coal in oxygen mixed with recycled flue (waste) gas rather than in air, which significantly reduces the overall volume of flue gas to process and raises the concentration of CO_2.

Oxyfiring, or oxyfuel combustion, is regarded as a viable solution due to its technical merits, as well as the technology's potential as a retrofit option for existing coal-fired power stations.

Air separation unit heat exchanger column

BARRY ISHERWOOD

GLENCORE

One of the most exciting aspects of being involved was to see the project completed on budget - albeit with a few twists and turns along the way. For such a large demonstration, to achieve this is testament to the excellent leadership and attention to detail of our Project Director Dr Chris Spero and his team.

A UNITED FRONT

This project demonstrated that oxyfiring technology is technically sound and viable and has been de-risked in quite a few areas making it ready to be up-scaled and ultimately play its part in the global carbon capture and storage world.

"It was so pleasing to see the excellent cooperation between partners – at times requiring robust discussions – but always resulting in the most sensible outcomes."

READY FOR THE NEXT STEP

The project proved that when the necessary economic drivers are put in place, and when combined with the necessary carbon storage component, this technology can make a true difference to the world's concerns about fossil-fuel emissions and their contribution to climate change. Whether for new build plant or retrofitting to existing power stations, oxyfiring technology is now ready to take the next step.

As a member of the team that produced the initial feasibility study in 2005, Barry was quick to recognise the potential for oxyfiring technology. With Barry's endorsement, Glencore (formerly Xstrata Coal) came on board and agreed to be a partner in the project's demonstration phase.

JIM CRAIGEN

DEPUTY DIRECTOR TECHNOLOGY
ACA LOW EMISSIONS TECHNOLOGIES (ACALET)

ACALET was one of the primary funders of the project and I was involved right from the beginning, monitoring the project's progress on behalf of ACALET and representing the organisation on the project's Technical and Investment Advisory Committee (TIAC). Initially, I worked alongside Burt Beasley, who was ACALET's representative on the project's management committee. Then, in the latter stages of the project, I took up a position on the management committee.

OVERCOMING CHALLENGES TO ACHIEVE SUCCESS

This project posed many challenges, but an important insight for me and for the wider team was to understand that a project of this scale and complexity would inevitably experience setbacks. However, the purpose of doing first-of-type projects like the Callide Oxyfuel Project is to have those setbacks and find ways of solving them so we could learn the lessons and help future plants be built with more confidence.

"It was so exciting and rewarding to work with such a highly competent and professional group of people – both among the project team and the funding bodies."

CONFIDENT FUTURE

As the need to capture and store CO_2 increases, the results of this project will be instrumental in assisting other groups to deploy oxyfuel technology with confidence.

ACALET, through the COAL21 Fund, was the Callide Oxyfuel Project's largest funder. This was not only the first major project investment made by ACALET but also one of its most strategically important investments. As ACALET's Deputy Director Technology, Jim Craigen was excited to be part of a major project that sought to demonstrate the technical viability of a core carbon capture technology.

GAVIN MCMILLAN

SITE SUPERINTENDENT
CALLIDE A POWER STATION

As the Callide Oxyfuel Site Superintendent, my role started in 2008 with the negotiation of a contract with Callide Oxyfuel Services Pty Ltd (COSPL) to manage Callide A Power Station through all phases of the project. Management of the contract involved ensuring the provision of services to the station, including coal and water, right through to maintaining and operating the station in its original air mode and oxyfiring mode.

I was attracted to this project as a way of generating clean energy to help meet the challenges of climate change. I also had a great desire to implement a team-based, workplace culture that would empower people to take ownership of their roles and really enjoy coming to work. The benefits of this included a great safety record and contract delivery.

RISING TO THE CHALLENGE

Developing a team to operate and maintain a plant that had never been built before was certainly a challenge. But thanks to the support of the team, we rose to the challenge.

It was really exciting to see how well the oxyfiring process actually worked. Getting to know the local and international participants in the project was also fantastic.

The project achieved everything it set out to achieve but our operations and maintenance team also achieved great things, including a great safety record, fantastic team morale and professionalism, and a contract that came in under budget.

"There is significant potential for this technology to reduce greenhouse gases on a huge and cost-effective scale."

Learning more about reducing greenhouse gases on a large and cost-effective scale provided Gavin McMillan with a strong motivation to be a part of the Callide Oxyfuel Project. Gavin knew that strong teamwork would be essential to the project's success and he set about making it happen.

AN INTERNATIONAL COLLABORATION

STRENGTH IN NUMBERS

As an international joint venture comprising seven partners, the success of the Callide Oxyfuel Project relied on both the individual strengths of its partners, supporters and participants, as well as the group's ability to collaborate effectively to achieve an innovative solution.

In addition to substantial equity from the project participants, the Callide Oxyfuel Project was awarded $63 million from the Australian Government under the Low Emissions Technology Demonstration Fund, $76.9 million from the Australian coal industry through ACALET, and also received financial support from the Japanese and Queensland governments with technical support from the Japan Coal Energy Center (JCOAL).

AUSTRALIAN AND JAPANESE EXPERTISE

The project brought together Japanese and Australian expertise in the areas of electricity generation, boiler construction, and the latest knowledge on coal combustion and flue gas processing, to investigate the potential application of oxyfuel technology to the electricity generation sector.

The partnership enabled joint research and development into oxyfiring and a design for a first-of-a-kind demonstration plant in Australia. Such innovation has created the potential to reduce the footprint of power generation facilities and enable the advancement of near-zero emissions technologies in Australia and globally.

> The Callide Oxyfuel Project is a prime example of what can be achieved when a range of stakeholders with a common interest work in collaboration. It is especially pleasing that Japan and Australia, as major trading partners, worked so well together both at the national government level and the industry sector level.
>
> **STEWART BUTEL, CHAIRMAN, AUSTRALIAN COAL ASSOCIATION LOW EMISSIONS TECHNOLOGY (ACALET)**

Representatives of the Japanese Government and joint venture partners at the launch of the project's demonstration phase in December 2012

THE CALLIDE OXYFUEL PROJECT WAS A JOINT VENTURE BETWEEN

- CS Energy
- IHI
- J-POWER
- Mitsui & Co., Ltd
- Schlumberger Carbon Services
- Glencore
- ACA Low Emissions Technologies (ACALET) (Special Contributor), and
- JCOAL (Supporting Collaborator)

It's a story about a genuine and harmonious collaboration between Australia and Japan. It's a story about people from government and industry in two countries creating a joint vision. And it's a story about engineers, scientists, accountants, and others from many disciplines – with great endeavour and stewardship, with good thinking and innovation – working very hard to make the Callide Oxyfuel Project a great success.

DR CHRIS SPERO,
PROJECT DIRECTOR

Ben Petty and Takahiro Goto inspect the plant

“The Australian economy is strongly supported by the country’s abundance of coal and low cost electricity from coal. Meanwhile, Japan has almost no coal resources and Australian coal is a very important resource that helps ensure our country’s energy security. It made sense for our two countries, which are clearly tied by coal, to develop and demonstrate efficient and cleaner coal technology.

DR TAKASHI KIGA, CHIEF ENGINEER, ENERGY & PLANT OPERATIONS, IHI CORPORATION

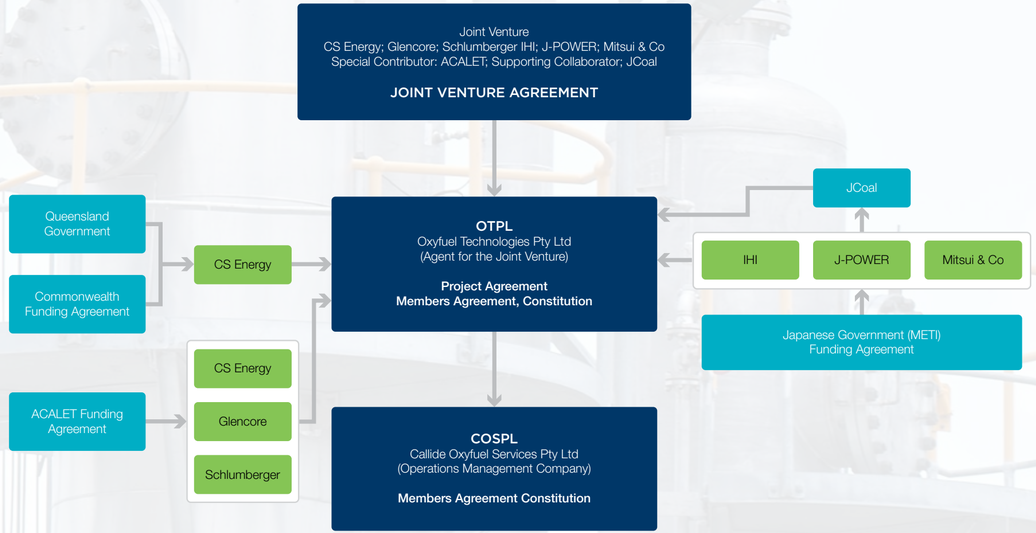
Australian and Japanese Government and industry dignitaries perform a traditional ceremony at the launch of the project’s demonstration phase. From left: Toru Namiki from JCOAL, Akira Yasui from the Japanese Ministry of Economy, Trade and Industry, Yoshitaka Akimoto, the Ambassador of Japan to Australia, Ross Willims from the ACALET, Jeff Seeney, the Member for Callide, and Martin Ferguson, the Australian Government’s Minister for Resources and Energy

FAR TOP RIGHT: Members of the team and Technical and Investment Advisory Committee at the Callide A Power Station

“As the former Australian Government Minister for Resources and Energy, I had the great pleasure of supporting and launching the Callide Oxyfuel Project in October 2008 alongside my ministerial colleagues from Queensland, Mines and Energy Minister Geoff Wilson and Japanese Vice Minister of Economy, Trade and Industry Yoshifumi Matsumura. The international collaboration between Australian and Japanese partners provided strength and knowledge to the project. I am confident the learnings and results from the project will be published and will provide another ‘option’ to future low emission projects worldwide.

MARTIN FERGUSON, AM, CHAIRMAN, COOPERATIVE RESEARCH CENTRE FOR GREENHOUSE GAS TECHNOLOGIES (CO2CRC)

PROJECT STRUCTURE



FRANCO MONTAGNER

PROJECT ENGINEER
CALLIDE OXYFUEL PROJECT

As Project Engineer, Franco Montagner worked on the Callide Oxyfuel Project for eight years from early 2006. Franco worked on many components of the project from its feasibility and financial investment phases, right through to the procurement, construction, commissioning and operational phases.

The prospect of working on a project that was challenging and innovative really attracted me – it's not every day that something like this comes along. And working as part of a small team to complete something extraordinary was a real career highlight for me.

MANY MOVING PARTS

The project's construction phase was quite complex with respect to the procurement of the equipment and services for the new plant being retrofitted to the Callide A Power Station. There were several different supply contracts so there were many relationships that we needed to manage effectively.

DEMONSTRATION MODE

The plant needed to operate for just over two years for the demonstration phase. This is a very short period compared to the normal operating life of a power station.

This required us to make decisions about how to maintain and operate the plant to achieve our demonstration goals, but manage any risks associated with operating a combination of old and new plant.

"I was surprised and gratified at the way the pieces of the puzzle fell into place so the project could reach its financial close despite the complexity of sourcing and managing funding from many different sources."

FUTURE-PROOFING

What we learnt from this project will help improve the reliability and risk management - and reduce the costs - of future builds which will help make near-zero emissions from coal-fired electricity generating plants a reality in the commercial world.

TOSHIHIKO YAMADA

MANAGER RESEARCH & DEVELOPMENT DEPARTMENT
ENERGY & PLANT OPERATIONS, IHI

I was a Technical and Investment Advisory Committee member and managed the testing, implementation and evaluation of the oxyfuel boiler and process.

THINKING AHEAD

My attraction to this project was the possibility of contributing to a project that would develop technology to help maintain an environment suitable for human life on earth for the future.

I was really surprised to see that the vintage plant at the 40-year-old Callide A Power Station could be operated for a project such as this.

I found Australia to be a huge land with much natural forest. I had the opportunity to see wild kangaroos, wallabies, turtles and emus.

"Working with the Australians on the team, I found we both bring a strong work ethic and sense of responsibility to each job."

STRONG TIES

I would welcome the opportunity to work on a project in Australia again one day. I found most Australian people are gentle and warm-hearted, and I believe projects like the Callide Oxyfuel Project can build good relationships between our two countries.

Relationships were key to the success of the Callide Oxyfuel Project. As a member of the Technical and Investment Advisory Committee, IHI Corporation's Toshihiko Yamada was instrumental in delivery of the oxyfuel combustion process. And of course there was also Australia's abundant and exotic flora and fauna which proved enthralling for the Japanese members of the project team.

DR HIROSHI SASATSU

DIRECTOR RESEARCH & DEVELOPMENT DEPARTMENT
J-POWER

I managed the communication between the Japanese and Australian partners to ensure the smooth operation of the project, especially at the beginning. For a time, I was an Executive Director of Oxyfuel Technologies Pty Ltd, the agent for the joint venture, and Callide Oxyfuel Services Pty Ltd, the operations management company for the project.

MEASURES OF SUCCESS

The project was successful because we were able to evaluate the technology based on the operational and maintenance data, but also through verification and discussion among the project members. We were also able to clarify issues that needed to be solved before commercial deployment.

"The project was a great opportunity to expand our personal engineer networks in both Japan and Australia."

A ROADMAP FOR THE FUTURE

The project gives us clear guidelines for the commercial design of this technology, which is one of the more promising CO_2 separation methods.

J-POWER had been developing both CO_2 separation technology and high efficiency technology for coal-fired power plants for some time and had found that oxyfuel technology was one of the more promising technologies. So for Dr Hiroshi Sasatsu, the Callide Oxyfuel Project was a valuable opportunity to properly evaluate this technology through demonstration.

THE GOALS

COMMON GOALS, SHARED SUCCESS

The combination of Australian and Japanese expertise, and the shared goal of demonstrating that electricity could be produced from coal with almost no emissions, formed the cornerstone of the Callide Oxyfuel Project.

> This project is an exemplar of technology collaboration to achieve the common purpose of low emissions, coal-fired power generation.

DR NOEL J SIMENTO, MANAGING DIRECTOR, AUSTRALIAN NATIONAL LOW EMISSIONS COAL RESEARCH AND DEVELOPMENT

Dr Chris Spero and Franco Montagner inspecting part of the carbon capture plant during one of the regular plant 'walkdowns'

The project goals were underpinned by an extensive research and development program which sought to characterise the performance of the oxyfuel boiler and the CO2 capture plant. The program included several field trials with a range of coals, and detailed scientific measurements around the various process components of the plant. An additional imperative was to conduct a series of injection tests with CO_2 product from the project to extend the fundamental knowledge of how CO_2 (with and without impurities) interacts chemically with storage rock.

> Whilst oxyfuel technology can be applied as a new-build, it can also be fitted to existing power stations which means potentially a quicker path to low emission electricity generation from coal.

DR CHRIS SPERO, PROJECT DIRECTOR

The Callide A Power Station control room. Dr Chris Spero discusses operation of the plant with Site Manager, Rick Jacobs. In the background, Takahiro Goto, Graeme Smallbone and Ian Collard.

IHI engineers during the early stages of planning for the construction of the Callide Oxyfuel Project

THREE PRIMARY GOALS

1. Demonstrate a complete and integrated process of oxyfuel combustion of pulverised coal within a national electricity market facility, incorporating oxygen production, oxyfuel combustion, CO_2 processing and liquefaction

2. Obtain detailed engineering design and costing data and operational experience to underpin the commercial development and deployment of new and retrofitted oxyfuel boiler applications for electricity generation

3. Obtain geotechnical design and costing data and operational experience through participation in a carbon storage trial as learnings for the development of large scale geological storage in excess of one million tonne of CO_2 per year

NOBUHIRO MISAWA

CHIEF MANAGER PLANNING AND MANAGEMENT OFFICE THERMAL POWER ENGINEERING, J-POWER

I had studied the application of oxyfuel technology to a commercial power plant in Japan, so having an opportunity to work on one of the first projects to modify a commercial power plant and demonstrate a full carbon capture system was very important to me.

HITTING GOALS

The project was very successful in meeting its goals and producing results. These results can now contribute to developing a large-scale demonstration project. This project also proved that international collaboration is very important in promoting carbon capture and storage.

"Through this project I gained a broad knowledge of foreign project management and business and I am confident this experience will be of benefit in the future."

FUTURE BENEFITS

This project proved that oxyfuel technology can work in a coal-fired power plant and that the captured CO_2 can be stored underground. These results will reduce the risk and cost of future large-scale demonstration projects and the commercialisation of carbon capture and storage technologies.

The forging of excellent relationships among Australian and Japanese participants in the project was paramount to the project's success and a source of personal and professional satisfaction for Nobuhiro Misawa, whose role from 2005 was to manage Japanese participants in the project and act as key contact for the Japanese funding partners.

RICK JACOBS

OPERATOR TECHNICIAN AND PLANT MANAGER CALLIDE A POWER STATION

As an Operator Technician, I worked on permits, operations manual writing and operator training during the construction phase and later commissioning and operations during the production and testing phases. Eventually I became plant manager and took on responsibility for the safety and welfare of personnel at the plant.

INFLUENCING THE FUTURE

When I heard the project would be looking at oxyfiring and combustion, I immediately wanted to get involved as I've always had an interest in combustion. I'm also a firm believer in the human impacts of emissions by thermal power plants and their contribution to global warming and the need to control levels of greenhouse gasses for future generations.

"I couldn't pass up the opportunity to be involved from the inception of a project that might influence the next possible generation of coal-fired thermal plants."

HITTING GOALS EARLY

I was so fortunate to have the opportunity to be in control of the plant when it transitioned to oxyfiring mode and dealing with the unknowns associated with this was very exciting. When we obtained the 10,000 hours of oxyfiring ahead of schedule, it was the achievement of a personal goal.

FUTURE VIABILITY

I would like to see this technology become commercially viable, particularly in Australia because of our vast coal reserves. Hopefully future generations will benefit from this technology that can help manage greenhouse gas emissions.

The role of an Operator Technician is multi-faceted, covering permits, operations manual writing, operator training, and commissioning and operations at the plant. Such a role becomes even more critical in a project that aims to test new technology such as the industrial-scale demonstration of oxyfuel combustion. For Rick Jacobs, demonstrating over 10,000 hours of oxyfuel combustion represented the attainment of both a professional and a personal goal.

THE SITE

OLD BECOMES NEW

The Callide Oxyfuel Project demonstrated that new technology could be applied to an old power station to produce cleaner electricity.

The Callide A Power Station near Biloela in Central Queensland was chosen as the demonstration site for the project for a number of reasons: the 30 megawatt capacity of the power station's Unit 4; the availability of spares from Callide A Units 1– 3; and the availability of operations and maintenance support from CS Energy's nearby Callide B and Callide C Power Stations. As such, retrofitting the Callide A Power Station with oxyfuel technology represented a low-risk and cost- and time-effective way to demonstrate clean coal technology on an industrial scale and heralded an exciting new era in the station's history.

Built in the 1960s, the Callide A Power Station is typical of the conventional coal-fired power stations that generate the majority of the world's electricity. This power station provided electricity for many years before being placed in storage at the end of its economic life.

> Throughout several years of the project, I was the Chief Executive of CO2CRC. The Callide Oxyfuel Project demonstrated that capturing CO_2 is not just something for the distant future; it is here and now! I was delighted when the step was taken to inject some of the captured CO_2 into the Otway storage site, clearly demonstrating the full carbon capture and storage process. I attribute its success first and foremost to the vision, persistence and leadership of Chris Spero and secondly, the willingness of CS Energy to back that vision. This project has shown the way for future oxyfuel projects and contributed enormously by demonstrating that retrofit is feasible.

PROFESSOR PETER J COOK, PROFESSORIAL FELLOW; PRINCIPAL ADVISER

SAFE STORAGE UNDERGROUND

The containment of oil and gas (especially methane and CO_2) in sedimentary rock formations has been demonstrated by nature over geological time. Learning from this natural analogue, the oil and gas industry has successfully injected CO_2 into declining oil and gas fields for more than 40 years to enhance oil and gas recovery.

As well as demonstrating carbon capture, the Callide Oxyfuel Project advanced industry knowledge of carbon storage through several activities:

- collaboration with Origin and Santos to appraise depleted natural gas fields in the Northern Denison Trough
- collaboration with the former ZeroGen CSS Project to appraise saline aquifers in the Northern Denison Trough
- studies funded by the Global CCS Institute that examined the carbon storage potential of the Surat Basin in South East Queensland and any associated environmental and social factors
- collaboration with Carbon Transport and Storage Company (CTSCo) on the development of a carbon storage trial in the Surat Basin.

Furthermore, in late 2014, the Callide Oxyfuel Project team in conjunction with the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) undertook a series of CO_2 injection tests. CO_2 captured during the Callide Oxyfuel Project (around 30 tonnes) was transported 2,000 kilometres by road and injected some 1,500 metres underground into porous rock (the Paaratte sandstone) at CO2CRC's Otway Project site at Nirranda South in South Western Victoria. These tests were used to evaluate the geochemical and physical behaviour of CO_2 within the storage rock.

Carbon storage research has been underway at the Otway Project since 2006 as part of comprehensive CO2CRC research program into carbon capture and storage; a developing technology for reducing global greenhouse gas emissions by capturing CO_2 emissions from large sources and storing them permanently and safely in deep underground rock formations.

Injection well No. 2 at the CO2CRC Otway Project site

> As a scientist and manager, the project was a powerful demonstration of what could be achieved through committed international collaboration. Right from the start, the project helped increase global carbon capture and storage knowledge on both operational and scientific levels, including successfully navigating the complex regulatory environment and pushing through financial barriers.
>
> **DR MATTHIAS RAAB,**
> **CO2CRC CHIEF OPERATING OFFICER**

KEY FACTS

- The Callide A Power Station in Central Queensland, Australia, was the first power station in the world to be retrofitted with oxyfuel carbon capture technology
- The Callide A Power Station (Unit 4) was commissioned in 1969
- The Callide A Power Station (Unit 4) was re-commissioned for the project in 2008
- The Callide A Power Station's Unit 4 boiler modifications were finished in March 2011
- The Unit 4 boiler operated in full oxyfiring mode for the first time in March 2012

IAN COLLARD

SHIFT OPERATOR TECHNICIAN
CALLIDE A POWER STATION

As a Shift Operator Technician, my role straddled both the operation of the plant and technical support of the control systems.

I was attracted to being a part of a project that aimed to assist with reducing the carbon footprint of the energy industry.

CYCLONIC CHALLENGES

The most challenging day for me was when I was acting operations coordinator during Tropical Cyclone Marcia. The operators scheduled to work were not able to make it to Biloela. It was difficult to arrange coverage with no landline at home, or at the power station, and a mobile service that was intermittent.

It was terrific to see how well different groups of people with different skills were able to work together as a coherent team.

"It was really exciting being involved in a genuinely international project. We worked with technical representatives from Europe as well as Japan."

FUTURE HOPE

We successfully proved the oxyfuel concept. Now, I hope the technology can be commercialised.

The skill and knowledge of project participants can mitigate many risks in a project of the scale of the Callide Oxyfuel Project. But not even the superb Callide Oxyfuel Project team could have predicted the impact of Tropical Cyclone Marcia. Thanks to Shift Operator Technician Ian Collard and the rest of the team, they overcame this challenge and maintained the power station's operation.

ANNE MARSHALL

ADMINISTRATION SUPPORT OFFICER
CALLIDE A POWER STATION

As the Administration Support Officer, my role was many and varied. Basically it was about seeing to people's needs on-site, including liaising and communicating with anyone associated with the project who visited the site, including joint venture partners, CS Energy representatives, Callide Oxyfuel Services Pty Ltd (COSPL) and contractors.

I'd never worked in the power industry so it was a new experience and a challenge. I was attracted to working as part of a small team to achieve a common goal. Plus I enjoy learning new things and reaching targets in set timeframes. It can be stressful but also very rewarding when goals are met.

COOL, CALM AND COLLECTED

It was a challenge to understand the process of a coal-fired power station and the new technology, and then to grasp the terminology used which was so foreign to me. It was up to me to remain cool, calm and collected when the men around me were under a lot of pressure to meet timeframes, fix technical issues and implement new processes.

I was surprised to learn that on a project like this, when little things go wrong, they can cause the biggest problems.

"It was very exciting meeting and working with very intelligent, passionate people who were on the project to make a difference."

A BETTER PLACE

I believe it is our duty to leave the world a better place for future generations. As Abraham Lincoln said, "You cannot escape the responsibility of tomorrow by evading it today."

The scope and ambition of the Callide Oxyfuel Project meant it generated interest nationally and internationally drawing visitors from across Australia and overseas. From August 2009, the Callide A Power Station in Central Queensland hosted more than 4,115 visitors, including 284 people from overseas. The person responsible for ensuring every visit ran smoothly was the station's Administrative Support Officer, Anne Marshall.

JEFF POWE

CONTRACT OPERATOR
CALLIDE OXYFUEL PROJECT

I've always enjoyed working on new projects, from building power stations to carrying out upgrades to plant. My role in this project had three stages. The first stage was as an Operator at the power station, carrying out isolations to allow inspections of the plant to be carried out safely on equipment that had been shut down, and also helping with the recommissioning and testing of plant. In the second stage, I carried isolations to allow oxyfuel equipment to be installed; and finally, during the third stage I had to develop and carry out isolations to enable the maintenance team to gain safe access to the equipment.

COLLABORATION KEY

I was surprised to see how well a small group of people can work together to make a project a success.

"Being able to operate a boiler and turbine using new technology like oxyfiring and carbon capture was like playing with a new toy."

MORE CHOICE

This project gives the world another choice on how coal can be used to generate electricity more cleanly.

For Jeff Powe, the Callide Oxyfuel Project was personal. He'd first been exposed to the Callide A Power Station as a young boy when he would follow his father Claude Powe - who was the station's Electrical Supervisor in the early 1960s – around at work.

THE PROCESS

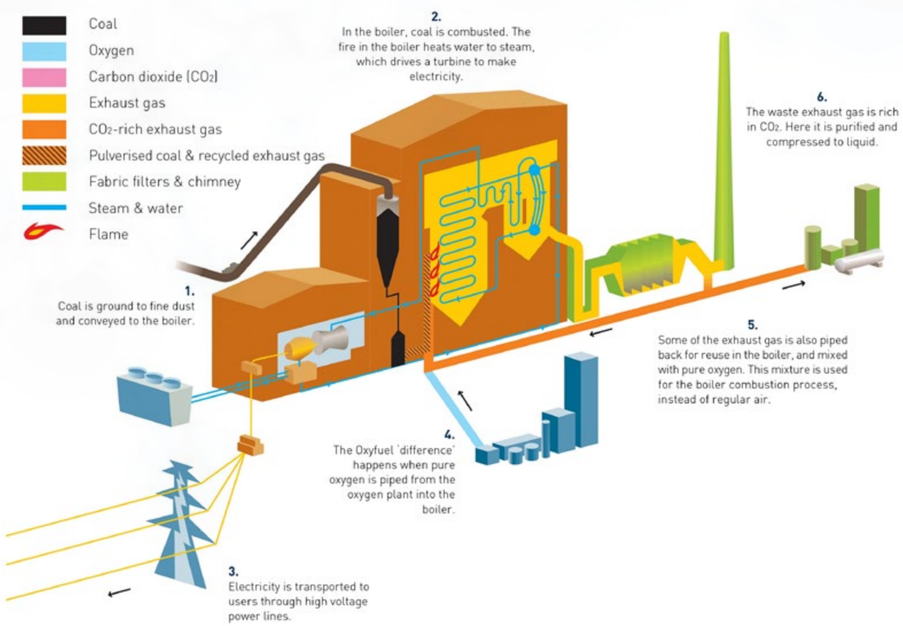
ACHIEVING LOW EMISSIONS

The Callide Oxyfuel Project demonstrated how electricity could be produced from coal with almost no emissions by capturing a predominant portion of the CO_2 as liquefied gas, and other waste gases such as oxides of nitrogen (NOx), oxides of sulphur (SOx), and heavy metals in condensate form from a power station.

THE CALLIDE OXYFUEL PROJECT INCLUDED TWO KEY PROCESSES

1. oxyfuel combustion and carbon capture at the power station
2. assessment of CO_2 storage capacity in Queensland, and injection testing of Callide Oxyfuel CO_2 product

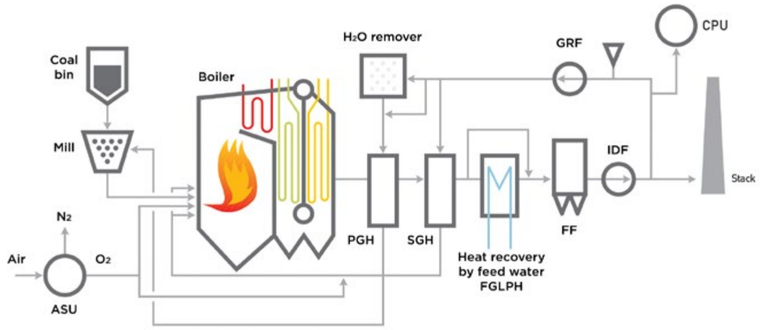
THE PROJECT — STEP-BY-STEP



WORLD'S LARGEST PROJECT OF ITS TYPE

The oxyfuel combustion process was first conceived by IHI in Japan in 1973, and IHI, J-POWER and JCOAL have been developing its application to power stations since the 1990s. The oxyfuel combustion process has been tested at a small scale in Japan, the USA, Canada, United Kingdom and Europe. However, while the Callide Oxyfuel Project was in progress, it was the largest project of its type in the world.

Oxyfiring of coal-fired boilers used for electricity generation involves the combustion of pulverised coal in a mixture of oxygen and recirculated flue gas in order to maintain stable combustion conditions. When compared to the normal air-firing case, this reduces the net volume of flue gases from the process, and substantially increases the concentration of CO_2 in the flue gases. Oxyfuel technology can therefore both technically and economically facilitate the capture of CO_2 for subsequent geological storage.



Callide Oxyfuel Process

LEGEND

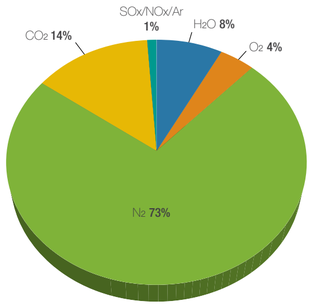
ASU – Air Separation Unit
PGH – Primary Gas Heater
SGH – Secondary Gas Heater
FF – Fabric Filter
GRF – Gas Recirculation Fan
IDF – Induced Draft Fan
CPU – CO_2 Purification Unit

The CO_2 cold box for the separation of inert gases from CO_2 product (rear) and flue gas dryers (foreground)

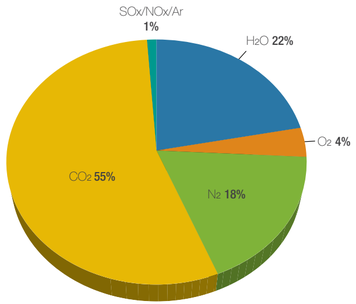
NATURE'S PROCESS USING MODERN TECHNOLOGY

The process of geosequestration involves the injection of CO_2 deep underground (generally to depths of greater than one kilometre) into porous and permeable rock structures, which are overlaid themselves by rocks with very low porosity and permeability, for the purpose of safe and permanent storage. To this end, the selection and characteristics of the CO_2 injection or storage site is critical. The CO_2 is retained and trapped within the rock (generally a sandstone), by a range of physical and chemical mechanisms for which we already have several natural analogues.

AIR-FIRED FLUE GAS (MOL. %)



OXY-FIRED FLUE GAS (MOL. %)



Pipework leading from the large air dryers to the oxygen air separation unit

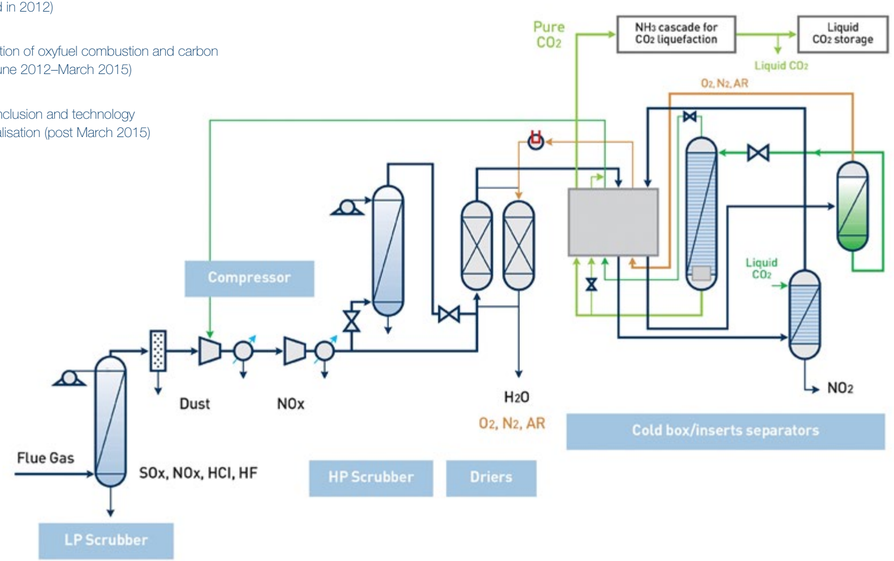
Senior Mechanical Tradesperson Brendan Nichols works on a modification to the CPU cold box venting pipe during the demonstration phase

KEY FACTS

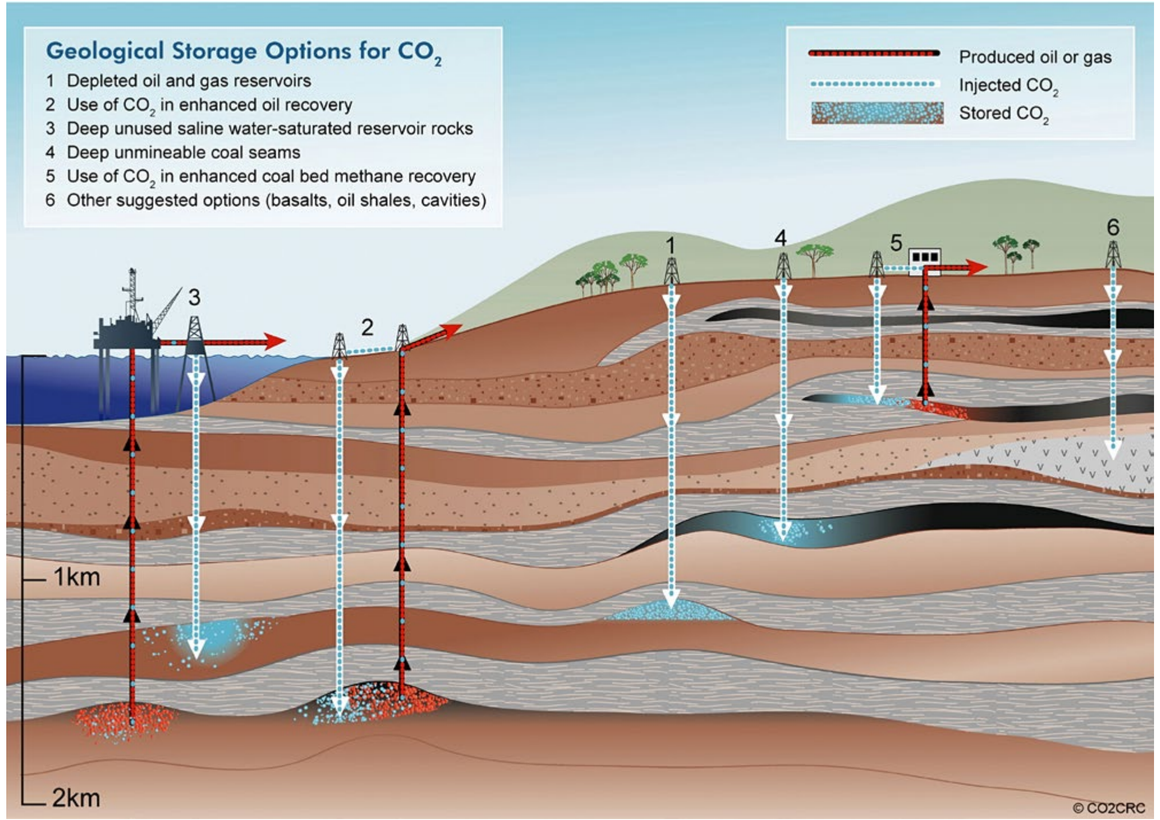
- More than 150 staff and contractors worked more than 500,000 hours during the construction and initial commissioning phases of the project
- 30 people were employed during the demonstration phase

KEY STAGES OF THE PROJECT

1. refurbishment of the existing Callide A Unit 4 near Biloela in central Queensland (completed in 2009)
2. retrofit of oxyfiring technology and carbon capture (completed in 2012)
3. demonstration of oxyfuel combustion and carbon capture (June 2012–March 2015)
4. project conclusion and technology commercialisation (post March 2015)



Schematic of Callide A CO_2 Capture Plant



ROD CALLOW

SITE MAINTENANCE SUPERVISOR
CALLIDE A POWER STATION

As Site Supervisor at the Callide A Power Station, I managed a small maintenance team. Our job was to maintain the plant to ensure its availability and reliability during the project. We also managed contracted services such as fire systems, site air-conditioning, waste disposal, industrial and domestic cleaning, labour hire and warehouse activities. I also coordinated planned and unplanned outages.

A WELCOME SURPRISE

I was really surprised at the reliability of the 40-year-old boiler that had been out of service for around ten years. We really didn't know how the boiler would manage. Our target was to operate in oxyfiring mode for 10,000 hours. Operating in oxyfiring mode meant that the back end temperatures of the boiler were higher than in air mode. There was always a threat of tube leaks. Yet we only encountered one tube leak during the project and we were able to plug the affected tube with no detriment to the boiler or the station's operations.

"Knowing this was a world-first demonstration project that could potentially reduce emissions distributed from a coal-fired power station was a definite attraction for me."

MEETING CHALLENGES

I would have to say the most exciting aspect of this project was being part of a team that continually met and exceeded safety and production targets, even with the challenge of working with a 40-year-old boiler.

MAKING A DIFFERENCE

I would like to think the success of the Callide Oxyfuel Project will lead to further carbon capture projects around the world and in turn, potentially reduce emissions worldwide and provide a cleaner energy future.

Safety and reliability are paramount in a project of the size and scale of the Callide Oxyfuel Project. Site Supervisor Rod Callow was instrumental in ensuring the safety of his team while maintaining the availability and reliability of the plant, both functions critical to the project's success.

TAKAHIRO GOTO

RESEARCH & DEVELOPMENT DEPARTMENT
ENERGY & PLANT OPERATIONS, IHI

I was a member of the permanent site staff responsible for testing the oxyfuel boiler system and reporting test results to the Japanese side. I was really attracted to being part of a project that would realise new technology at a large-scale plant.

ON THE FRONT-LINE

While it was challenging trying to resolve the many problems involved with obtaining long-term oxymode operation, it was very exciting to be at the front-line performing various tests that helped us achieve oxyfiring operation at the power plant.

"The whole team worked very hard and I would love to have another opportunity to work on a project in Australia in the future."

CLOSE COLLABORATION IN A NEW LAND

Australia is such a large land with beautiful oceans and varying climates. It was very interesting to work with the Australian team and learn how we each approach the implementation of safety rules.

The close collaboration between Australia and Japan was a hallmark of the Callide Oxyfuel Project and fundamental to its success. United in their joint vision, people from Japan and Australia worked together as a team to achieve world-first results in producing electricity from coal with almost no emissions. As a Technical and Investment Advisory Committee member, IHI's Takahiro Goto made an important contribution to the team.

THE RESULTS

PROVEN SUCCESS

The Callide Oxyfuel Project's demonstration phase drew to a close in March 2015. During close to three years of operation, the $245 million international joint venture demonstration project achieved more than 10,200 hours of oxyfuel combustion and over 5,600 hours of carbon capture from the coal-fired electricity generation facility at CS Energy's Callide A Power Station.

Ian Collard monitoring the plant's operation from the control room

> At a time when the world is looking toward a low emission future while meeting the growing need for energy, the Callide Oxyfuel Project demonstrated that there is a way to generate electricity using coal, but with lower CO_2 emissions. This is essential for continuing to power economic growth and to meet the global demand for reliable, cost-effective electricity.
>
> **STEWART BUTEL, CHAIRMAN, AUSTRALIAN COAL ASSOCIATION LOW EMISSIONS TECHNOLOGY (ACALET)**

CLEAN ENERGY FROM FOSSIL FUELS

One of only a handful of low emission coal projects in the world, the Callide Oxyfuel Project made a significant contribution to the international carbon capture and storage knowledge bank. The results from the project can be applied to future low emission projects worldwide aimed at producing cleaner and affordable electricity from fossil fuels.

A VIABLE TECHNOLOGY

The project helped create a pathway for the design and construction of larger scale oxyfuel combustion plants with carbon capture, as both 'bolt-on' technology to existing plant or as new-build plant, offering exciting future possibilities. When linked with geological carbon storage, this technology has the potential to reduce CO_2 emissions from coal-fired power stations by around 90 per cent, providing a realistic technology option for low emission electricity generation. This technology is now ready to be scaled up and is available to build commercial scale, capture-ready power plants.

Tadashi Hamano from J-POWER reviewing a paper presented at a Technical and Investment Advisory Committee meeting held at the Callide A Power Station

CONTRIBUTION TO GLOBAL KNOWLEDGE

The project team collaborated with research and development organisations and participants in other projects internationally to share knowledge to help progress the commercialisation and deployment of oxyfuel combustion technology around the world.

Several additional research projects were initiated during the development, construction and demonstration of oxyfuel technology at the Callide A Power Station. The Australian National Low Emissions Coal (ANLEC) Research and Development Program identified oxyfuel technology as a priority, and supported a number of fundamental and applied research and development activities during the project's operational phase. This work provided valuable technical learnings that will inform future designs and commercial applications of this technology.

The Callide Oxyfuel Project also helped advance the power generation industry's investigations into the viability of carbon storage through its collaboration with CO2CRC. Testing was carried out at the CO2CRC's Otway Project site in South Western Victoria to evaluate the geochemical and physical behaviour of the CO_2 from the Callide Oxyfuel Project within the storage rock.

Results and learnings from the project have been published either directly, or through its association with research organisations such as Australian National Low Emissions Coal (ANLEC) and the Global CCS Institute. Work will continue to collate, analyse and synthesise new knowledge about the technology to facilitate deployment and commercialisation of oxyfuel combustion and carbon capture technology.

The Callide A Power Station boiler operating in oxyfiring mode

> As the largest oxyfuel demonstration in the world, this was a project of global significance. It is evidence that Australia – through its coal industry, power generation industry and government – contributes its fair share to the worldwide pursuit of emissions reduction.
>
> **DR NOEL J SIMENTO, MANAGING DIRECTOR, AUSTRALIAN NATIONAL LOW EMISSIONS COAL RESEARCH AND DEVELOPMENT**

Students from the University of Newcastle were involved in the project

KEY FACTS

- total generation: 14,800 hours
- hours of oxyfiring operation: 10,200
- hours of carbon capture: 5,600
- tonnes of coal burned: 320,000 tonnes
- coal supplied from: Anglo American's Callide Mine, but several other coals were also tested
- type of coal used: black coal
- number of people employed during construction: 150
- number of hours worked during construction: 500,000
- number of people employed during demonstration: 30

Operator Technician Colin Garth knew that bringing an old power station back to life wouldn't be easy. But when he was offered the chance to be a part of such a ground-breaking project, he didn't hesitate; in fact he embraced the opportunity.

COLIN GARTH

OPERATOR TECHNICIAN
CALLIDE A POWER STATION

The prospect of bringing an old generating unit back to life and working with new technology really attracted me to this project.

NEW CHALLENGE, NEW APPROACH

Understanding and operating the carbon processing unit was the most challenging aspect of the project because it required a totally different approach from running a power generating unit.

"The most exciting aspect of the project was working with engineers from all around the world doing things that had never been done before."

ULTIMATE SATISFACTION

Once the desired result was achieved, fine-tuning the process was both challenging and very satisfying.

DOUG RANIE

BUSINESS MANAGER
CALLIDE OXYFUEL PROJECT

As the project's Business Manager, my role was to manage the commercial and financial operations of the joint venture, provide business directions and support, lead the non-technical functions of the project, coordinate legal and insurance requirements, and act as Company Secretary for the joint venture companies.

BRINGING EVERYONE TOGETHER

Successfully managing the interaction of many different groups – engineers, scientists, operations and maintenance personnel and management groups – was essential if this project was to succeed. Managing these interactions was a challenge for the project management group and their success in doing so was one of the project's great achievements.

"It surprised me how smooth the initial changeovers between air and oxyfuel combustion were. The reality was we were bringing together old and new plant and I was expecting many more challenges than we experienced."

SOLUTIONS-FOCUSED

Whenever there were technical, operational and financial challenges to overcome, people threw themselves into finding solutions. The desire of all the different groups to make this project succeed was the most exciting aspect for me.

For Doug Ranie, executing his role as Business Manager was all about balance: balancing the many requirements and goals of the project's participants and being involved in myriad different aspects of the project from the plant's construction and operation through to discussions with lawyers, accountants and communications professionals.

THE LEGACY

FROM IDEA TO REALITY

From its conception in 2003, the Callide Oxyfuel Project took oxyfuel technology from an idea to a reality and in doing so, demonstrated that our most abundant fossil fuel resources can still have a place in the economic future of Australia and countries across the world.

Our project has helped create a pathway for the design and construction of larger scale oxyfuel combustion plants with carbon capture, as both 'bolt-on' technology to existing plant or as new-build plant. The future for this technology is very exciting.

DR CHRIS SPERO, PROJECT DIRECTOR

ABUNDANT POSSIBILITIES

Oxyfuel technology is now firmly on the map of technology alternatives for low emission electricity generation from coal. The Callide Oxyfuel Project has demonstrated that coal can maintain its economic competitiveness while meeting environmental standards.

> This was a technically challenging project using what is essentially a very old power station and incorporating new, leading technology into it. The project's success is testimony to the tenacity of the international partners and a collective desire to contribute to a cleaner energy future.
>
> **MARTIN MOORE, CEO, CS ENERGY AND CHAIR OF THE CALLIDE OXYFUEL PROJECT JOINT VENTURE MANAGEMENT COMMITTEE**

CS Energy CEO Martin Moore and Joint Venture Management Committee members meet at CS Energy's offices in Brisbane

> It is a rare privilege to witness a research program develop into a viable technology option. It is a real credit to the leadership and teams who delivered the successful project.
>
> **DR NOEL J SIMENTO, MANAGING DIRECTOR, AUSTRALIAN NATIONAL LOW EMISSIONS COAL RESEARCH AND DEVELOPMENT**

- Oxyfuel technology can be retrofitted to an existing plant
- When linked to CO_2 geological storage, oxyfuel technology has the potential to reduce greenhouse gas emissions to less than 10 per cent of normal coal-fired power plant emissions
- Oxyfuel technology can reduce all other emissions such as SOx, NOx and heavy metals to near-zero compared to levels from conventional coal-fired power plant
- Oxyfuel technology is ready to be scaled up for at least semi-commercial demonstration (of oxyfuel combustion and carbon capture), and to full commercial scale for capture-ready power plants

BEN PETTY

OPERATOR TECHNICIAN
CALLIDE A POWER STATION

As an Operator Technician, I was part of the operations team whose role was the operation of the boiler/turbine unit, the air separation units and the CO_2 plant.

I was attracted to this project because it offered me the chance to work on something unique and world-leading. And the fact it was being done right here at Callide made it an opportunity that I couldn't pass up.

MEETING CHALLENGES

The operation of the air separation units and the CO_2 plant was a particularly challenging task especially in the earlier days and during commissioning. It was new technology for all of us and it took some time to build up experience and develop a good working knowledge of the plant.

"The amount of interest in the project from domestic and international parties was surprising. There were always visitors and representatives of project partners from around the world coming to site to see the project in operation."

ALWAYS SOMETHING DIFFERENT

Being a research and demonstration project, there was always something different going on and we were pushing the boundaries of the plant operation. It was definitely more exciting than the operation of your average power station.

FUTURE POSSIBILITIES

I think the success of this project will lead to the development of larger scale projects to further develop the technology of oxyfiring and perhaps even other technologies as well. I believe this project and the current development of carbon capture and clean energy technologies will be a key step to the world's management of climate change.

When a world-first endeavour like the Callide Oxyfuel Project comes along, people are naturally drawn to it, lured by the opportunity to be part of something unique. When Callide A Power Station Operator Technician Ben Petty heard about the project, he couldn't pass up the chance to be a part of it even though it meant acquiring new knowledge and meeting many new challenges.

SANDEEP SHARMA

REGIONAL MANAGER ASIA – AUSTRALIA
SCHLUMBERGER CARBON SERVICES

The Callide Oxyfuel Project was a unique venture backed by the leading companies in the power generation, coal, oil and gas industries. For Schlumberger it was an ideal project to demonstrate the viability of carbon capture and storage. We had a technical team supporting the project in Brisbane while I had a managerial and oversight role based in Perth.

NEW TECHNOLOGY AND SURPRISES

The prospect of bringing an old generating unit back to life and working with new technology really attracted me to this project. And there were surprises too. For example, I was really surprised at how the two identical air separation units behaved differently.

CHALLENGES LEADING TO RESULTS

It was challenging screening a number of storage options and developing a selection criteria, very often from a limited amount of data. More than seven quality geological studies resulted from the project.

"It was really satisfying being a part of a demonstration that actually captured a high purity CO_2 stream and therefore validated the oxyfuel concept."

FUTURE VIABILITY

The project demonstrated the technical viability of the oxyfuel process and highlighted areas of improvement for future developments. The project also generated a significant amount of intellectual property which will support the future viability of the technology in applying carbon capture and storage to other power plants.

A key component of the Callide Oxyfuel Project was to trial carbon storage and as Schlumberger's Regional Manager for Asia - Australia, Sandeep Sharma was instrumental in evaluating the geological storage options for the project.

PROJECT PARTNERS

CS ENERGY

CS Energy is a Queensland Government-owned energy company with almost 400 employees, three power stations and a generation capacity of 2,475 megawatts.

CS Energy's generation portfolio comprises coal-fired and pumped storage hydro power stations, which provide a mix of baseload, intermediate and peaking electricity into the market. The company operates its power stations with a focus on safety, reliability and commercial discipline.

CS Energy owns and operates the Callide A and B power stations near Biloela in Central Queensland, the 750 megawatt Kogan Creek Power Station near Chinchilla in South West Queensland, and the 500 megawatt pumped storage hydroelectric Wivenhoe Power Station near Esk in South East Queensland. The company has a 50 per cent interest in the Callide C Power Station as part of a joint venture with InterGen.

ROLE IN THE CALLIDE OXYFUEL PROJECT

CS Energy played a lead role in the Callide Oxyfuel Project with the oxyfuel demonstration taking place at CS Energy's Callide A Power Station.

KEY FACTS

- CS Energy has the largest energy trading portfolio in Queensland
- CS Energy's Kogan Creek Power Station is one of the newest and most efficient coal-fired power stations in the Australian electricity market

ACALET

ACA Low Emissions Technologies (ACALET) is an industry body whose member companies are the black coal producers in Australia. ACALET member companies operate in New South Wales, Queensland, Western Australia and Tasmania.

In 2006, ACALET member companies established the COAL21 Fund as part of a world-first, whole-of-industry funding approach to support research and pre-commercial demonstration of low emission technologies in the power generation sector. The COAL21 Fund raises industry funds from a voluntary levy on coal production.

ROLE IN THE CALLIDE OXYFUEL PROJECT

ACALET, through the COAL21 Fund, was the Callide Oxyfuel Project's largest funder. The project's industry connections went beyond the service providers to this new industry to include participants in the electricity generation sector itself. The involvement of ACALET ensured broad stakeholder involvement in the development of oxyfuel technology. Through the COAL21 Fund, ACALET has focused effort on the demonstration of low emission coal technologies.

COAL21 FUND

KEY FACTS

- In 2006, the establishment of the COAL21 Fund was part of a world-first, whole-of-industry funding approach to support greenhouse gas abatement
- The COAL21 Fund is governed by ACA Low Emissions Technologies Limited (ACALET) and is raising industry funds from a voluntary levy on coal production to support the pre-commercial demonstration of low emissions technologies and supporting research and development
- ACALET recognises there will not be a single "one size fits all" solution to greenhouse gas emissions from coal production and use and has established a strategic portfolio of project investments. These include:
  - Callide Oxyfuel Project
  - NSW Storage Assessment
  - Queensland Storage Assessment – CGI and CTSCo
  - ANLEC R&D
  - fugitive emissions from coal mining
- Other project investments will be considered as the strategic need is identified

IHI

IHI Corporation (IHI) was established in 1853 during the dawn of the modern age in Japan. Since then it has developed businesses in a wide range of fields - from ships, on-shore machinery and plants to aero engines and space - and has underpinned industrial development and improvement of quality of life in both Japan and the whole world through its advanced engineering capabilities. In 2013, IHI celebrated its 160th anniversary. In order to make dreams come true for people all over the world, IHI Group will continue to draw on its technologies to contribute to the development of society in the years to come.

ROLE IN THE CALLIDE OXYFUEL PROJECT

IHI was responsible for retrofitting the vintage Callide A Unit 4 boiler with oxyfuel technology, so that the boiler would be able to burn the pulverized coal in the oxyfuel environment.

KEY FACTS

- IHI employs over 27,000 people and has eight works and 17 branches/sales offices in Japan, and 15 overseas offices (at 1 July 2014)
- IHI has built over 100 pulverized coal firing boilers for various clients throughout the world
- IHI now has broad capabilities in designing, manufacturing and constructing a variety of boilers ranging from small packaged boilers with a capacity of 130 kilograms per hour to super-critical pressure boilers having a steam generating capacity of over 3,000 tonnes per hour for 1,050 megawatts thermal power plants
- IHI is the national leader in the production of jet aircraft engines in Japan

J-POWER

J-POWER (Electric Power Development Co., Ltd.) was established in 1952 through a government initiative to increase the supply of electricity in Japan.

Over the 60 years since then, J-POWER, as a wholesale power company, has provided an inexpensive and stable supply of electricity to Japan's 10 major electric power companies (EPCOs). At the same time, J-POWER has contributed to the development of the Japanese economy and the improvement of the quality of life in Japan by constructing and operating a nationwide network of transmission trunk lines for EPCOs.

ROLE IN THE CALLIDE OXYFUEL PROJECT

J-POWER played an integral role in the project management of the Callide Oxyfuel Project, bringing more than 60 years of experience in electricity generation and knowledge of research and development activities for clean coal technologies from Japan.

J-POWER
EPDC

KEY FACTS

- has built, and currently operates, 68 power plants throughout Japan
- has 20 wind power locations operating in Japan
- provides international consulting services for technical cooperation with electric power development and to protect the environment since the 1960s, and has executed a total of 349 projects in 64 countries and regions (at 31 March 2014)
- involved in 35 independent power producer (IPP) projects in seven countries and regions, which translates into a total generation capacity of about 19.6 million kilowatts, of which 6.09 million kilowatts is owned by J-POWER (at 31 March 2014)

MITSUI & CO.

MITSUI & CO., LTD

Mitsui (or Mitsui & Co., Ltd) is one of the most diversified and comprehensive trading, investment and service enterprises in the world, with 140 offices in 66 countries as of April 2015. Utilising these global operating locations, network and information resources, Mitsui is multilaterally pursuing business that ranges from product sales, worldwide logistics and financing, through to the development of major international infrastructure and other projects in the following fields: Iron and Steel Products, Mineral and Metal Resources, Infrastructure Projects, Integrated Transportation Systems, Basic Chemicals, Performance Chemicals, Energy, Food Resources, Food Products and Services, Consumer Services, IT and Communication and Corporate Development. Mitsui is actively taking on challenges for global business innovation around the world.

ROLE IN THE CALLIDE OXYFUEL PROJECT

As the major Japanese entity with global interests in metal products and minerals, machinery and energy, Mitsui brought its expertise in project management and coal-fired generation processes to the project.

KEY FACTS

- Mitsui was established in 1947
- Mitsui has 140 offices in Japan and overseas (at April 2015)
- Mitsui is founding member of the first international coal mining and export joint venture in Australia, which started production in 1962
- The strategy of the energy segment of Mitsui's business is to develop a balanced portfolio of upstream energy interests based on an overview of diversified energy resources, secure a stable supply to customers, and take environment-related initiatives

Schlumberger

SCHLUMBERGER CARBON SERVICES

Schlumberger Carbon Services provides technologies and services for the long term geological storage of CO_2. Schlumberger offers experience and a detailed understanding of the varied challenges posed by carbon storage, gained by participation in many Carbon Capture and Storage (CCS) projects worldwide, and backed up by a corporate history of over 80 years in the oil and gas industry.

Schlumberger's multidisciplinary teams bring the project management, communications and technology delivery skills needed to integrate all the services for storage safety, reliability and regulatory compliance. The company works to combine its storage knowledge together with that of other providers in the areas of capture and transport, to deliver safe and successful CCS projects.

With a worldwide Schlumberger corporate presence in over 140 countries, Schlumberger has the capability to support carbon storage projects anywhere in the world.

ROLE IN THE CALLIDE OXYFUEL PROJECT

Schlumberger Carbon Services was responsible for managing the geological storage of CO_2 from the Callide Oxyfuel Project. This included site selection, detailed characterisation, storage risk assessment and development of a monitoring and verification plan.

KEY FACTS

- We employ over 84,000 people of more than 140 nationalities working in approximately 80 countries
- Our founders, Conrad and Marcel Schlumberger, transformed the energy industry in the 1920s with the revolutionary idea of using electrical measurements to map subsurface rock formations
- Schlumberger engineers recorded the first electrical resistivity well log in Pechelbronn, France in September 1927

GLENCORE

Glencore is one of the world's largest global diversified natural resource companies and a major producer and marketer of more than 90 commodities. The Group's operations comprise about 150 mining and metallurgical sites, oil production assets and agricultural facilities.

With a strong footprint in both established and emerging regions for natural resources, Glencore's industrial and marketing activities are supported by a global network of more than 90 offices located in over 50 countries. Glencore's customers are industrial consumers, such as those in the automotive, steel, power generation, oil and food processing industries. The company also provides financing, logistics and other services to producers and consumers of commodities. Glencore's companies employ around 160,000 people, including contractors.

GLENCORE IN AUSTRALIA

Australia is an important part of Glencore's global business. The company has operated there for nearly 20 years and is a major employer, with nearly 16,000 people working across industries that include coal, copper, cotton, grain and oilseeds, nickel and zinc. In 2015, Glencore contributed more than $13.5 billion to the Australian regional, state and national economies in the form of wages and salaries, taxes and royalties, goods and services and capital investment.

GLENCORE'S COAL BUSINESS IN AUSTRALIA

Glencore is one of Australia's largest coal producers with 13 mining complexes – including 17 operational mines – across New South Wales and Queensland. The company employs about 8,000 Australians and in 2014 managed the production of 98 million tonnes of thermal and coking coal, predominantly for export. Glencore has a strong safety and environmental performance and plays an active role in the development of low emission coal technology.

ROLE IN THE CALLIDE OXYFUEL PROJECT

As a funding partner in the Callide Oxyfuel Project, Glencore was involved in the pre-feasibility stages of the project (through the former Xstrata Coal) and helped project manage the delivery of the demonstration trial.

Glencore's financial investment in the Callide Oxyfuel Project demonstrates the company's continuing belief in the value of the project as one of the world's most significant low emission technology demonstration initiatives.

GLENCORE

KEY FACTS

- Glencore is Australia's largest coal producer with 13 mining complexes across New South Wales and Queensland
- Glencore employs more than 9,000 people in its coal business in Australia
- Glencore is a major contributor to Australia's COAL21 Fund, a voluntary coal industry fund for the development, demonstration and commercialisation of clean coal technology in Australia
- Glencore is a member of the Voluntary Principles on Security and Human rights and the International Council on Mining and Metals. The company is also a participant in the Extractive Industries Transparency Initiative

JCOAL

The founding organisation of the Japan Coal Energy Center (JCOAL) was established in 1948. In 1990 it was restructured as a non-profitable organisation supervised by the Ministry of Economy, Trade and Industry of Japan (METI) in order to merge coal-concerning expertise agencies.

JCOAL covers all coal-related issues from upstream to downstream and supports the development, commercialisation, transfer and dissemination of coal technologies and human resource development, in order to ensure international coal supply while maintaining harmony with the environment.

ROLE IN THE CALLIDE OXYFUEL PROJECT

JCOAL was involved in the pre-feasibility stages of the project, assisted with the organisation of funding resources from the Japanese partners and has played an active role in the project's Technical and Investment Advisory Committee.

Callide
Oxyfuel Project