ACARP

# 2016 ANNUAL REPORT

# CHAIRMAN'S REPORT

Welcome to our 2016 Annual Report.

Firstly, I would like to thank Brett Garland, who served for a year as chairman of ACARP and who retired last November. The board wishes Brett well in his future endeavours.

It continues to be a challenging business environment, but we are hopefully starting to see signs of recovery in the market. The research program continues to operate efficiently and deliver valuable outcomes to our industry, supported by a strong contingent of over 140 industry people with an interest and commitment to research. The Commonwealth and the Minerals Council of Australia completed a joint review of ACARP in June and we are awaiting its release so that we can continue to learn and improve. I believe ACARP provides great value to our industry, and that the ACARP model itself could also be valuable if applied within other industries.

Improving safety, boosting productivity and minimising the environmental impacts of mining continue to be the focus of the research strategy. The various components of that strategy will help our industry to achieve those goals using enhanced measurement technologies, increased automation, improved products and processes, and disseminating increased technical knowledge and understanding. ACARP's role is to communicate those outcomes to the industry in a way that best accelerates their implementation.

ACARP funded 229 research projects across Australia during the year to a value of $71.68 million, including new funding of $16.5 million for 79 projects approved in December 2015. That is an enormous effort from a volunteer organisation, and a tribute to what we can achieve as an industry.

I thank all the volunteers who make ACARP work. I also wish to thank all the researchers who continue to innovate and develop new concepts on the industry's behalf. ACARP's success is a direct consequence of the quality, competence and determination of those who participate in the program. This is exemplified by the three individuals profiled in this Annual Report, each of whom have been part of the program for 15-20 years.

On behalf of all those involved in ACARP please enjoy your review of our 2016 Annual Report.

Ian Neill
Chairman
Australian Coal Research Board

# AT A GLANCE

## Vision

To assist the Australian coal industry develop and adopt world leading sustainable mining practices and, through collaboration, to ensure a sustainable position for the global use of coal.

## Mission

Utilise the collective technical competence and resources of the Australian coal industry to develop and manage a comprehensive research program which, through technological and process innovation, assists coal producers achieve their financial, environmental and social objectives for sustainable development.

ACARP – the Australian coal industry's research program - is the nation's pre-eminent coal research funding organisation.

To maintain their position as world leaders, Australian coal producers must be profitable, innovative and, at the same time, mindful of their social and environmental obligations. Through ACARP, they combine their expertise and resources to direct and fund world class research that benefits the whole industry.

A commitment to meeting the growing demands of the present without compromising the ability of future generations to meet their own needs has produced a realignment of company goals. Today's coal mining companies measure their success in terms of sustainable financial, social and environmental performance.

As a key driver of research and development in the coal industry, ACARP has responded to this evolution by broadening its research focus. Today our projects cover a wide range of subjects, from developing and enhancing technology to reduce production costs, to improving safety for mine workers and to measuring our impact on the communities within which we operate.

Key facts about ACARP:

- Every year we invest approximately $16 million in research projects of relevance to all areas of coal production.
- We are completely funded by Australian black coal producers via a levy of five cents per tonne of product coal, currently committed to June 2020.
- We operate under a Memorandum of Understanding between the Commonwealth Government and the Minerals Council of Australia.
- The strength of the program is derived from the 140 senior technical people who are members of the technical committees and task groups, which provide direction and control.
- Many mine sites host ACARP research projects.
- We have provided $273 million in funding to 1,468 projects since ACARP's inception in 1992.

# THE BOARD

Australian Coal Research (ACR) Limited is responsible for strategic planning, funding and the overall management of ACARP.

## ACR Board of Directors and Alternates*

*Roles are listed as at the time of their appointment.

DIRECTORS

**Mark Bennetts**
Executive Director and Company Secretary for ACR Limited

**Ian Neill**
General Manager Development for Wesfarmers Resources Limited (elected chairman of the ACR Board on 9 December 2015)

**Stephen Burgess**
General Manager Projects and Engineering for Centennial Coal Pty Ltd

**Ashley Conroy**
Group Advisor – Coal Technology, Energy for Rio Tinto Coal Australia Limited

**Brian Cox**
General Manager – Development and Technical for Idemitsu Australia Resources Pty Ltd

**Stephen Eames**
General Manager Resource Development for the New Hope Group Limited

**Tony Egan**
Manager Project Governance for Glencore Coal Assets Australia Pty Ltd

**Frank Fulham**
Chief Development Officer for Yancoal Australia Ltd

**Brett Garland**
Chief Executive Officer for Caledon Coal Pty Ltd

**Quentin Granger**
VP Technical Services for Peabody Energy Australia Pty Ltd

**Hans Hayes**
Head of Mining Excellence Open Cut for Anglo American Metallurgical Coal Pty Ltd

**Todd Harrington**
Chief Development Officer for Cockatoo Coal Limited

**Greg Hurney**
Engineering Manager Development for Bloomfield Collieries Pty Ltd

**Jacob Orbell**
Technical Resources Manager for Stanwell Corporation Limited

**Milind K Oza**
Chief Executive Officer for Wollongong Coal Limited

**Carl Pritchard**
General Manager Technical Services for the Jellinbah Group Pty Ltd

**Michael Watson**
Head of Integrated Operations for BHP Billiton Mitsubishi Alliance (BMA) Coal

ALTERNATES

**Greg Briggs**
Group Engineering and Supply Manager for Centennial Coal Pty Ltd

**Bruce Denney**
Chief Operating Officer for the New Hope Group Limited

**Simon Ewart**
Acting Site Manager at Meandu mine for Stanwell Corporation Limited

**John Grieves**
Project Manager Minyango for Caledon Coal Pty Ltd

**Paul Martinkus**
Manager Project Studies for Idemitsu Australia Resources Pty Ltd

**Jim Randall**
Executive General Manager Mining for the New Hope Group Limited

**Jim Sandford**
Project Manager for Glencore Coal Assets Australia Pty Ltd

**Sanjay Sharma**
Company Secretary for Wollongong Coal Limited

**Trevor Stay**
General Manager Gas & Carbon for Anglo American Metallurgical Coal Pty Ltd

**Andrew Walker**
Mine Planning and Development Manager for Wesfarmers Resources Limited

# STRATEGY

The Research Committee, together with the Executive Director, is responsible for the overall operation and strategic direction of ACARP research. It takes a whole of industry view, striking a balance between the priorities of the five technical committees, short term operational challenges and longer term strategic issues. The individual technical committees develop detailed research priorities and select projects in their respective areas, addressing critical issues such as safety, licence to operate, cost effective resource utilisation and market support.

Communicating project outcomes is vital. The Research Committee encourages constructive engagement with government and community groups. ACARP also provides high quality technical information to key industry organisations. The technical committees publicise their individual project results through on site demonstrations, focused seminars, conference papers, journal articles, via the ACARPMatters E-Newsletters, and the internet.

"IT TAKES A WHOLE OF INDUSTRY VIEW, STRIKING A BALANCE BETWEEN THE PRIORITIES OF THE FIVE TECHNICAL COMMITTEES, SHORT TERM OPERATIONAL CHALLENGES AND LONGER TERM STRATEGIC ISSUES."

## Research Committee

| | | |
|---|---|---|
| Tony Egan | Manager, Project Governance, Coal Assets Australia (co chair, Research Committee) | Glencore |
| Trevor Stay | General Manager Gas (co chair, Research Committee) | Anglo American |
| Ben Armitage | General Manager Technical Services | Vale Australia |
| Steve Burgess | Executive General Manager Engineering & Operations Support | Centennial Coal |
| Brad Elvy | Principal Production Improvement | South32 Illawarra Coal |
| Bob Gallagher | Director Studies | Peabody Energy Australia |
| John Grieves | Manager – Studies | Caledon |
| Kim Hockings | Specialist Technical | BHP Billiton |
| Bernie Kirsch | Environmental Specialist | Centennial Coal |
| Ben Klaassen | Principal Environment A & I | BHP Billiton |
| Andrew Lau | Regional Technical Services Manager, Open Cut Operations Eastern Region | Yancoal Australia |
| Kevin Rowe | Group Manager of CHPPs | Glencore |
| Jim Sandford | Group Manager Underground Projects | Glencore |
| Chris Stanford | Manager Technical Marketing | Peabody Energy Australia |

## Responsibilities

The Research Committee is responsible for a range of long term strategic initiatives, assisted by the five technical committees and associated specialist task groups. A proportion of funding is retained by the Research Committee for major strategic projects. The Committee is also directly responsible for strategic environmental projects that impact beyond the mine site.

# PROJECTS UNDER MANAGEMENT

ACARP continued to fund 229 research projects during 2015-16 with a gross financial commitment of $71.68 million. This included additional funding of $16.5 million for 79 new projects.

ACARP funding is summarised in the following table in categories that demonstrate the diversity of projects supported by the program.

| Current During the Period | | ACARP Funding | No of Projects |
|---|---|---|---|
| Underground | Detection and Prevention of Fires and Explosions | 470,000 | 1 |
| | Environment — Subsidence and Mine Water | 823,800 | 2 |
| | Exploration | 1,406,962 | 6 |
| | General | 120,000 | 1 |
| | Maintenance | 2,354,288 | 10 |
| | Mining Technology and Production | 4,399,951 | 11 |
| | Occupational Health and Safety | 2,317,743 | 8 |
| | Roadway Development | 3,474,469 | 5 |
| | Strata Control and Windblasts | 3,957,996 | 13 |
| | Ventilation, Gas Drainage and Monitoring | 2,256,866 | 9 |
| Open Cut | Drilling and Blasting | 1,559,277 | 5 |
| | Environment | 6,421,151 | 26 |
| | Geology | 3,494,142 | 13 |
| | Maintenance and Equipment | 6,507,440 | 5 |
| | Mining and the Community | 239,215 | 1 |
| | Occupational Health and Equipment Safety | 2,342,881 | 11 |
| | Overburden Removal | 2,725,883 | 5 |
| Coal Preparation | Dewatering | 1,742,073 | 8 |
| | Environmental Improvement | 40,000 | 1 |
| | Fine Coal | 3,337,793 | 22 |
| | General | 562,217 | 5 |
| | Gravity Separation | 1,874,829 | 10 |
| | Major Projects | 1,318,748 | 1 |
| | Process Control | 386,685 | 2 |
| Technical Market Support | General | 1,164,382 | 7 |
| | Major Project | 3,042,475 | 3 |
| | Metallurgical Coal | 3,520,287 | 21 |
| Mine Site Greenhouse Mitigation | | 3,029,042 | 8 |
| Major Projects | | 4,229,733 | 1 |
| Scholarships | | 2,563,322 | 8 |
| | | 71,683,650 | 229 |

The Australian coal mining industry must address sustainability issues over the longer term if mining companies are to retain their licence to operate. ACARP has responded by funding the development of new and innovative technologies and practices that will help operators achieve their financial, environmental and social goals.

## Productivity

ACARP has a strong focus on increasing yield and reducing the cost of production. The coal preparation area continues to invest in research designed to improve plant efficiency, and the underground operators are pushing hard to improve the rate of roadway development which continues to lag behind the increasingly productive Australian longwalls. In open cut operations the focus is on improving equipment performance and reliability.

## Occupational Health and Safety

ACARP's number one program priority is occupational health and safety, which reflects the industry's aspiration for a zero harm workplace.

## Community and the Environment

The cumulative effects of coal mining are assuming a greater importance in Australia and a more collaborative approach is needed to assess and understand the complex range of economic, social and environmental impacts of new mine development and the expansion of existing ones. ACARP continues to support research in this important area.

# CASE STUDIES

## Introduction

ACARP has contributed to Australian coal research in a way that individual companies could not have otherwise achieved. It combines resources and expertise from individual producers and shares the risks and benefits across the industry.

The ACARP model is built on a triumvirate of; industry monitors, who track research progress and provide technical guidance; researchers, who undertake the projects and research coordinators, who have a largely administrative role.

In this annual report we profile an ACARP family trio, each with experience in one of these roles, and showcase three of their favourite research projects.

# TREVOR STAY

Who are ACARP industry monitors and what do they do? What type of people are drawn to this voluntary role? In this profile we learn a little bit about what Trevor Stay, General Manager Gas with Anglo American, gets up to outside of work hours and why he has taken on a number of roles within ACARP.

## Life is a gas for Trevor

Imagine a remote, alpine environment somewhere in Canada. A heavy snowfall has left a carpet of untracked powdery snow. Access is only possible by chopper. It's a skier's paradise. This is one of Trevor Stay's favourite locations.

Jump on a plane and head over the Atlantic. You are now in the French Alps on your bike, straining out of the saddle. You are on the tail end of your 100-kilometre ride. Although enjoying the challenge of the moment, your mind has drifted from the steep climb to the gourmet feast and accompanying wines waiting for you at day's end. This is another of Trevor's favourite pastimes.

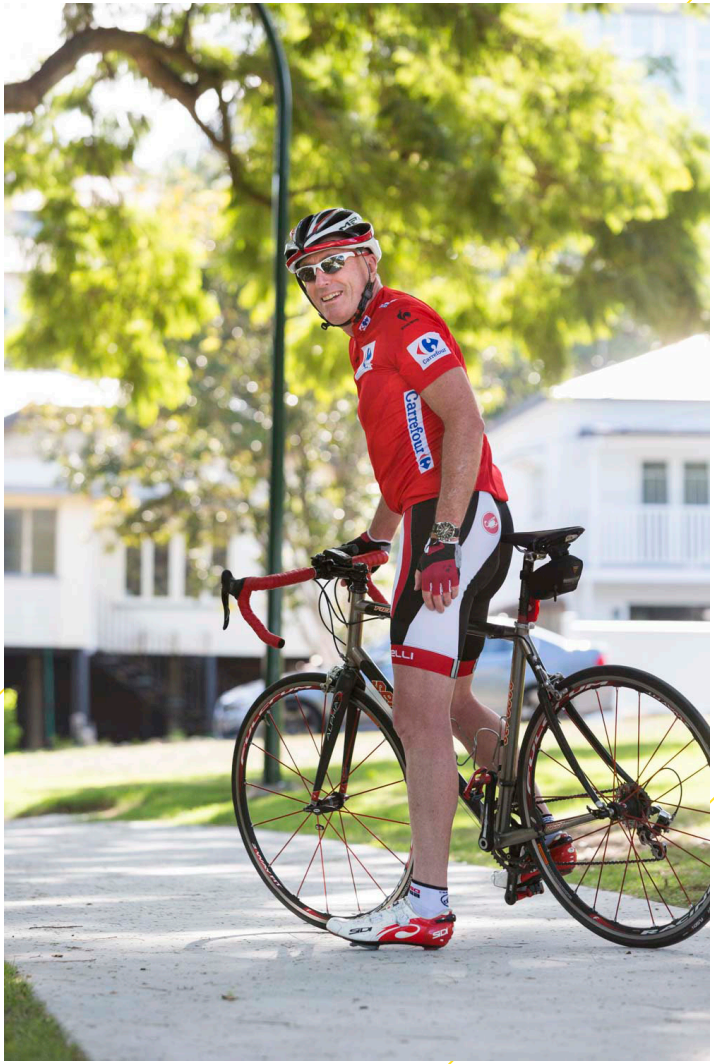
"I've always been a runner or cyclist, so I enjoy the exercise. I always feel that the best days of my life are when I've woken up early and gone for a ride. The rest of the day seems easy after that," Trevor said.

"It's the endorphin buzz, the camaraderie and the coffee afterwards. There are a dozen of us who cycle regularly. We're all good friends and occasionally we go away for weekends of cycling."

On average Trevor clocks up 200 kilometres a week on the bike, three 40 kilometre rides followed by 80 kilometres on the weekend.

Pushing the envelope is what makes life interesting. Trevor's is planning  a trip to Antarctica and he hopes to cross this off in February next year. He has booked a five-week adventure to the Ross Iceshelf aboard a research-style vessel. Limited to 50 guests, this trip will involve getting out on the ice and exploring the old Antarctic explorers' huts.

"This is as close to the South Pole as you can get on a boat. It's a long way to get down to deep Antarctica. All I've done is book it; I've still got to get there," he said.



A mining engineering graduate from University of Queensland, Trevor has worked in New South Wales, Western Australia and Queensland, and has had a stint in Germany. He has been employed by Shell/Anglo American for 24 years, primarily managing the gas drainage activities that support the company's underground operations. He joined ACARP's Mine Site Greenhouse Mitigation task group when a carbon tax was first muted and the industry was considering its response, particularly around the measurement of mine site emissions.

"I believe in global warming and I believe that the burning of fossil fuels contributes to it. The part that interests me is how much greenhouse gas we generate through fugitive emissions and the way we mine coal, rather than the combustion of coal. Methane is a very potent greenhouse gas, so the more efficiently we can collect it and utilise it, the less emissions we create on the way to produce that coal," he said.

"Our deep underground mines can each produce around 1.5 million tonnes of CO2-e a year, so we're far from insignificant. If we can manage that, we can reduce Australia's overall greenhouse emissions."

In addition to his work with the task group, Trevor is co-chair of the Research Committee, and an industry monitor.

"A monitor is the industry person assigned to track the progress of the research project and make sure the researcher stays on task. We need to be technically across the brief; understand what work is involved and how it is going to contribute to advancing the Australian coal industry," he said.

"We are also involved in project management. Inherently researchers tend not to have really good project management skills. They have very good ideas – we have an excellent standard of researchers in Australia – but it's almost a different mindset to delivering project outcomes on time. So the role is about monitoring how the project is going, how it is progressing against budget and whether it is going to deliver the outcomes that were in the original submission."

Trevor said he found the role of industry monitor technically stimulating and he enjoyed the opportunity to share his expertise. However, the workload could be demanding.

"To do the job justice, you need to do a fair bit of reading and communicating with the researchers, so we can only monitor two to three projects a year in addition to our normal jobs," he said.

And the process seems to be working. Trevor believes ACARP is one of the best industry-funded research programs in the world.

"I think it's a really good model. It's cost-effective and seems to be delivering the results in some really important areas," he said.

"A MONITOR IS THE INDUSTRY PERSON ASSIGNED TO TRACK THE PROGRESS OF THE RESEARCH PROJECT AND MAKE SURE THE RESEARCHER STAYS ON TASK. WE NEED TO BE TECHNICALLY ACROSS THE BRIEF; UNDERSTAND WHAT WORK IS INVOLVED AND HOW IT IS GOING TO CONTRIBUTE TO ADVANCING THE AUSTRALIAN COAL INDUSTRY."

# VAMCO DELIVERS PROMISING RESULTS FOR VENTILATION AIR METHANE ABATEMENT

Stone dust. It's cheap and in abundant supply at underground coal mines. Imagine using this material to help oxidise ventilation air methane (VAM) – thereby reducing greenhouse gas emissions – and then being able to reuse it as a dust explosion suppressant – no waste. Sounds fanciful? Well preliminary results from the University of Newcastle's VAM Chemical Oxidiser (VAMCO) indicate this is more than a possibility. In its third phase of ACARP funding, VAMCO has impressed industry monitor Trevor Stay.

"Chemical looping is a relatively novel process that seems to have great potential. This is perhaps the project that has interested me the most because it's novel, cost-effective and could oxidise methane at temperatures which make it safe to use. So it's looking promising," he said.

University of Newcastle researchers Behdad Moghtaderi and Kalpit Shah are active in chemical looping and calcium looping research. In casual discussions over coffee they had asked each other whether this technology could be applied to VAM abatement.

"The idea came about organically. We'd been talking about other projects, other applications and then we had a Eureka moment which we followed through to determine whether it was a good idea or not. As it turns out, it was," Behdad said.

Managing fugitive methane emissions has proven to be a challenge for the underground coal industry. Around 64 per cent of its fugitive emissions come from the VAM stream. Because ventilation airflows are large and contain very dilute concentrations of methane, they cannot be oxidised by conventional combustion processes without auxiliary fuel. In addition, fluctuating flow rates and concentrations make VAM difficult to handle and process into usable forms of energy. There are two key methods of VAM mitigation – destruct or use VAM in dilute form (thermal/catalytic oxidation) or increase the concentration of methane (carbon composites).

In its most basic form, the process developed by Behdad and Kalpit involves the cyclic carbonation/calcination of stone dust particles as a means of oxidising methane in ventilation air under low temperatures and non-flaming conditions. The process can be explained by looping reactions in the calciner and carbonator reactors. During the 'calcination' reaction, stone dust is thermally decomposed using either natural gas or goaf gas. The resulting calcium oxide then catalytically promotes the reaction between VAM and air, resulting in the conversion of methane to carbon dioxide and steam.

Meanwhile, the carbon dioxide generated from the methane conversion, along with the carbon dioxide present as an inert gas in the ventilation air, react with calcium oxide. This converts it back to calcium carbonate again – the 'carbonation' reaction. The process can be operated in a single or dual reactor configuration depending on whether the stone dust particles are regenerated in situ or ex situ. The dual configuration provides a near zero emission solution for coal mines and is the only VAM abatement technology to do so.

Kalpit and Behdad have undertaken comprehensive experimental and modelling work, including:

- Evaluating optimum stone dust looping process conditions in a fluidised bed reactor.
- Studying further improvement in the stability of stone dust with different additives and the effects of moisture and coal dust on stability.
- Conducting more than 150 hours of testing and experimentation on the prototype 10 litres/minute plant.
- Carrying out detailed process simulations to test the process, quantify the energy footprint and identify the self-sustainability of the process.

Kalpit said VAMCO had a number of advantages over other VAM abatement technologies.

“The unique feature of VAMCO is that its operational temperature can be reduced to 450 degrees Celsius, which is about 20 or 30 per cent below the auto-ignition limit of methane. It’s very safe,” he said.

“Secondly, unlike expensive catalysts used in other technologies, stone dust is abundantly available at coal mines and is extremely cheap. For example, it’s about $200 to $300 a tonne compared with $5000 to $10,000 per kilogram for some catalysts.

“Thirdly, there is no waste generated from this process because after stone dust is used for VAM abatement, it can be reused at the mine for dust explosion prevention.

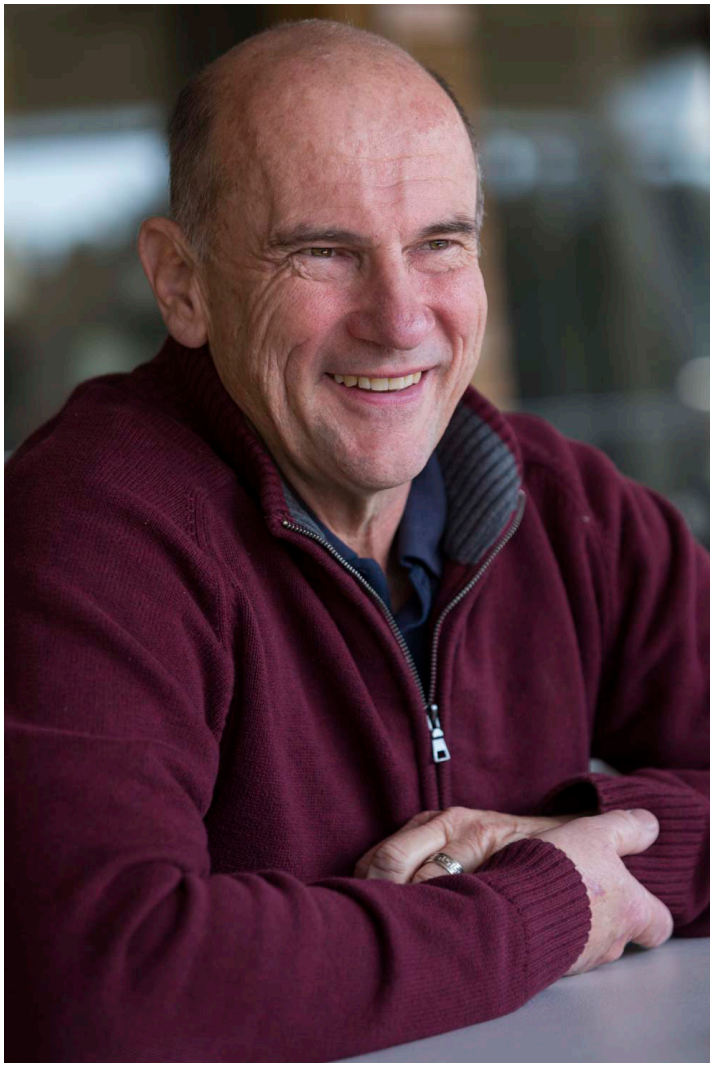
“Fourthly, the process can operate at concentrations as low as 0.2 per cent methane. All other technologies fail to even demonstrate their applicability at concentrations below 0.4 per cent.

“Both VAMCO configurations are economically feasible and have paybacks of less than five years, which is very attractive.”

Following this demonstration scale project, Behdad and Kalpit are hoping to work on the integration of the two reactors (carbonator and calcinator) then conduct a detailed techno-economic assessment. They have had preliminary discussions with manufacturers with the view to commercialising VAMCO.

VAMCO was the recipient of the 2016 Australian Engineering Excellence Award from Engineers Australia (Newcastle Division).

# MERRICK MAHONEY



**Researchers are the lifeblood of ACARP, but what does it take to secure ACARP funding for industry research? In this profile we put Merrick Mahoney under the microscope. Merrick has a wealth of industry research experience. He heads up the Chemical Engineering team at the Newcastle Institute for Energy and Resources (NIER), which is part of the University of Newcastle. But there are a couple of things you may not know about him …**

## Collaboration and non-linear thinking deliver results

"Ever since I was a kid, I had always wanted to fly. Dad was in the RAAF. He built runways and had respect for pilots. As soon as I got a job that paid real money, I started learning to fly. That was back in December '83. I got a student licence, a restricted private licence, unrestricted licence and then a commercial licence for a single engine aircraft. Although I have never flown commercially, the extra training was really worth it," he said.

In the early days, Merrick discovered some very strange and interesting places on flying safaris with the Newcastle Aero Club, where up to 22 aircraft headed off the beaten track for two-to-three weeks.

"It's just incredible the number of amazing places in Australia that have aerodromes. Some of my favourites are Mataranka, Kununurra and Lightning Ridge. Mataranka is just outside Catherine and has an airfield next to some thermal springs. Kununurra is a gateway into the Kimberly and there are some real characters at Lightning Ridge," he said.

"Flying is an adventure, but it's more than that; it's a challenge. You do all your homework and prepare for the conditions but you can still get surprises out there and you have to be able to respond to them.

"My motto is never give up trying new things because it makes life interesting. There are lots of new things to try when you're flying, so it just fits in really well with my personality and what I like to do."

Some other "new things" have included bare boat chartering in the Whitsundays and trying to out-manoeuvre a cyclone; taking up photography using a 'real' camera and developing his own work; tackling the gym after a relatively sedentary period in his life; and launching into obstacle racing (rope climbs, swimming under water, running with a 20 kilogram pack over courses varying in length from five to 20 kilometres).

"I like the physical and mental challenges of these activities; and that feeling is great," Merrick said.

This passion is not restricted to Merrick's leisure pursuits. He is also enthusiastic about his work.

After completing a PhD in electro-chemistry and spectroscopy, Merrick joined BHP Research in December 1983 and spent 26 years working primarily on coal-related projects such as underground coal safety, coal seam methane, coke making and coke in the blast furnace. When BHP decided to outsource its research, he joined the University of Newcastle.

It was then that his research focus shifted to projects that were more fundamentally focused and that had impacts for the whole industry rather than just BHP. With guidance from colleague and "brilliant mentor" Sid Maguire, who had been an ACARP Committee Chair before his retirement, Merrick began applying for funding from ACARP.

In 2010, his team joined the Newcastle Institute for Energy and Resources (NIER) which is part of the University of Newcastle.

"NIER's idea is to promote cross-disciplinary research. I think it's a good approach being well lead by Alan Broadfoot," he said.


VH-RNY
Royal Newcastle Aero Club

The NIER approach mirrors Merrick's own collaborative style of research. With a small team comprising himself, a full-time post-doctoral fellow, a part-time post-doc and a technician, solving significant industry problems requires collaboration with other researchers who have complimentary skills.

"What we try to do is identify the smart people out there who can help us solve these problems and then set up collaborations. We have established collaborative relationships with The University of Queensland (Karen Steele), CSIRO at QCAT (Graham O'Brien's group in particular) and at North Ryde (where our theoretical modeller is), and the University of Wollongong. I'm not smart enough to work any other way," he said.

Merrick said this collaborative approach had been integral to progress being made on a persistent industry challenge: improving the predictions of coking behaviour of coals and blends. Researchers had been applying the same thinking to this problem for many years without success.

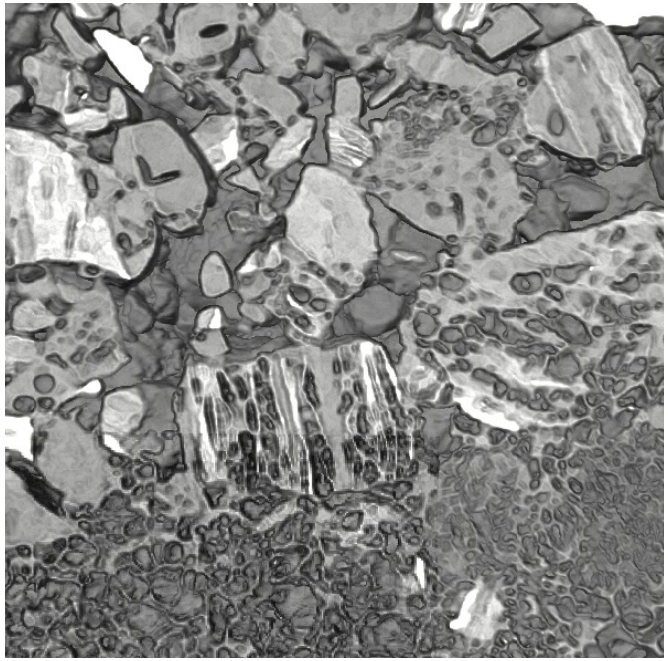
"People keep repeating the same thing over and over again and get surprised when they get the same result. One of the great things about the people we're working with – Karen Steele and David Jenkins in particular – is that they challenge that traditional thinking and they're not afraid to throw ideas out there for discussion. That gives us a chance to move forward," he said.

Merrick has found the process of applying for funding from ACARP significantly less onerous than other funding sources he is familiar with.

"ACARP is absolutely brilliant to work with. The proposal system is sensible. The industry people are really engaged and interested in what you're doing, and the head office people are the most helpful people I've ever worked with. It's a real joy to work with them," he said.

"THE NIER APPROACH MIRRORS MERRICK'S OWN COLLABORATIVE STYLE OF RESEARCH….." "WHAT WE TRY TO DO IS IDENTIFY THE SMART PEOPLE OUT THERE WHO CAN HELP US SOLVE THESE PROBLEMS AND THEN SET UP COLLABORATIONS."

# TAKING A PORTFOLIO APPROACH TO COKE MAKING RESEARCH



Predicting the coking behaviour of coals and coal blends has been a persistent challenge for the Australian coal industry. While traditional research approaches have provided solutions largely based on statistical analysis of coking data, current marketing demands require more robust predictions. Built on an improved understanding of the coking process, a new 'portfolio' approach is starting to produce results. Merrick Mahoney provides an insight into this approach and introduces the project – Links Between Microstructure Development in Softening Coal and the Characteristics Controlling Coke Quality (C23048).

Although the coking process has had a long history, it remains difficult to accurately predict the coking characteristics of both specific coals and blends. The price of coal on the spot market is influenced by predicted coking behaviour. Placement of coals to obtain best benefits for suppliers and users also requires reliable predictions of coking behaviour. Merrick Mahoney said as new coal products came onto the market, it was challenging to determine their utilisation behaviour and market acceptance from customers without extensive and expensive pilot oven testing.

"We want to be able to help suppliers. However, developing a robust model that can successfully predict coking performance of coals from a range of sources remains a serious challenge. Coking coal is a complex material that undergoes complex transformations as it converts to coke. Its properties and behaviour vary depending on geographical sources and the conditions under which it formed. We need to supplement traditional measurements with advanced techniques for characterising this material if we want to develop understanding based on the fundamental physical and chemical processes occurring," he said.

Using such a fundamental scientific approach would provide two major benefits. Firstly, coke quality predictions could be reliably performed on coals from a range of sources. Secondly, it would be possible to see the fundamental reasons why a particular coal produces a strong or weak coke and, therefore, make it possible to devise ways to improve the behaviour of poor performing coals.

The portfolio approach uses a number of research projects to address three questions:

- What structures make a strong coke and a weak coke?
- How do these structures form in the plastic layer during coking? The plastic layer is a bubbling foam consisting of a mixture of gas, liquid and solid coal components at 400-500°C.
- How does the chemistry of the coal blend control the plastic layer properties?

Merrick said no one group could be across all the advanced techniques needed to undertake this work. The collaborative portfolio approach provided the necessary expertise from four different research organisations.

"We have established collaborative relationships between University of Queensland, CSIRO at QCAT and at North Ryde, the University of Wollongong and the University of Newcastle," he said.

"As a group we want to move away from doing what has been done historically; which is measuring a lot of coal properties, making cokes, measuring a lot of coke properties, then doing a regression between the two and getting a 80 per cent accurate solution," he said.

"Instead we want to understand what makes coke strong and what makes it weak, to identify those structures. To do this we use computed tomography (CT) imaging, fractography and tribology – techniques that are about the fundamental factors that control the strength of materials.

"The next step is to understand how those structures form during the coking process. When you heat a coking coal in the absence of air, part of it melts. If you keep heating it, it resolidifies or thermosets. When the coal is molten, gas is generated within the liquid creating a foam. The final structure of the coke is locked in when the foam resolidifies. We use high temperature rheometry to obtain the real mechanical properties of the foam and CT imaging

of quenched samples to understand structure formation. We're trying to understand the physical processes that are occurring to lock in the structure of the foam. What determines the structure of the coke determines its properties.

"The third step is to understand how coal properties and coal chemistry determine foaming behaviour. If we have a good, fundamental understanding of these three elements, we can produce a much more robust model than using simple regression sets (question 3 above). However, developing this understanding requires a range of techniques, including fractography and tribology, complex rheology, CT, advanced chemical analysis and coal grain analysis, which was developed by CSIRO."

Project C23048 is a key step towards understanding how structures form in the plastic layer during coking. This project was led by University of Queensland Chemical Engineering researcher Karen Steel and the research team comprised Robin Dawson, David Jenkins, Robin Pearce, Merrick Mahoney, Hannah Lomas, Richard Roest and Harold Rogers.

Karen said project C23048 had two key objectives: to further develop understanding of the relationships between key microstructural features of coke and coke strength indices; and to examine the development of the key microstructure features by identifying the mechanisms that led to the formation of those features during carbonisation.

"We produced samples that we quenched at different stages of the coking process so we could trace how the structure was developing. We also considered how different feeds affected the process," she said.

Overall the project produced three outcomes:

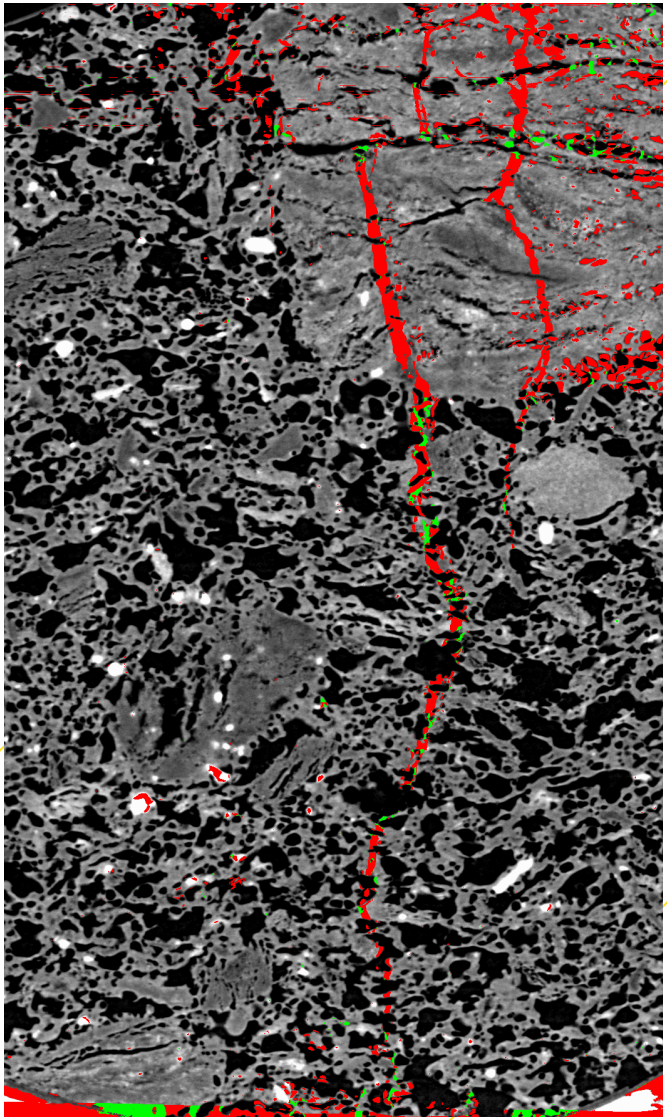
- Development of advanced methods to characterise the structural features of coke and the resulting stress distribution.
- Identification of the features in coke microstructure that have strong influence on coke strength.
- Understanding of the mechanisms that led to formation of the key microstructure features.

Karen said the project identified a number of features that influenced coke strength. Firstly, although it was known that high porosity and large pores could adversely affect coke strength, results from this project strongly suggested that bubble coalescence was the key reason for pore contraction.

"Secondly, we found that variations in permeability may result from the coal grind and influence expansive behaviour of the coal particles," she said.

"Thirdly, our work suggests that some inertinites may adversely affect strength while others do not. CT analysis of the high inertinite, high strength coke found a breakage crack propagating through an inert rather than around it, suggesting that the inertinite was well bound and perhaps indicating why it did not adversely affect the strength," she said.

This project has produced one piece of the coke prediction puzzle. Other ACARP projects are addressing further pieces of the puzzle.



# JOHN BRETT

In this profile we delve into John Brett's life to determine what it takes to be an ACARP research coordinator and why anyone would want to be one.

## ACARP is not a fish

"ACARP is not a fish". This insightful phrase, coined by former ACARP research coordinator John Brett, has become part of the Australian coal industry vocabulary. Plastered on an overhead transparency at a Moranbah industry-researcher meeting in the early days of the program, the phrase has lightened some pretty tense moments over the years.

John has an impressive mining pedigree. After early schooling at St Peter's Boys School (also attended by British Prime Minister Edward Health) and Chatham House Grammar School (also attended by Edward Health as well as comedian and scriptwriter Frank Muir) – both in Kent, England – John graduated from Sheffield University's Mining Engineering School in 1959. John insists that these credits are only deserving of the schools, not his participation!

Eleven days after marrying sweetheart Kim Mullings, John and his bride headed off to South Africa where John worked for Union Corporation Company, which was developing the deep underground gold mines of Welkom, Orange Free State and Evander. He worked in South Africa for 12 years. After a brief stint in Tasmania – "not one of my best moves", John confides – the Bretts moved to Queensland in 1971. John had accepted a role with the Utah Development Company as Mining Superintendent at Peak Downs. He later worked at Goonyella before heading up Utah's Deep Stripping Project.

"The main purpose of this project was to assess the stripping requirements as the mines went deeper, investigate ways of providing the additional stripping capacity required, and carry out feasibility studies and justifications for acquisition of the machinery and people required," he said.

"They were exciting times and involved world travel to look at what was being done elsewhere.

"The project culminated in the acquisition of the bucketwheel excavator and conveyor system at Goonyella. Design and construction commenced around 1978 and commissioning began in 1981. Overall the project was regarded as a success with the 1500 bcm/h (7.5 Mbcm/year) rated system actually achieving more than 12 Mbcm/year. Unfortunately, due to a structural failure several years later, it collapsed and was written off.

"In addition to deep stripping, we started looking at highwall mining. Again, this required overseas visits, mainly to the US, to investigate what was available. This project resulted in the design, construction and installation of the highwall mining system at Moura mine. From an open cut perspective, once a commitment is made to undertake highwall mining, the writing is on the wall."

John has been active in various industry associations and research forums, including AusIMM as a Southern Queensland councillor, and the Federal Government's National Energy Research Development and Demonstration Council (NERDDC) as an industry representative. With the establishment of ACARP after a memorandum of understanding in 1992, John became the inaugural chairman of the ACARP Open Cut Committee.

Following his retirement from BMA in 2000, John was invited to join ACARP as the open cut projects Research Coordinator, a role he held for 15 years.

"From my perspective, the role of a research coordinator is to bring the researchers and industry monitors together and to facilitate the interaction between the two groups so that net project outcomes are the best they can be for the industry," he said.

"Trying to get four or five people together at a convenient time and on the same day can be challenging, but it's just part of the job, perhaps even the part of the job. The role also requires general project administration such as preparing agendas, taking minutes and so on."

A profile of John Brett wouldn't be complete without discussing his 'dream car'. A fan of the BBC's television program Top Gear, John was struck by Jeremy Clarkson's question: What can you buy for £3,000? The answer – an old-ish Bentley or other 'well-loved' luxury vehicles – prompted John to ask himself the same question. For him, though, Jaguars were the archetype luxury car. After much consultation and reassurance from his barber, he bought a 2006 Jaguar X-type that Kim named Mick (as in Mick Jag[ger]uar). Sadly, after five years, Mick has been traded in for a much more practical Mitsubishi ASX.

Over the years John and Kim have become quite the cruise enthusiasts. They have cruised around New Zealand and have been on board the three queens – Queen Mary 2, Queen Elizabeth and Queen Victoria. Elizabeth gets their tick of approval, and no wonder … they managed to secure the prestigious Livingstone Suite!

"After walking our clickety-clacking luggage over two wharves and being forced to join queue after queue after queue before even getting to the reception area, we were told that our cabin – which had been specially chosen months ahead – had been reallocated," John said.

"Boarding the ship and being told to walk as far aft as we could to find our new cabin, Mr and Mrs Grumpy were fast becoming Mr and Mrs Grumpier and Grumpier. Finally arriving at a double-door entry, we found that our cabin had been upgraded to a suite! It had a lounge, dining room, kitchen, three (yes, three) vanities, a huge shower with shower roses all over the place, a spa bath, large bedroom and a 20 metre-long wraparound balcony, not to mention a butler and assistant butler!

"The only downside is that we now have a taste for the high life that we can't really afford."

John said he was extremely grateful for the support and opportunities provided to him over his career by the companies he had worked for and the people he had met.

"I have also enjoyed the camaraderie of the ACARP team – Roger, Anne and Nicole – and my fellow research coordinators," he said.

"Overall, I think I have gained more from my association with ACARP than ACARP has gained from me.

John said his philosophy had been to never stop learning: "Don't think you know it all, and always learn from other people."

# HYDROGEN PEROXIDE SHOWS PROMISE AS AN ALTERNATIVE TO AMMONIUM NITRATEIN THE EXPLOSIVES MIX

Nitrogen oxide fume events remain an issue for the Australian coal industry despite the release of guidelines specifically developed for coal mining.

Ammonium nitrate (AN) is the main oxidising agent for most explosives used in mining applications. During an ineffective detonation reaction caused by external factors that are difficult to control, nitrogen monoxide can be produced. This in turn oxidises into nitrogen oxides (NOx). The presence of toxic NOx post-blast can be identified by plumes which range in colour from yellow, orange to purple, depending on the NOx concentration.

To address the emission of NOx from blasting, researchers from The University of Queensland and CRCMining have proposed replacing AN with hydrogen peroxide (HP) as the oxidising agent, eliminating nitrogen from the mix and thereby preventing the generation of NOx.

The proposal for the project which has tested this hypothesis – Alternative and Sustainable Explosive Formulations to Eliminate Nitrogen Oxide Emissions – captured ACARP's imagination. John Brett helped to administer the project, which he believes has merit.

"This project by Italo Onederra and Miguel Araos was initially based on the replacement of ammonium nitrate-based explosives with hydrogen peroxide, which produces mainly steam and carbon dioxide. It may not be economically viable in the short term, but even if it enables a reduction in the usage of AN or the development of a new HP gel mixture with other nitrates, it will be advantageous," he said.

Italo and Miguel have been working on this concept for a number of years. Miguel discussed some preliminary ideas with Italo. "We've got to eliminate the nitrogen out of the formulation. If you eliminate nitrogen, then you don't produce NOx," Miguel said. Italo agreed. The concept made sense. Miguel then reviewed a series of oxidisers that do not have nitrogen in the molecule. There were a number of oxidisers that fit this profile, but HP was the only one that is currently produced in large quantities for industrial applications.

The researchers then submitted a proposal to ACARP for funding. The successful project had four objectives:

- Demonstrate that the new HP-based products detonate in a variety of different densities and diameters without any risk of NOx production.
- Demonstrate a feasible system to manufacture and deliver the blasting agent.
- Demonstrate that this new explosive product can adequately break and fragment rock and match the performance characteristics of conventional AN-based products.
- Conduct a business case for the further development and implementation of this new explosive product.

Italo said the project had been successful, meeting all four objectives. Experimental results showed that the HP product behaved similarly to commercial explosives and, consequently, mixtures could be tailored to achieve specific detonation performance targets.

"We conducted more than 160 unconfined detonation tests to characterise the detonation performance of our product. Our explosives can detonate at different densities, different diameters and different HP concentrations. In addition, we can use a variety of techniques to sensitise the product, such as chemical gassing, glass microballoons and expanded polystyrene," he said.

The researchers also confirmed the rock breakage performance of their product through fully instrumented single and multiple-hole blasting trials in a limestone quarry.

“Direct measurements of velocity of detonation, pressure and temperature confirmed that complete reaction is taking place within a short distance after the initiation of our product. Under confined conditions, we were able to compare the behaviour of our product with a conventional AN-based product. Our product matched and, in some instances, exceeded the performance of the conventional product,” Italo said.

“These tests confirmed the ability of the HP mixtures to both fragment and effectively displace the rock mass under evaluation. We also conducted advanced blast modelling to evaluate physical results and provide a calibrated platform for further analysis and evaluations from product testing in larger production blasting scales.”

Italo and Miguel have also designed, developed, built and tested a safe, simple and low-cost all-in-one prototype manufacturing plant and delivery system. The blasting agent can be manufactured in the unit and delivered on site at ambient temperature.

“Our prototype offers a new way of making a gel product that would be water resistant and could be manufactured on site. Our vision has always been that everything stays within the mine lease. This means you don’t need an explosives plant making the emulsion and then transporting it on site. You can literally make it on site when you need it,” Italo said.

Italo and Miguel are now working on a subsequent ACARP project to test the product and mixing unit in the field. They are also looking at the potential of blending HP with other nitrates to develop a new series of hybrid products.

# GARY GIBSON

## What a wonderful bloke he was!

In 2004 it became apparent that ACARP needed to increase its investment in roadway development and to do so would require input from a professional mine manager with a passionate desire to fire up development rates. Who could be a better choice than Gary Gibson.

That same year Ian Kraemer and Roger Wischusen were sent to the Panorama House Restaurant overlooking the Bulli Pass to meet Gary and work out a plan. To the Roadway Development Task Group's delight Gary showed real enthusiasm and signed on to provide guidance and oversight of the then fledgling research program, a role he pursued for over 12 years until his untimely death in July 2016.

Gary's extensive 35 year career included numerous engagements as Technical Services Manager, Mine Manager, Operations Manager and other senior roles across the Bowen Basin and Illawarra underground mining operations.

His early efforts involved the running of numerous regional workshops with input and engagement from mine operators. This led to many open discussions around the barriers to improving development rates. These barriers were then used to define where research money was to be invested. There was no one better that the unflappable and at all times enthusiastic Gary to pull together these workshops.

Behind the friendly smile was a very careful and meticulous approach which assisted the task group develop well thought through strategies which remain in place today. While progress has been difficult, Gary never lost confidence in our ability to improve development rates.

The task group and his industry colleagues continue to struggle with his death. Each and everyone who worked with him is better for the experience. He exemplified the qualities of a professional Mine Manager; always ready to share, support and encourage and remained a good bloke.

"BEHIND THE FRIENDLY SMILE WAS A VERY CAREFUL AND METICULOUS APPROACH WHICH ASSISTED THE TASK GROUP DEVELOP WELL THOUGHT THROUGH STRATEGIES WHICH REMAIN IN PLACE TODAY."

# INCOME / EXPENDITURE

| Income | 15/16 | 14/15 | 13/14 |
|---|---|---|---|
| Levy | 20,292,126 | 20,246,179 | 19,629,382 |
| Interest | 911,139 | 981,071 | 1,046,470 |
| Other | 49,256 | 40,382 | 33,529 |
| Total | 21,252,521 | 21,267,632 | 20,709,381 |

| Expenditure | 15/16 | 14/15 | 13/14 |
|---|---|---|---|
| Research Projects* | 15,040,241 | 17,168,976 | 16,345,213 |
| ACR Project Management | 516,808 | 411,504 | 454,218 |
| ARA Project Administration | 1,527,381 | 1,563,806 | 1,512,730 |
| Total | 17,084,430 | 19,144,286 | 18,312,161 |

| Outstanding commitment for research at 30 June | | | |
|---|---|---|---|
| Projects Started | 19,493,926 | 18,720,966 | 19,721,307 |
| Projects Yet to Start | 2,392,867 | 1,428,450 | 2,828,319 |
| Total | 21,886,793 | 20,149,416 | 22,549,626 |
| Cash Reserves | 35,314,403 | 31,146,312 | 29,022,966 |

*Reconciliation with Financial Report Australian Coal Research Ltd for 2015/16

| | |
|---|---|
| ACARP Research Project Expenditure | 14,887,715 |
| Reversal of Invoicing Lag July 15 | -710,357 |
| Invoicing Lag June 16 | 862,883 |
| Research Project Expenditure Financial Report ACR | 15,040,241 |

| Funding Committed by Technical Area | 15/16 | 14/15 | 13/14 |
|---|---|---|---|
| Underground | 5,552,568 | 6,346,269 | 4,781,342 |
| Open Cut | 5,511,863 | 4,269,996 | 4,320,731 |
| Coal Preparation | 2,395,961 | 2,017,563 | 1,973,450 |
| Technical Market Support | 1,697,363 | 3,701,459 | 1,409,979 |
| Mine Site Greenhouse Mitigation | 352,865 | 608,880 | 687,516 |
| Major Project | — | — | 485,000 |
| Scholarships | 990,000 | 330,000 | — |
| ACARP Total | 16,500,620 | 17,274,167 | 13,658,018 |
| Other Funding | 8,406,206 | 18,854,804 | 12,666,135 |
| Total Funding | 24,906,826 | 36,128,971 | 26,324,153 |
| Leverage | 1.49 times | 2.09 times | 1.93 times |

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