COAL INNOVATION NSW

Income, expenditure and project evaluation

October 2020

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Contents

Tables

Executive Summary

Income and expenditure

For the financial year 2019/2020, the Coal Innovation Fund (CIF, or the Fund) received income of $509,800. Expenditure from the fund was $4,537,000 and funds remaining at the end of the financial year total $71,038,435 (Table 1 & Table 2).

Table 1: Coal Innovation Fund financial summary

Extract from financial statement	Value ($)
Opening balance as at 1 July 2019 (credit)	75,065,634
Interest and other revenue	509,800
Total	75,575,434
Less expenditure (see Table 2)	4,537,000
Total at 30 June 2019 (credit)	**71,038,435**

Table 2: Coal Innovation Fund expenditure

Description	Value ($)
Coal Innovation NSW membership, meetings and sub committees	20,000
Coal Innovation NSW Secretariat	505,244
Research, Development and Demonstration (RD&D) projects including peer reviews	3,693,235
NSW CO_2 Storage Assessment Program	261,221
Clean hydrogen study	30,000
Audit fees	27,300
Total	4,537,000

Evaluation

The financial year 2019-20 was a period of success for Coal Innovation NSW (CINSW). Low emissions coal technologies were advanced through expenditure on 19 of our Research, Development and Demonstration grants.

Our 'Future of NSW coal fired electricity generation study' was published and a clean hydrogen study was completed which is pending publication.

CINSW has further refined plans for Stage 2 of the NSW CO_2 Storage Assessment Program. The NSW CO_2 Storage Assessment Program aims to identify safe and secure geological storage for

CO_2 in NSW. Further success will secure a viable pathway to deep decarbonisation of the NSW economy, particularly in hard to abate sectors such as mining, steel and cement manufacture and transport.

CINSW liaised with key stakeholders to further develop a work program to reduce fugitive emissions from coal mining in NSW. The program builds on previous work to Ventilation Air Methane (VAM) in Australia including several projects funded by CINSW. CINSW aims to support a state-of-the-art VAM abatement facility in NSW and demonstrate safe abatement of VAM. CINSW is developing a Research, Development and Demonstration grants program to support safety and efficiency improvements of VAM abatement technology to expand the fugitive emissions reduction potential in NSW.

Purpose of the annual report

The *Coal Innovation Administration Act 2008* (the Act) requires an annual report detailing expenditure from the Coal Innovation Fund (Section A and B of this report) and an evaluation of the effectiveness of the expenditure (Section C of this report).

The Act legislates four purposes for which money can be expended from the Fund, noted in **Appendix A**. The Fund is administered by the NSW Government and kept in a Special Deposits Account, separate from Consolidated Funds.

The *Public Finance and Audit Act* 1983 mandates the Auditor-General audit the CIF Special Deposits Account. The audited financial report is included in Section D of this report and comprises a statement of net assets, comprehensive income and associated note disclosures.

All figures are GST exclusive unless otherwise stated. This report is for the 2019/20 financial year, ending 30 June 2020.

The Coal Innovation Fund and Coal Innovation NSW

The Coal Innovation Fund was established by the *Coal Innovation Administration Act 2008*. CINSW (or the Council) is an independent advisory council that makes recommendations to the Deputy Premier and Minister for Regional NSW, Industry and Trade, responsible for expenditure from the Fund. Administration of the fund is supported by the Secretariat, a team within Mining, Exploration and Geoscience (MEG), in the Department of Regional NSW (DRNSW).

Sections of the Act relevant to this annual report are included in **Appendix A**.

Income, expenditure and evaluation

A. Payments received (income)

The Fund received the following income (Table 3):

- Interest earnings of $509,800
    - This was deposited directly into the Fund's bank account. The interest was calculated on the daily balance of the bank account and paid at the cash rate , on a monthly basis, using the Westpac Interest Apportionment Service.
- No other revenue was received

Table 3: Income

Description	Value ($)
Interest revenue	509,800
Other revenue	0
Total income (2019-20)	**509,800**

B. Expenditure

This financial year CINSW expended $4,537,000 dispersing funds across key areas shown in Table 4.

Table 4: Expenditure

Description	Value ($)
Coal Innovation NSW membership, meetings and sub committees	20,000
Coal Innovation NSW Secretariat	505,244
Research, Development and Demonstration (RD&D) projects including peer reviews	3,693,235
NSW CO_2 Storage Assessment Program	261,221
Clean hydrogen study	30,000
Audit fees	27,300
Total expenditure (2019-20)	**4,537,000**

B1. Coal Innovation NSW membership, meetings and sub committees

Table 5 shows the expenditure on Coal Innovation NSW membership remuneration, meetings and subcommittee or working group expenses. This financial year, expenses were solely associated with remuneration of the CINSW Chairperson.

Table 5: Expenditure – CINSW membership, meetings and sub committees

Description	Value ($)
Coal Innovation NSW member remuneration	20,000
Total	**20,000**

B2. Coal Innovation NSW Secretariat

Table 6 shows expenditure on the CINSW Secretariat including salaries, travel and staff development.

Table 6: Expenditure – CINSW Secretariat

Description	Value ($)
Secretariat costs including salaries and on costs, telecommunications and office supplies.	497,110
Travel	4,820
Training and staff development (including conferences)	3,314
Total	**505,244**

B3. Research, Development and Demonstration (RD&D) projects

CINSW has funded three rounds of RD&D grants through a competitive Expression of Interest process. Applications were assessed by a Technical Working Group and successful grantees endorsed by CINSW and the Deputy Premier and Minister for Regional NSW, Industry and Trade. The grant rounds commenced in 2009, 2015 and 2019.

Table 7: Expenditure – RD&D projects

Description	Value ($)
Round 1 2009 grants	0
Round 2 2015 grants	894,841
Round 3 2018 grants	2,786,361
Peer reviews	12,033
Total	**3,693,235**

Round 1 2009 RD&D grants

All funds associated with the 2009 Expressions of Interest R&D projects have been expended and all projects are complete. No funds were expended this financial year.

Round 2 2015 RD&D grants

Table 8 shows expenditure on Round 2 2015 grants.

Table 8: Expenditure – RD&D Round 2015

Applicant	Project description	Value ($)
CSIRO (Hai Yu)	Advanced aqueous ammonia-based carbon capture technology	300,000
CSIRO (Halliburton)	Aerosol formation case study	103,088
CO2CRC (Qader)	Membrane gas-solvent contactors	225,107
University of Newcastle (Donne)	Direct carbon fuel cell demonstration	209,096
University of Newcastle (Moghtaderi)	Combining redox energy storage at a coal-fired power generation plant	57,550
Total		**894,841**

Round 3 2018 RD&D grants

Table 9 shows expenditure on Round 3 RD&D Round 2018 projects:

Table 9: Expenditure – RD&D Round 2018

Applicant	Project description	Value ($)
CO2CRC (Qadar)	Reduction of greenhouse gas emissions in steel production	203,444
CSIRO (Feron)	Water production from an amine based post-combustion CO_2 capture process	290,198
CSIRO (Milani)	Highly integrated solar heat in carbon capture technology	162,588
CSIRO (Shi)	Ventilation air methane catalytic mitigator	560,806
CSIRO (Thiruvenkatachari)	Harnessing energy with CO_2 utilisation	74,000
CSIRO (Yin)	CO_2 capture at a cement plant	70,000
Sunset Power (Callen)	Battery energy storage system at Vales Point Power Station	241,500
Toshiba (Byak)	Ultra-supercritical hybrid solar/coal pathway	658,125
University of Newcastle (Doroodchi)	Assessment of geothermal assisted power generation	69,415
University of Newcastle (Wall)	Manufacture of carbon fibres	161,457
University of Melbourne (Arranz)	Enabling broader low-emissions advocacy coalitions in the NSW coal related sectors	95,208
University of Sydney (Ho)	Bioenergy carbon capture and storage feasibility study	69,146
University of Technology Sydney (Zhang)	Solar photovoltaic and concentrated solar power for coal-fired power plants	67,473
University of NSW (Walsh)	Silica gels for improved CO_2 containment and mitigation	63,000
Total		**2,786,361**

Peer reviews

When required, CINSW engages external peer reviewers to assess project stage-gate and final reports. These independent reviewers have specialist knowledge in various areas of low emission coal technologies. Their contributions reduce the risk to CINSW when assessing project outcomes, results and recommendations.

CINSW expended $12,033 on four peer reviews. A summary of the peer reviews conducted are provided in Table 15.

B4. NSW CO_2 Storage Assessment Program

Table 10 shows expenditure on the NSW CO_2 Storage Assessment Program:

Table 10: Expenditure – NSW CO_2 Storage Assessment Program

Description	Value ($)
Deloitte – Carbon capture, transport and storage in NSW study	245,821
Gamma Energy Technology peer review of the carbon capture, transport and storage in NSW study	15,400
Total	**261,221**

B5. Clean hydrogen study

The Global CCS Institute was retained to undertake a study into production options for clean hydrogen in NSW. Funds expended against this project are shown in Table 11.

Table 11: Expenditure – Clean hydrogen study

Description	Value ($)
NSW Hydrogen scoping study	30,000
Total	**30,000**

B6. Audit fees

CINSW spent $27,300 on an independent financial audit (Table 12). The *Public Finance and Audit Act* 1983 mandates the Auditor-General audit the Coal Innovation Fund as it is a Special Deposits Account. The audited financial report is included in Section D of this report and comprises a statement of net assets, comprehensive income and associated note disclosures.

Table 12: Expenditure – Audit fees

Description	Value ($)
Audit Fees for FY 2019-20	27,300
Total	**27,300**

C. Evaluation

Evaluation of the effectiveness of each of the projects and other activities that received funding under the *Coal Innovation Administration Act 2008* (Act):

C1. Coal Innovation NSW membership, meetings and sub committees

The *Coal Innovation Administration Act 2008* established an independent advisory council (CINSW) that makes recommendations to the Deputy Premier and Minister for Regional NSW, Industry and Trade, responsible for expenditure from the Fund. Composition of CINSW is prescribed by the Act. CINSW comprises an independent chairperson, two members from government, two representatives of the NSW black coal industry and up to four independent members with qualifications or experience relevant to the function of CINSW.

Members of CINSW for the financial year were:

- Prof. Jim Galvin, Independent Chair (resigned 31/12/2019)
- Prof. Michael Dureau, Deputy Chair, Warren Centre for Advanced Engineering, Chairperson (from 27/04/2020)
- Prof. Hugh Durrant-White NSW Chief Scientist and Engineer (resigned 31/12/19)
- Dr Chris Yeats, Executive Director, Geological Survey NSW
- Mr Michael Buffier, Group Executive, Glencore
- Mr John Richards, Managing Director, The Bloomfield Group
- Prof. Dianne Wiley, Head of School, University of Sydney
- Dr Noel Simento, Managing Director, Australian National Low Emissions Coal R&D
- Mr Greg Everett, Managing Director, Sunset Power International (Delta Electricity).
- Mr James Hay, Deputy Secretary Energy Climate Change, Sustainability at Department of Planning, Industry and Environment NSW

Memberships to CINSW expire on 31/12/2021 except for Michael Dureau and James Hay whose memberships expire on 26/04/2022.

CINSW held three meetings in the financial year:

- Meeting 28 –12 August 2019
- Meeting 29 – 3 December 2019
- Meeting 30 – 6 April 2020

Members of the CINSW are eligible to claim remuneration for their services as prescribed by the Public Service Commission's 'Classification and Remuneration Framework for NSW Government Boards and Committees'. Only the chairperson of the CINSW claimed remuneration for the financial year equating to $20,000.

Evaluation:

CINSW meeting 28 – 12 August 2019

The Council received a presentation by Deloitte Access Economics updating Package 1 sensitivities, including the modelling outcomes on the net present value of carbon capture and storage (CCS). This demonstrated that the cost to NSW for CCS, including storage and transport, between 2019-2050 is approximately $16.432 billion. The Council decided stage 3 and 4 of Deloitte study were no longer required. Deputy Premier John Barilaro, having carriage of CINSW and a guest at the meeting, acknowledged receipt of the Chair's correspondence and his support of CINSW in their continued forward planning. Future work programs and headline budget of $62 million were discussed, including furthering the drilling program, trial injection of the most prospective site, and ongoing research studies.

CINSW meeting 29 – 3 December 2019

CINSW received presentations on two completed research projects from the Round 2 (2015) grants program. Dr Abdul Qadar presented his work on the completed membrane gas-solvent contactor pilot plant trials. Professor Behdad Moghtaderi (UON) presented on the completed research project, Combining Thermochemical Energy Storage with Coal-Fired Power Generation.

Both reports were accepted by CINSW. Dr John Yin from CSIRO Energy provided an update on the work on the Round 3 project: Development of a novel Ventilation Air Methane (VAM) catalytic mitigator (VAMMIT). The future work program and budgets were discussed, with a focus on fugitive emissions; developing a VAM strategy was a key action for this meeting. The report by University of NSW on Third Generation Membrane Material was accepted by the Council.

CINSW meeting 30 – 6 April 2020

This meeting was held online via Microsoft Teams due to the COVID-19 pandemic. The Secretariat outlined MEG is seeking to increase total expenditure limit through a parameter and technical adjustment (PTA), allowing $40 million expenditure from the CIF over the next four years; key to delivering the proposed CINSW work program.

The Energy and Emissions Reduction Memorandum of Understanding between the Commonwealth and NSW Government was outlined, the Council noting the shared interests of VAM, the Council's desire to fund VAM abatement research technologies and potential funding opportunities in this space.

COAL21 presented plans to commercialise VAM technologies, identifying safety and regulatory incentives as key issues to address. The Council agreed that whilst incentives are required for the uptake of this technology, CINSW funds are best spent improving safety, efficiency and commercial viability of VAM systems.

Dr Hai Yu presented work on his Round 2 (2015) project researching advanced ammonia (NH_3) capture; Marcus Dawe from Mineral Carbonation International presented results from his Round 1 (2009) project. Both projects were accepted by the Council as was the CSIRO - Rotating Liquid Sheet Contactor project. Gary Byak from Toshiba presented on Toshiba's supercritical CO_2 cycle coal platform and CO_2 utilisation strategies.

C2. Coal Innovation NSW Secretariat

Due to a Machinery of Government (MoG) change in early 2020 the Secretariat moved from the Department of Planning, Industry and Environment (DPIE) to the newly formed Department of Regional NSW (DRNSW). In addition, the Division of Resources and Geoscience, which housed the Secretariat, transitioned to Mining, Exploration and Geoscience (MEG).

The CINSW Secretariat comprises five staff:

- Manager
- Senior Project Officer
- Project Officer
- Assistant Project Officer
- Grant and Program Analyst (0.5 full time equivalent)

Significant tasks for the financial year centred on:

- managing current grantee projects, including working with researchers in the development of final research and development reports and engaging independent peer reviewers
- developing options and budgets for the Fund's future programs particularly in VAM and the NSW CO_2 Storage Assessment Program
- completion and publication of the 'Future of NSW coal fired electricity generation study' and a clean hydrogen study
- consultation with industry, state and commonwealth governments on future research options
- upgrades to the CINSW website.

C3. Research, Development and Demonstration (RD&D) projects

CINSW has funded three rounds of grants through a competitive expression of interest process. Applications were assessed by a Technical Working Group and successful grantees endorsed by CINSW and the Deputy Premier and Minister for Regional NSW, Industry and Trade. The grant rounds commenced in 2009, 2015 and 2019.

Round 1 2009 RD&D grants

Eight projects were funded through this grants program with $11.8 million committed by CINSW. No expenditure on these projects occurred this financial year as all projects are complete. Additional information on these projects can be found in previous annual reports or on at the CINSW website https://www.resourcesandgeoscience.nsw.gov.au/investors/coal-innovation-nsw/about-coal-innovation-nsw.

An update on the Mineral Carbonation International project is provided below as the project was finalised and published this financial year.

Project: Permanent large-scale CO_2 storage by mineral carbonation

Grantee: Mineral Carbonation International

The GreenMag Group and University of Newcastle Priority Research Centre for Energy were awarded grant funding in 2009, contingent on securing matching Commonwealth and industry funding, to research and demonstrate industrial processes for mineral carbonation (i.e. permanently storing carbon dioxide gas as solid carbonate in rocks). In 2013, together with Orica Ltd, the grantees formed Mineral Carbonation International Pty Ltd (MCi). This joint venture established CO_2 mineral carbonation pilot plants at the University of Newcastle with the aim of demonstrating that captured CO_2 emissions can be transformed into forms of carbonate rock to be trialled as new green building materials for the construction industry. The project was overseen by a steering committee comprising representatives from MCi, CINSW and the Commonwealth Government.

The major project goal was to reduce the cost of the mineral carbonation process and to demonstrate that the process involved can be scaled up from the laboratory to pilot scale. The MCi project encompassed three main strands, including:

- pilot plant construction and operation
- intensive research and development
- program governance, communication and commercialisation.

Evaluation:

Following a 4.5-year research program, a draft final report was received in July 2018 and subjected to peer review. The outcomes and recommendations from the independent peer review were considered by the grantee and a revised report submitted in May 2019. The revised final report was accepted by the project steering committee in November 2019 and by CINSW in April 2020. CINSW has recommended the Deputy Premier and Minister for Regional NSW, Industry and Trade accept and publish the report on the CINSW website.

A project highlight was the development and successful operation of two pilot plants with capacity to store 150 tonnes of CO_2 per year. The plants produced data for life cycle analysis, tested and optimised innovative components and processes, and provided saleable products for assessment.

The pilot plant work was supported by a successful laboratory research program focused on improving fundamental understanding of the chemical reactions and optimising production methods and processes. This included the development of a new two-stage mineral carbonation process which offered improvements over the current process.

Materials for use in concrete and plasterboard were produced at lab scale. The carbonates produced are inert and stable and establish mineral sequestration as an environmentally suitable CO_2 storage solution. The sale of these materials was included in the economic assessment of the technology to offset the costs of the carbonation process. It was reported that a cost reduction from $243 per tonne of CO_2 down to as low as $128 per tonne of CO_2 could be achieved for the existing mineral carbonation (single-stage Albany Research Centre) process. A net revenue of $240 per net tonne CO_2 was estimated for the two-stage process based on an average product price of $100 per tonne of output material.

The MCi project produced a variety of spin off projects supporting several PhD and postdoctoral students, making a significant contribution to the field of mineral carbonation.

Round 2 2015 RD&D grants

The Round 2 2015 RD&D grants program comprises eight projects with a total value of $8.6M (Table 13). Of the eight projects, six are complete, one is under review prior to publication (Halliburton) and one is ongoing (Donne).

CSIRO received funding from the first round of CINSW grants in 2009 to relocate and refurbish a post-combustion capture (PCC) pilot plant from Munmorah Power Station to Vales Point Power Station. This pilot plant is now a critical piece of infrastructure and test facility used for experimental campaigns on real flue gas under real power station operating conditions. The first five projects listed in Table 13 conducted testing using the PCC pilot plant at Vales Point Power Station.

Table 13: Evaluation – Round 2 RD&D Projects 2015

Applicant	Project description	Status	Awarded funding ($)	Expended FY19/20 ($)
CO2CRC Pty Ltd	Membrane gas-solvent contactors	Complete	1,259,473	1,259,473
CSIRO (Feron)	Energy harvesting from CO_2 capture	Complete	578,991	578,991
CSIRO (Hai Yu)	Advanced aqueous ammonia-based carbon capture technology	Complete	2,000,000	2,000,000
CSIRO (Halliburton)	Aerosol formation case study	Complete. Pending approval of final report.	687,252	687,252
CSIRO (Wardhaugh)	Rotating liquid sheet contactor	Complete	1,274,045	1,274,045
University of Newcastle (Donne)	Direct carbon fuel cell (DCFC) demonstration	Ongoing	1,643,001	1,086,918
University of Newcastle (Moghtaderi)	Combining redox energy storage with coal-fired power generation	Complete	383,663	383,663

Applicant	Project description	Status	Awarded funding ($)	Expended FY19/20 ($)
University of NSW (Chen)	Third generation membrane material development	Complete	862,803	862,803
Total			**8,646,655**	**8,133,145**

Membrane gas-solvent contactors demonstration project

Grantee: CO2CRC Pty Ltd

This project investigated a new type of technology, known as a Membrane Gas-Solvent Contactor to capture flue gas CO_2 from a coal-fired power station. Membrane contactors are a hybrid technology incorporating the advantages of both solvent absorption and membrane separation. The project aimed to establish the viability of this new hybrid technology and enable design scaling to support a potential large-scale CO_2 capture demonstration. If the technology can be achieved at scale, it would enable it to be cost competitive and help drive down the costs of capturing CO_2 for carbon capture and storage.

The trials were undertaken at Vales Point Power Station using a refurbished pilot plant with a 100 kg/day CO_2 capture capacity, the largest known of its kind. Commercially available membranes and conventional absorption liquid (30 per cent monoethanolamine or MEA) were used in the study to ensure CO_2 capture and subsequent regeneration of this liquid (i.e. removal of the CO_2) could be achieved.

Evaluation:

The project commenced in January 2017, with a draft final report submitted in May 2019. The report was reviewed by the Secretariat and an independent subject matter expert. The grantee resubmitted a revised final report in August incorporating feedback from the review. This was accepted by CINSW in December 2019 who recommended the Deputy Premier and Minister for Regional NSW, Industry and Trade accept and publish the report on the CINSW website.

The project progressed from initial screening studies of suitable membranes in the laboratory through to pilot plant campaigns, where the effectiveness of the technology in separating CO_2 from a slipstream of flue gas from Vales Point Power Station was assessed. Commercially available membrane contactors successfully separated out CO_2 from the flue gas in combination with conventional solvent liquids. The pilot plant campaign determined the optimal conditions for efficient CO_2 capture and solvent regeneration over an extended period.

A high level economic and lifecycle analysis was undertaken. Using the pilot plant results, a CO_2 capture cost of $58/tonne was estimated for a large-scale membrane contactor process with 90% recovery. This is comparable with costings of traditional solvent-based CO_2 capture technology. When a cheaper price for the power consumed by the operation was used (cheaper due the co-location of the capture plant with the power station), the cost of capture reduced to $30/tonne, thereby meeting the project's economic performance target (20% reduction in cost of capture compared to traditional processes).

The membrane contactor technology may be a cheaper carbon capture option compared to conventional technologies however, further work is required to enable commercial adaptation.

Rotating liquid sheet contactor pilot scale testing project

Grantee: CSIRO

This project involved designing and testing a new and potentially more efficient gas separation technology referred to as a 'rotating liquid sheet (RLS) contactor' for the capture of CO_2 from power station flue gas. The project aimed to validate the design, costs and performance of the RLS contactor in a post combustion capture (PCC) cycle using real flue gas in a pilot plant at Vales Point Power Station.

The RLS contractor is a device where continuous thin liquid sheets of absorption liquid are sprayed out from slots in a specially designed rotating central tube. The liquid sheets come into contact with and absorb the CO_2 from flue gas. One of the project's objectives was to provide a liquid surface area for the CO_2 to come into contact with, that is equivalent to conventional CO_2 capture technology but with less equipment and fewer process steps. This would significantly reduce capital and operating costs. If proven, this novel technology could then be incorporated into a conventional CCS process and be retrofitted to existing coal-fired power stations to reduce their carbon emissions by more than 90 per cent.

Evaluation:

The project began in January 2017, following a successful two-year research program. A draft final report was submitted in April 2019. The report underwent a peer review including independent evaluation by a subject matter expert. The grantee resubmitted a revised final report in October incorporating feedback from the reviewers. This was accepted by CINSW in April 2020 who recommended the Deputy Premier and Minister for Regional NSW Industry and Trade accept and publish the report on the CINSW website.

The research comprised of an experimental laboratory program involving design and performance testing of the rotating central tube and a pilot testing campaign using a single unit retrofitted to the existing CSIRO pilot CO_2 capture plant at Vales Point Power Station. The design and functionality of the rotating central tube was comprehensive and resulted in all the lab-based performance targets being met. The pilot plant processed a flue gas slipstream taken from Vales Point coal fired power station operated by Delta Electricity. This is the first pilot scale test facility for this technology. CO_2 capture rates of the RLS contactor were comparable to or exceeded conventional carbon capture technology.

Successful completion of the pilot-scale testing regime allowed existing process and cost models to be updated for an up-scaled demonstration-sized plant. Modelling showed that the novel RLS contactor technology had an 11 per cent lower total capital investment cost and 5 per cent lower operating cost than an equivalent plant using conventional carbon capture technology, and 7 per cent lower costs over the life of the project.

The final report provided a high quality, comprehensive account of the work contributing to the project. The project aim, objectives, milestones and key performance measures were all completed to the satisfaction of CINSW.

Third generation membrane material development

Grantee: University of NSW

This project developed new high-performance membrane materials that physically separated or sieved out CO_2 from a coal-fired power station's flue gas. The aim of the project was to provide an accurate technological and economic assessment of the high performance membranes for CO_2 capture based on pilot testing using real flue gas from Vales Point Power Station. This would advance the potential for commercialisation of this carbon capture technology.

A unique feature of this project was all the materials used for membrane development were commercially available and therefore the process developed was amenable to existing large-scale fabrication used in membrane production. This project could provide a pathway for carbon capture membrane technology into industrial scale manufacturing in NSW.

Evaluation:

The project began in January 2017, research was completed by early 2019 and a draft final report submitted in April 2019. The report was reviewed by the Secretariat and an independent peer reviewer. The grantee submitted a revised report incorporating feedback from the reviewers which was accepted by CINSW in December 2019. CINSW recommended the Minister accept and publish the report on the CINSW website.

During the initial phases of the study, high performance hollow fibre membranes were fabricated by applying a state-of-the-art, layer-by-layer coating technique This technique successfully transformed inexpensive water treatment membranes into novel gas separation membranes. The use of commercially available and low-cost materials will in the future facilitate the mass production of these membranes at an industrial scale.

Following membrane fabrication, a comprehensive laboratory screening process identified four membranes suitable for pilot-scale testing that met performance targets in terms of the separation of CO_2 from a flue gas stream. A pilot-scale testing facility was also designed, constructed and tested at the University of NSW and then relocated to Vales Point Power Station. Results from a four-month onsite testing campaign using three selected membranes and flue gas met specified performance targets. During the trials it was determined flue gas required partial pre-treatment to mitigate any performance declines in the membranes.

Using the on-site results, an economic study was undertaken showing that the membranes had lower capital and operating costs than a conventional liquid absorption PCC process, but had much higher CO_2 avoided costs due to a lower CO_2 removal capability (43-67 per cent vs 90 per cent). Both the membrane performance and process design require further optimisation to enhance CO_2 recovery. The use of a second membrane downstream in a cascading process would improve CO_2 removal but increase costs. The laboratory experiments and pilot campaigns demonstrated the new membranes were capable of successfully capturing CO_2 from flue gas, however both the membrane performance and process design require further optimisation to enhance CO_2 recovery.

The project provided a worthwhile examination of membrane technology to recover of CO_2 from power station flue gas and has contributed significantly to the field of high-performance membranes tested in real world conditions.

Aerosol formation case study

Grantee: CSIRO

This study is evaluating the potential for pollutant emissions being produced whilst using a PCC process on coal-fired power stations. The project aim is to provide an understanding of the generation of aerosol emissions to address any knowledge gaps or potential environmental issues in CO_2 capture plants that use an amine-based absorbent.

This project will answer the question of where, and under which conditions, aerosols are formed in the conventional CO_2 capture process. The findings will provide new information on whether aerosol emissions are a potential issue and potentially lead to techniques for reducing airborne emissions and consequential reductions in the cost of plant operations.

Evaluation:

This project started in January 2017 and passed its first stage gate assessment by delivering a state-of-the-art review of aerosol genesis and absorbent loss in PCC processes. The review also critically evaluated the effectiveness and limitations of current aerosol sampling methodologies, enabling the most appropriate research approaches to be selected for the experimental testing phase of the project.

Approximately 2,000 laboratory experiments were completed to investigate the principal drivers and aerosol forming potential of several sulphur and nitrogen-based gases present in the flue gas stream and various absorption-based PCC operational processes. The trace gas sulphur trioxide (SO_3) was found to be the primary driver of aerosol formation. In addition, aerosols formed when nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) reacted to form SO_3. These findings were studied

further in the pilot scale experiments at Vales Point Power Station using real flue gas. Maintaining low levels of these acid gases in the flue gas entering a PCC absorption unit was vital to minimise the creation of aerosols.

A draft final report was submitted in May 2020 and is undergoing peer review including evaluation by an independent reviewer.

Advanced aqueous ammonia-based carbon capture technology

Grantee: CSIRO

This project focussed on demonstrating the benefits of an advanced aqueous ammonia-based PCC process, developed by CSIRO using the pilot plant located at Vales Point Power Station. Parallel to the pilot plant trials, lab-based research was undertaken to develop 'proof of concept' and the prototyping of an entirely new "trimonia process" utilising high concentration aqueous ammonia (NH_3) as a CO_2 capture medium.

The pilot stream aimed to demonstrate the application of advanced aqueous NH_3-based PCC technology to new and existing coal-fired power stations in NSW to significantly reduce CO_2 emissions in an affordable and environmentally benign way. The technology uses NH_3, a cheap, stable and locally available chemical, as the chemical solvent to remove CO_2, SO_2 and other pollutants from the flue gas in power stations and other industries. This work aims to deliver a locally developed carbon capture technology concept based around a locally available solvent suitable for NSW power plants.

The project aimed to prepare the technology for a large-scale demonstration in NSW and ultimately benefit the NSW coal industry by providing a cost-competitive, low-emission coal technology for capturing CO_2 emissions for utilisation and storage.

Evaluation:

This project started in January 2017, experimental work was completed in early 2019 and a draft final report submitted in May 2019. The report was reviewed by the Secretariat and an independent peer reviewer. The grantee submitted a revised report incorporating feedback from the reviewers which was accepted by CINSW in April 2020. CINSW recommended the Deputy Premier and Minister for Regional NSW, Industry and Trade accept and publish the report on the CINSW website.

Following the development of a technology roadmap for the aqueous NH_3-based PCC process, the project team commenced work on both the advanced NH_3 process pilot testing and laboratory trimonia process work in parallel. The pilot plant trials demonstrated several benefits brought about by improvements to the capture process including:

- enhanced removal of sulphur dioxide (SO_2)
- a reduction in the amount of absorbent lost during the capture process
- improved processes for separating out the CO_2 in the flue gas stream and then subsequently recovering it from the absorbent.

A subsequent techno-economic assessment showed the avoided CO_2 capture cost for an Australian coal-fired power station integrated with the advanced NH_3-PCC process would be 31% lower than a conventional amine-based capture process. The pilot plant study established a solid foundation for a large-scale demonstration project.

Each of the three individual operations of the trimonia process were tested separately in laboratory-scale and mini-pilot scale equipment to determine the range of operational and technical limits. This included the use of NH_3 in a vapour form to capture CO_2 from flue gases, followed by a reverse osmosis process to separate out the NH_3 that had absorbed CO_2 from unreacted NH_3, and finally an operation to re-heat the unreacted NH_3 to return it to a vapour ready for the next capture cycle. In each case, the components achieved degrees of capture or separation exceeding the

requirements of the project. The design of an integrated process has been proposed for a future project.

The pilot plant study demonstrated and optimised a PCC process using NH_3 that largely overcame short comings of the conventional process, resulting in improved cost estimates, lower thermal efficiency losses and a lower CO_2 footprint. The project established the foundation for a future large-scale demonstration of the advanced NH_3 PCC process. The lab-based research also successfully validated each of the three-unit operations, and in doing so highlighted a new method for greatly reducing the energy demand of the conventional capture process.

Direct carbon fuel cell (DCFC) demonstration

Grantee: University of Newcastle

This project is building on previous studies on the DCFC funded under the 2009 R&D Round with further fundamental research to support development of a DCFC demonstration plant. The project aims to develop a first-of-kind fuel cell converting the chemical energy from coal into electricity through an electrochemical reaction. The DCFC technology has potential to be one of the most efficient ways of producing electricity with significantly less CO_2 emissions.

The DCFC technology has undergone a major boost in international research interest in recent years; however, technical barriers have prevented commercialisation. This project will bridge a crucial gap between research and commercialisation of DCFC technology.

Evaluation:

This project commenced in June 2017 following the successful completion of the '*Development and Optimisation of the Direct Carbon Fuel Cell*' project.

The project includes two discrete streams. The first stream includes fundamental/pilot-scale work predominately building on the previous project. A small DCFC test rig has been built in the laboratory to allow testing of fundamental aspects of the electrochemical generation of electricity from coal. Significant progress has been made in understanding the processes operating within the DCFC, with the work culminating in a three-fold increase in the electrical output from that achieved in the first project funded by CINSW in 2009.

The second stream is focused on the build and operation of a demonstration fuel cell system. The design and construction of a 1kW unit is complete and testing is underway to optimise operations based on the findings from the first stream.

Energy harvesting from a CO_2 capture process

Grantee: CSIRO

The project was successfully completed in financial year 2018/19. For more information refer to the 2018-19 Annual Report on the CINSW website.

Combining redox energy storage with coal-fired power generation

Grantee: University of Newcastle

This project focused on developing an energy storage unit termed "redox energy storage" which performs a role akin to a large-scale battery. This technology could help coal-fired power stations better manage their load by storing energy in off-peak periods for later dispatch. The project aimed to determine the key science and engineering issues underpinning the performance of the Redox Energy Storage unit for energy storage.

A Redox Energy Storage unit works by storing large amounts of electricity as chemical energy at off-peak times when electricity demand is low, which can then be converted back to electrical energy and supplied to the grid during peak times when demand is high. In this way, the impact of

peaks and troughs in power demand imposed on power stations can be reduced allowing the plant to run more smoothly and efficiently.

A Redox Energy Storage unit has potential to provide flexibility to coal-fired power plants to operate in the cycling mode without disrupting their baseload operation. This reduces the need for more high cost capital generation equipment to service times of peak electricity demand only, whilst reducing greenhouse gas emissions.

Evaluation:

This project commenced in January 2017, research was completed in early 2019 and a draft final report submitted in March 2019. The report was reviewed by the Secretariat and an independent peer reviewer. The grantee submitted a revised report incorporating feedback from the reviewers which was accepted by CINSW in December 2019. CINSW recommended the Deputy Premier and Minister for Regional NSW, Industry and Trade accept and publish the report on the CINSW website.

Following a literature review on energy storage technologies, two thermochemical energy storage processes were selected for further modelling. These included a redox energy storage (RES) cycle and a calcium carbonate-calcium oxide looping (CaL) cycle. For modelling purposes these two processes were coupled to two different power blocks, being an open cycle gas turbine (OCGT) and a secondary steam cycle (SSC). Thus, the modelling work included process modelling of four different energy storage configurations, followed by techno-economic evaluation and greenhouse gas life cycle analysis of the considered processes. The CaL+SSC configuration was the most economically viable and met all targets set for the project.

Experimental work involved a series of tests from laboratory to large pilot scale to demonstrate the effects of scaling-up. The main finding from testing was the calcium-rich particles could be used as the energy carrier in the thermochemical energy storage process to produce energy, thereby preventing cycling of the power plant and decreasing its maintenance and operational costs.

Results from the project supported the adoption of the CaL+SSC configuration over Lithium-ion batteries as an energy storage solution as it had a lower environmental impact (e.g. one third of the CO_2/MWh emitted due to its higher energy density).

Round 3 2018 RD&D grants

The Round 3 2018 RD&D grants program comprises 14 projects with a total value of $6.5 million (Table 14). Of the 14 projects, eight are under review prior to publication and six are ongoing.

The Round 3 2018 RD&D grant funding was distributed across two funding streams. This included a research stream capped at $1.5 million per project and a maximum duration of three years, and a seed stream capped at $100,000 of one-year duration. The research stream aimed to support projects demonstrating reduced deployment timeframes of a specific technology to garner market advantage or share. The seed stream aimed to support projects generating new ideas to achieve a specific goal, test an innovation or undertake essential desktop studies.

Table 14: Evaluation – Round 3 RD&D Projects 2018

Grantee	Project description	Status	Awarded funding ($)	Expended FY2019/20 ($)
CO2CRC (Qadar)	Reduction of greenhouse gas emissions in steel production	Complete. Pending approval of final report.	387,550	387,550

Grantee	Project description	Status	Awarded funding ($)	Expended FY2019/20 ($)
CSIRO (Feron)	Water production from an amine based post-combustion CO_2 capture process	Ongoing	1,347,874	565,297
CSIRO (Milani)	Highly integrated solar heat in carbon capture technology	Ongoing	505,145	266,784
CSIRO (Shi)	Ventilation air methane catalytic mitigator	Ongoing	1,496,424	1,014,905
CSIRO (Thiruvenkatachari)	Harnessing energy with CO_2 utilisation	Ongoing	154,923	99,492
CSIRO (Yin)	CO_2 capture at a cement plant	Complete. Pending approval of final report.	100,000	100,000
Sunset Power (Callen)	Battery energy storage system at Vales Point Power Station	Complete. Pending approval of final report.	460,000	460,000
Toshiba (Byak)	Ultra-supercritical hybrid solar/coal pathway	Complete. Pending approval of final report.	946,500	804,500
University of Newcastle (Doroodchi)	Assessment of geothermal assisted power generation	Complete. Pending approval of final report.	99,165	99,165
University of Newcastle (Wall)	Manufacture of carbon fibres	Ongoing	753,468	317,533
University of Melbourne (Alfonso)	Enabling Broader Low-Emissions Advocacy Coalitions in the NSW Coal Related Sectors	Ongoing	418,828	95,208
University of Sydney (Ho)	Bioenergy carbon capture and storage feasibility study	Complete. Pending approval of final report.	96,630	96,630
University of Technology Sydney (Zhang)	Solar photovoltaic and concentrated solar power for coal-fired power plants	Complete. Pending approval of final report.	96,390	96,390

Grantee	Project description	Status	Awarded funding ($)	Expended FY2019/20 ($)
University of NSW (Walsh)	Silica gels for improved CO_2 containment and mitigation	Complete. Pending approval of final report.	90,000	90,000
Total			**6,534,069**	**4,493,454**

Retrofitting calcium carbonate looping to an existing cement plant for CO_2 capture: A techno-economic feasibility study

Grantee: CSIRO

This project involves a techno-economic feasibility study of retrofitting a novel calcium looping process to an existing cement plant to reduce CO_2 emissions. The CO_2 capture cost of calcium looping could be significantly lower than other post-combustion capture (PCC) technologies. Globally, there has been no research on retrofitting existing cement plants with calcium looping in an industrial setting. Successful completion of this project would help bridge this gap and possibly lead to a near-zero emission cement plant in NSW.

The project includes a technology survey of pilot-plant development of calcium looping, site visits to the Berrima cement plant in southern NSW to collect relevant technical information and understand its current operation, and techno-economic feasibility assessment to understand the capital costs, economic return and CO_2 emissions reduction.

The production of cement involves sintering of carbonate minerals producing clinker and CO_2 and accounts for about eight per cent of total greenhouse gas (GHG) emissions worldwide. Calcium looping exploits the reaction taking place at medium temperatures (650 to 700º C) between lime (CaO) and CO_2 to form limestone ($CaCO_3$), which can be reversed at higher temperatures (900-950º C) to release a relative pure stream of CO_2 ready for utilisation or geosequestration. The process is tolerant to sulphur dioxide (SO_2) and has the potential to reduce nitrogen oxide (NO_x) emissions.

The Boral Berrima cement plant in NSW is the reference plant for this study. It is envisaged its CO_2 emissions can be reduced by >90 per cent by retrofitting a calcium looping process.

Evaluation

The final report for this project has been submitted and the Secretariat has started the review process including engaging an independent reviewer.

An in-depth assessment of geothermal assisted power generation for NSW coal-fired power plants

Grantee: University of Newcastle

This project involves studying the feasibility of applying geothermal assisted power generation (GAPG) to NSW coal-fired power stations. The GAPG concept is designed to directly reduce the greenhouse gas (GHG) emission intensity of these plants by partly replacing coal with geothermal heat. The GAPG concept refers to the use of low-grade geothermal heat (between 70°–170°C) to provide a thermal boost to the existing coal-fired power plants via feedwater preheating.

This rather simple yet effective concept could enable either an increase in generating capacity without increasing coal consumption, or the ability to maintain capacity whilst reducing coal consumption. In both cases, emissions of GHGs per unit of generation capacity are reduced.

Economically, co-locating a geothermal power plant with an existing coal-fired power plant enables the sharing of existing power generating facilities, land uses and transmission lines, helping to save significant cost and the time required for developing geothermal resources.

The project consists of four main tasks, including: characterisation of NSW geothermal resources and coal-fired power plants, thermodynamic study and optimisation of retrofit options and operation modes, techno-economic assessment of two selected coal-fired power stations upgraded with a GAPG system, and consolidation and dissemination of project findings.

Evaluation:

The final report for this project has been submitted and has undergone internal review by the Secretariat and specialists from the Department of Regional NSW. The grantee will present their findings at the next CINSW meeting.

The final report for this project identified that all the milestones are complete. An Aspen model was developed using heat and mass balance data from Liddell Power Station and geothermal resources were studied. Multicriteria analysis was used to select the most viable NSW power plants for applying the GAPG concept. Thermodynamic and optimisation studies were also completed.

The project characterised the two most viable NSW power plants, Bayswater and Eraring, and their nearby geothermal resources, within a 40km range and up to 5km deep. The maximum achievable well head temperature was estimated to be 184 °C, at a depth of 5km, 15 km from Bayswater Power Station.

The GAPG system was found to be a feasible and economic means of reducing CO_2 emissions from coal-fired power stations. Each of the NSW coal plants were assessed for their suitability for application of the technology, with the Bayswater Power Station considered the best option.

Optimal design of solar photovoltaic and concentrated solar power system for coal-fired power plants in NSW

Grantee: University of Technology, Sydney

This study involves designing the optimal capacity and size of solar photovoltaic (PV), concentrated solar power (CSP) and energy storage systems integrated with coal-fired power plants to minimise coal consumption and spinning reserve cost. Renewable designs at coal-fired power plants will assist NSW to optimise the electricity grid with a balanced energy portfolio in the near future. Long term, hybrid solar/coal power plants could help in the transition to a low-carbon electricity system.

The project investigates the optimal sizing of PV, CSP and the corresponding energy storage for the hybrid solar and coal-fired power plant by considering solar irradiance, investment, life cycle cost, payback period, power demand, generation capacity and solar capacity factor. An optimal trade-off between generation capacity, economic investment, life cycle cost and carbon reduction will be achieved. This project also aims to simulate technical and financial constraints in the planning model.

Evaluation

The grantee has submitted a final report and the Secretariat has commenced the review process. A literature review and data study is complete and a paper published. Vales Point Power Station was selected to be modelled in the project. Technical and operational data on the coal plant and an existing trial PV unit, along with two sets of air quality monitoring data, were organised as inputs for computer models. Modelling considerations included site-specific solar irradiance and prevailing weather conditions, available land, technology specification, investment and life-cycle cost, payback period, power demand, generation capacity, and uncertainties of solar energy.

A presentation was given by the grantee to representatives from Delta Electricity, the Secretariat and other interested government agencies in December 2019 following submission of the initial draft report. A second presentation is required as part of the process of acceptance of the final report by the Council.

Feasibility assessment of bioenergy carbon capture and storage (BECCS) deployment with municipal solid waste (MSW) co-combustion at NSW coal power plants

Grantee: University of Sydney

The project aims to assess the feasibility of co-combustion of coal, MSW, and commercial/industrial waste biomass in conventional coal-fired power plants in NSW. In developing this assessment, the negative emissions gained through implementation of BECCS will also be evaluated. The outcomes from the project will demonstrate the technical and economic feasibility of MSW co-combustion and CCS, which may aid in facilitating the uptake of low emissions coal technologies.

Wide-scale co-combustion of biomass waste feedstocks at coal power plants could lead to reducing Australia's GHG emissions by 9 million tonnes of CO_2 each year by 2020. Preliminary assessment suggests that wide-scale biomass with 10 per cent co-combustion in NSW's existing coal power plants could see the state's emissions reduced by up to 7 million tonnes. If this is coupled with CCS, the emissions reduction potential could be over 54 million tonnes each year.

Evaluation:

The grantee has submitted a final report and the Secretariat has commenced the review process. An expert consultant has been engaged to complete an independent peer review.

A literature review of co-combustion technologies and modelling of fuel-flexible combustion data was completed. Mapping of existing and proposed MSW sources, coal power plants and geological storage sites in NSW was also finalised along with computer modelling of fuel-flexible power generation. A techno-economic analysis for the technology was also done. The study concluded that BECCS has significant potential to reduce CO_2 emissions in NSW. Additional sources of biomass would be required to unlock greater opportunities to integrate BECCS into NSW coal plants and could come from other Local Government Authorities (LGA) clusters or greater understanding of the suitability of other waste streams.

Deployment of silica gels for improved CO_2 containment and risk mitigation

Grantee: University of New South Wales

This project involves a preliminary investigation into the feasibility of deploying silica sols in fractured wellbore cement to mitigate CO_2 and carbonated brine leakage from wells used to store captured CO_2 underground. Long-term sequestration of CO_2 requires robust and effective caprock barriers and wellbore seals to prevent vertical migration of carbonated brines or supercritical CO_2 from the storage reservoir. This project investigates the potential for colloidal silica gels to serve as an effective barrier to the leakage of carbonated brines and supercritical CO_2.

This technology could provide a mitigation strategy reducing the risks of long-term CO_2 storage, or a rapid response to prevent leakage. Importantly, by reducing the risk of leakage, silica gels have the potential to reduce the costs of CO_2 sequestration even if not deployed, as this technology would lower insurance costs associated with long-term sequestration sites, by reducing the potential hazard of adverse events.

Evaluation:

The grantee has submitted a final report and the Secretariat has commenced the review process. The grantee modelled fractures in a wellbore environment by exposing cement samples to supercritical CO_2 and carbonated brine. In addition, the grantee also studied unreacted samples, as well as samples exposed to hydrochloric acid to simulate more extensive degradation of the cement. The permeability of these samples was measured before and after being plugged with silica sol gels. The results of the permeability studies demonstrate that sol gels can successfully plug open cement fractures and that the resulting seals are robust despite significant changes in the fracture stress. Study into the effects of brine exposure on silica gels indicates that the gels are relatively insensitive to prolonged exposure to brines of even quite high salinity (2M, or 117g/L) and low acidity (<2 pH).

Low emission coal in the manufacture of carbon fibres

Grantee: University of Newcastle

This project is further developing a low emission industrial process to manufacture carbon fibres from coal. If coal could be substituted for polyacrylonitrile (a petroleum-derived material currently used in the manufacture of 90 per cent of carbon fibres) it would reduce the industry's emissions by ~34 per cent (minimum estimate) and significantly reduce the cost of production (by at least 50 per cent). Coal is uniquely placed to overcome this cost barrier but requires the extrusion process to be further developed for fibre production.

This project builds on advanced research into coal conducted at the University of Newcastle, whereby carbon fibres are manufactured by separating and concentrating coking coal's vitrinite component and then thermally extruding this material as it softens and becomes fluid. The extruded material is then drawn down to commercial fibre size (to fractions of a millimetre in thickness) and strengthened by annealing at high temperature.

Evaluation:

This project is progressing well with all reports up to first quarter 2020 accepted by the Secretariat. Coal samples have been acquired and preparation techniques to concentrate vitrinite have been explored. The characterisation of feed samples has been completed and included the mapping of different temperature and extrusion pressure conditions. Batch extrusion was successful, achieving filament sizes of 320μm when drawn down. Continuous extrusion using the industrial extruder is in the commissioning phase.

Enabling broader low emissions advocacy coalitions in the NSW coal-related sectors

Grantee: University of Melbourne

This social-science project aims to better understand and utilise the mechanics of 'advocacy coalitions' for low carbon technologies in coal and coal-related sectors (notably mining, electricity and steel-making). State-of-the-art sociological research shows that coalitions (groups of like-minded people) have either core or peripheric beliefs, which determine the likelihood of them joining other coalitions or changing their interim goals. Further, it is key opinion leaders (KOLs) in these coalitions who will largely be responsible for spreading awareness of, support for, or opposition to a technology. Therefore, this study examines the ways, if any, of making as many NSW low-carbon advocacy coalitions as possible converge in their beliefs and goals about low emissions coal technologies, not least by targeting the KOLs in these coalitions. Policy proponents can leverage this knowledge for better targeting of funding and resources for low emissions coal technologies, most notably carbon capture and storage.

This project aims to understand who specifically forms the advocacy coalitions that operate in the NSW low carbon technologies space and what their belief systems are. This process will facilitate identifying their KOLs. The study then seeks to learn from interactions between KOLs in order to both help improve any communication strategy and commence new coalition building.

Evaluation:

This project began in early 2020 and is progressing well with the quarter one report accepted by the Secretariat. Research design for the project is completed including choosing methodology for key tasks and identifying key terminology used in the sector. The Hunter Valley and Illawarra have been identified as sites of key interest. Regional sorting of archived social network data is ongoing, and the results will be used to train algorithms for use on 2020 Twitter data.

Battery storage at Vales Point Power Station

Grantee: Sunset Power International Pty Ltd

This project includes a techno-economic assessment of integrating a battery energy storage system (BESS) with an existing turbogenerator at Vales Point Power Station. The proposed system will enhance the generation capability of the plant and provide frequency stabilising support to the electricity network to compensate for instability attributable to the increasing proportion of intermittent forms of renewable energy generation.

The BESS will contribute to a reduction of greenhouse gas emissions from the power station and the national electricity market (NEM) overall. This is achieved by reducing losses in the turbogenerator caused by constant frequency oscillations of up to 10 MW required to provide frequency services to the NEM while minimising plant ramping and cycling operations.

Evaluation:

The grantee has submitted a final report and the Secretariat has commenced the review process. An expert was engaged to complete an independent peer review.

Through a review of commercially available battery storage technologies, lithium-ion batteries were found to be the preferred application for utilities due to rapidly decreasing costs and a developed supply chain. A BESS sizing of 40MW/20MWh for each of the two Vales Point units was adopted based on assessment of the most advantageous grid services and revenues potentially provided by a 'behind the meter' installation. Potential locations within the Vales Point site were identified for installation, a 14-month construction program was planned, development approvals pathways were identified, a risk register was developed, and a detailed control system strategy for providing contingency frequency control ancillary services (FCAS) with a BESS was described.

Whilst shown to be technically feasible, the cost for large scale energy storage was found to outweigh the anticipated revenues from this BESS configuration due to high battery capital costs and a relatively short project life of 10 years. It was therefore concluded that the BESS and synchronous generator configuration put forward in this case study would be difficult to realise in the NEM without additional market mechanisms to value and support the provision of energy capacity or spinning reserve.

Development and site trials of a novel pilot ventilation air methane catalytic mitigator

Grantee: CSIRO

This project involves undertaking the further development of a novel technology that aims to reduce the greenhouse gas emissions (GHG) from underground coal mining. Approximately 50-85 per cent of coal mining methane, a potent GHG, is emitted to the atmosphere through mine ventilation air, depending on mine site specifications. Ventilation air methane (VAM) is very challenging for the coal industry to mitigate or use as an energy source because the air volume is large, and the methane resource is dilute and variable in concentration. CSIRO has previously successfully trialled a novel VAM mitigator (VAMMIT) at the Appin coal mine in southern NSW and is using the current funding to improve the performance and safety of this technology.

This project aims to reduce the operating temperature of the VAMMIT to much safer levels by incorporating two layers of catalysts inside the refractory bed of the existing VAMMIT unit at Appin mine. Then, the unit will be commissioned and trialled with VAM to demonstrate its performance.

Evaluation:

The project was progressing well in accordance with the project plan until early 2020, with all quarterly reports during this period accepted. Project delays have been experienced this year due to the COVID-19 lockdown period and state border closures. Lab testing shows the catalytic VAMMIT can be operated at 300-600 ºC (i.e. below the 450-750 ºC originally planned). Test unit designs and fabrication of the catalytic beds have also been completed and the beds successfully installed in the VAMMIT at the Appin mine. Commissioning and function tests are ongoing, and progress is expected to continue once travel bans due to COVID-19 are lifted.

Water production from CO_2 capture

Grantee: CSIRO

This project is undertaking a pilot plant demonstration of a desalination process integrated with an amine-based CO_2-capture process. This addresses the obstacle of increasing specific cooling load, and hence increased water requirement of coal fired power plants, as a result of the implementation of CO_2 capture. The project includes establishing principles underpinning the process and equipment design, identification of the most suitable or best performing desalination membrane for incorporation into amine carbon capture and a techno-economic evaluation of the process concept for NSW coal fired power plants.

Evaluation:

The project is progressing well with all quarterly reports up to the second quarter 2020 accepted by the Secretariat. Some delays have been experienced due to the COVID-19 pandemic which are largely caused by the delay of supplies and impacts to onsite working. Suitable amines and membranes were selected and analysed. Forward osmosis experiments are also complete. Information gathered from the laboratory experiments will guide the forward osmosis process and equipment design for use in the Vales Point PCC pilot plant.

Harnessing energy with CO_2 utilisation: A feasibility study

Grantee: CSIRO

This project involves a feasibility study of a novel method of simultaneously mixing CO_2, that has been absorbed into a liquid CO_2 capture solvent as part of a PCC process, with wastewater brine rejects from coal mines in order to harvest electrical energy and produce a saleable product (bicarbonate soda).

The fundamental principle behind this technology is harnessing the mixing energy of two aqueous electrolytes through porous carbon composite electrodes, as well as using the CO_2 mineralisation process to produce a useful carbonate salt. The ability to strip out the CO_2 from the capture solvent (i.e. regenerate the solvent back to its original state) used in a PCC process also offers a potentially more efficient alternative to conventional thermal regeneration techniques. CSIRO has developed electrodes made from carbon composites considered suitable for this process. This feasibility study aims to conduct a life cycle assessment to provide an estimate of potential CO_2 emissions reductions from the process, evaluate the economic viability of this technology, and assess its commercialisation pathway.

Evaluation:

The project has progressed well with all quarterly reports accepted by the Secretariat. A life cycle analysis (LCA) for the electrochemical process with CO_2 has been completed based on a technical review of electrochemical processes, CO_2 utilisation with bicarbonate production, and the

associated LCA methodologies. The grantee has developed process configurations, simulations and cost estimates and is preparing a final report.

A novel platform for highly integrated solar heat in carbon capture technology

Grantee: CSIRO

This project involves a desktop investigation of the use of a customised solar stripper (So-St) array as an alternative means of stripping out captured CO_2 from the CO_2-loaded solvent in a PCC process. The novel process involves replacing the conventional, energy intensive desorber unit with a specially developed solar array where a rich solvent is heated with solar energy to strip out the captured CO_2. This innovative approach could enhance the techno-economics of carbon capture and advance commercialisation of this technology.

Evaluation:

The project has experienced some delays due to COVID-19 but is otherwise progressing well with all quarterly reports up to quarter two 2020 accepted by the Secretariat. Modelling to identify and optimise the key design parameters for a single solar stripper is complete. The grantee produced a paper *'Tailored solar field and solvent storage for direct solvent regeneration: A novel approach to solarise carbon capture technology'* that was published in the journal of Applied Thermal Engineering. A reaction kinetics and physico-chemical study is ongoing as well as the development of operational control modes and control logistics. The grantee developed two control strategies to achieve the 90% CO_2 capture target. Solvent storage has also been modelled by the grantee.

Reduction of greenhouse gas emissions in steel production

Grantee: CO2CRC Limited

This project is exploring the pathways for reducing CO_2 emissions in steel production. The main cause of CO_2 emissions from a steel plant is the essential use of coal in the steel making process. The grantee will assess the application of carbon capture in the steel making process and the use of innovative technologies to improve efficiency and productivity of the process. The utilisation of carbon rich gases to provide high-quality value-added products will also be explored. The grantee will assess more efficient use of coal, reduction in greenhouse gases and generation of new revenue streams in steelmaking.

Evaluation:

The grantee has completed the project and the Secretariat has commenced the review process including an independent review. The grantee completed a review of the Australian and global steel industry and GHG emission reduction initiatives. The most promising pathways for emissions reduction by Port Kembla Steel Works in NSW were identified and these were analysed considering operational and emission data obtained from the plant. The project also considered the suitability of two different chemical processes for transforming carbon gases into saleable products.

300-200MW ultra supercritical hybrid solar/coal R&D pathway study

Grantee: Toshiba International Incorporation Pty Ltd

This project involves developing a design pathway for ultra-supercritical (USC) hybrid solar/coal plants. This pathway is set to reduce emissions substantially compared to the existing sub-critical plants in NSW, by adopting a 300 MW class USC hybrid solar/coal plant with an energy ratio of 25 per cent/75 per cent. The long-term objective is for a horizon pathway which includes molten salt energy storage and CO_2 capture using oxyfiring.

A key aim of this research is to show that coal can be an integral part of the energy mix, that it can remain competitive in the rapidly changing low emission market where a large focus is on dispatchable generation. The USC hybrid solar/coal plant will show significant commercial and

technical advantages over alternative hybrid dispatchable solutions such as solar or wind plus battery storage solutions.

Evaluation:

The project is progressing ahead of schedule with all quarterly reports accepted by the Secretariat. Hybrid designs have been refined based on technical input from Abengoa, IHI, and Toshiba. The cycle definition is complete and design and the sizing of the solar subsystems, boiler systems and steam turbines is underway. Refining of some technological parameters has led to variations in the final designs of the hybrid pathways. The plant control logic developed considers three operational modes: boiler only mode, hybrid solar/coal mode, and boiler plus PV mode. The grantee has completed revisions for each operation mode and finalised the reports for two different pathway designs. A third horizon pathway including carbon capture and an economic evaluation is complete and a final report has been submitted to the Secretariat.

Peer reviews

When required, CINSW engages external peer reviewers to assess project stage-gate and final reports. These independent reviewers have specialist knowledge in various areas of low emission coal technologies. Their contributions reduce the risk to CINSW when assessing project outcomes, results and recommendations.

CINSW expended $12,033 on four peer reviews. A summary of the peer reviews conducted are provided in Table 15.

Table 15: Peer review expenditure

Project peer reviewed	Value ($)
A techno-economic assessment of BESS at Vales Point Power Station – Round 3 project	2,142
Combining thermochemical energy storage with coal-fired power generation – Round 2 project	1,800
Feasibility assessment of bioenergy with carbon capture and storage (BECCS) deployment with municipal solid waste (MSW) co-combustion at NSW coal power plants – Round 3 project	2,853
Corporate finance reimbursement for the project above including GST which will be returned in financial year 2019/20	3,183
Membrane gas solvent contactors for cost effective carbon capture: demonstration and evaluation on a coal fired power station – Round 2 project	2,100
Total	**12,033**

C4. NSW CO_2 Storage Assessment Program

The 2014 drilling campaign in the Darling Basin (Stage 1B) discovered the first prospective site in NSW for the storage of CO_2 captured from coal-fired power stations and other industrial sources. Analysis of data from the Mena Murtee-1 well in the Pondie Range Trough, north-west of Cobar, revealed multiple sandstone reservoirs with the potential to store hundreds of millions of tonnes of CO_2 overlain by competent layers of top seal rocks.

A business case for Stage 2 Darling Basin exploration program was completed in 2017. The project remains on hold pending an increase to MEG's total expenditure limit which allows $40 million expenditure from the CIF fund over next four years on the CINSW forward work program.

Stage 2 aims to make NSW CO_2 storage ready by proving the Pondie Range Trough and neighbouring Poopelloe Lake Trough as suitable CO_2 storage sites.

A comprehensive seismic survey and exploration drilling strategy is proposed to address several key uncertainties in relation to the stratigraphy, geological structure, reservoir and seal properties, and hydrogeology of the three targeted sub-basins.

Project success could justify a follow up trial injection and demonstration of safe geo-sequestration of CO_2 in NSW. Demonstration of large-scale CO_2 geo-sequestration in NSW would secure a viable pathway to deep decarbonisation of the NSW economy, particularly in hard to abate sectors such as mining, steel and cement manufacture and transport.

CINSW continues to refine the Stage 2 Darling Basin exploration program and is ready to execute the program.

A review of carbon capture, transport and storage in NSW

In March 2019 after a competitive tender, Deloitte Access Economics was commissioned to conduct a study on carbon capture, transport and storage in NSW. $245,821 was expended on the study in the 2019/20 financial year.

The study comprised four packages. After reviewing packages 1 and 2 of the study, CINSW commissioned an independent peer review of the underlying modelling assumptions and study methodology. Based on conclusions from the peer review, CINSW determined no further work was required and packages 3 and 4 should not proceed.

The key findings of the study showed the Darling Basin in NSW has the lowest cost for capture, transport and storage of CO_2 compared to CCS storage in the Surat (Queensland) or Gippsland (Victoria) basins. For more information refer to the 2018-19 Annual Report or the CINSW website.

C5. Clean hydrogen study

The Global CCS Institute (GCCSI) was retained to investigate clean hydrogen (H_2) production options in NSW. The study, titled *Replacing 10% of NSW Natural Gas Supply with Clean Hydrogen: Comparison of Hydrogen Production Options,* will help inform DRNSW's ongoing contribution to the NSW Hydrogen Strategy. The study links to the broader sphere of CINSW work by utilising low emissions coal technologies, such as CCS, to reduce carbon emissions from hard to abate sectors such as steel, cement, mining and manufacturing.

The NSW Government supports a technology-neutral stance in the NSW Hydrogen Strategy in developing the clean hydrogen sector. Clean hydrogen is produced using renewable energy or fossil fuels with CCS. Production via fossil fuels coupled with CCS is termed blue hydrogen and was demonstrated by the study to be a cheap, scalable way to establish a clean hydrogen industry.

NSW is already taking action to support research and pilot studies along the blue hydrogen supply chain. This includes the NSW CO_2 Storage Assessment Program led by CINSW. The program aims to identify safe and secure geological storage for CO_2 in NSW that could support fossil-fuel based hydrogen production and decarbonisation of other hard-to-abate industries.

C6. Audit fees

No evaluation required.

Appendices

Appendix A. Sections of the *Coal Innovation Administration Act 2008* relevant to the annual report

Section 5 of the Act establishes the Purpose of the Fund, as follows:

(a) to provide funding for research into, and development of, low emissions coal technologies,

(b) to provide funding to demonstrate low emissions coal technologies,

(c) to provide funding to increase public awareness and acceptance of the importance of reducing greenhouse gas emissions through the use of low emissions coal technologies, and

(d) to provide funding for the commercialisation of low emissions coal technologies.

Section 7 of the Act, details Payments out of the Fund as follows:

(1) There is payable from the Fund:

  (a) payments approved by the Minister for the purposes of the Fund,

  (b) administrative expenses incurred in relation to the Fund or CINSW, and

  (c) payments directed or authorised to be paid from the Fund by or under this or any other Act or law.

(2) Any money paid into the Fund on the condition that is to be used only for a specified purpose, including any proceeds of the investment of that money in the Fund, is only payable from the Fund for the specified purpose and a proportionate share of the administrative expenses payable from the Fund.

(3) The Minister is to produce an Annual Report detailing fund allocations and the projects and other activities that received funding under this Act during the year.

(4) The Annual Report is to include an evaluation of the effectiveness of each of the projects and other activities that received funding under this Act.

(5) The Annual Report is to be tabled in each House of Parliament within 6 months after the end of the financial year to which it relates.

(6) The Minister is to publish each Annual Report, so as to promote low emissions coal technologies to the NSW public.

Section 10 of the Act, prescribes the Membership of CINSW, as follows:

(1) CINSW is to consist of the following members appointed by the Minister:

  (a) an independent person appointed by the Minister to be the Chairperson of CINSW,

  (b) two persons, each of whom is employed in or by a government agency,

  (c) two persons who are nominated jointly by the Australian Coal Association and the Minerals Council to represent the New South Wales black coal industry,

  (d) such other persons (up to a maximum of 4) as the Minister may appoint from time to time, being persons whom the Minister considers have qualifications or experience relevant to the functions of CINSW.

Section 11 of the Act establishes Coal Innovation NSW (CINSW) and prescribes its functions.

(1) The functions of CINSW are as follows:

(a) to give advice and make recommendations to the Minister concerning the funding from the Fund of projects and other activities for the purposes of the Fund, including advice about priorities for funding and recommendations concerning applications for funding,

(b) to advise the Minister on policies to encourage the development and implementation of low emissions coal technologies,

(c) to make recommendations to the Minister concerning opportunities for involvement by private and public sector entities in interstate, national and international research projects involving low emissions coal technologies,

(d) to advise the Minister on such other matters concerning low emissions coal technologies as the Minister may refer to the CINSW,

(e) such other functions with respect to low emissions coal technologies as the Minister may from time to time direct.

(2) CINSW may give its advice and make its recommendations either at the request of the Minister or without any such request.

(3) CINSW has such other functions as are conferred or imposed on it by or under this or any other Act.

Appendix B. Audited financial report for Coal Innovation NSW 2019/20

Coal Innovation Fund

Financial Report

for the year ended 30 June 2020

TABLE OF CONTENTS

Coal Innovation Fund Statement of net assets
Statement of the Deputy Secretary

for the year ended 30 June 2020

I declare, on behalf of the Coal Innovation Fund (the Fund) that in my opinion:

1. The accompanying financial report provides details of the transactions of the Fund for the year ended 30 June 2020;
2. The financial report has been prepared as a special purpose financial report in accordance with the basis of preparation described in Note 1(b); and
3. The accompanying financial report exhibits a true and fair view of the net assets of the Fund as at 30 June 2020 and of its income and expenditure for the year ended on that date.

Further, I am not aware of any circumstances which would render any particulars included in the financial report to be misleading or inaccurate.

Michael Wright
Deputy Secretary, Mining, Exploration and Geoscience
Department of Regional NSW

Date: 23 October 2020

Coal Innovation Fund Statement of net assets
Statement of the Deputy Secretary
as at 30 June 2020

	Notes	Actual 2020 $'000	Actual 2019 $'000
Revenue			
Interest revenue	1(e)	510	1,197
Other revenue		-	4
Total revenue		**510**	**1,201**
Expenses			
Auditor's remuneration - audit of financial report		27	27
Research and development grants		3,681	5,173
Other contractors and professional expenses	1(c)	304	437
Salaries and wages (including recreation leave)		430	432
Superannuation		37	42
Payroll tax and fringe benefits tax		25	27
Other operating expense		23	26
Travel		4	7
Administration fees		1	2
Training and staff development		3	2
Telecommunication		1	-
Motor vehicle		1	-
Total expenses		**4,537**	**6,175**
Net result		**(4,027)**	**(4,974)**

The accompanying notes form part of the financial report.

Coal Innovation Fund Statement of net assets
Statement of the Deputy Secretary
as at 30 June 2020

	Actual 2020 $'000	Actual 2019 $'000
ASSETS		
Current assets		
Cash and cash equivalents	72,454	76,535
Department of Planning and Environment	-	41
GST receivable	66	151
Total current assets	**72,520**	**76,727**
Total assets	**72,520**	**76,727**
LIABILITIES		
Current liabilities		
Creditors	720	1,662
Department of Regional NSW	761	-
Total current liabilities	**1,481**	**1,662**
Total liabilities	**1,481**	**1,662**
Net assets	**71,039**	**75,065**

The accompanying notes form part of the financial report.

Coal Innovation Fund Statement of net assets
Statement of the Deputy Secretary
as at 30 June 2020

1. Summary of significant accounting policies

(a) Reporting entity

The Coal Innovation NSW Fund (the Fund) is a not-for-profit fund (as profit is not its principal objective) and the Fund does not have a cash generating unit.

The Fund has been established and is governed under the *Coal Innovation Administration Act 2008 (the Act)*. Part 2 Section 4 of the Act establishes the Fund as a special deposits account.

The financial report has been prepared on the basis that the Fund is not a reporting entity under the Australian Accounting Standards. The financial report for the Fund is therefore a special purpose financial report with the financial period being from 1 July 2019 to 30 June 2020.

This financial report for the year ended 30 June 2020 has been authorised for issue by the Deputy Secretary, Division of Mining, Exploration and Geoscience, Department of Regional NSW, on the date the accompanying Statement by the Deputy Secretary was signed.

Key activities

Part 2 Section 5 of the Act establishes the purpose of the Fund as follows:

a) to provide funding for research into, and development of low emissions coal technologies,
b) to provide funding to demonstrate low emissions coal technologies,
c) to provide funding to increase public awareness and acceptance of the importance of reducing greenhouse gas emissions through the use of low emissions coal technologies, and
d) to provide funding for the commercialisation of low emissions coal technologies.

Funding sources for the Fund

Part 2 Section 6 of the Act states that:

1) There is payable into the Fund:
a) all money advanced by the Treasurer to the Fund, and
b) all money appropriated by the Parliament for the purposes of the Fund, and
c) the proceeds of the investment of money in the Fund, and
d) all money directed or authorised to be paid into the Fund by or under this or any other Act or law, and
e) all money received for voluntary contributions to the Fund made by any person or body.
2) A voluntary contribution to the Fund may be made on the condition that the contribution is to be used only for a specified purpose.

Payments out of the Fund

Part 2 Section 7 of the Act states that:

1) There is payable from the Fund:
a) payments approved by the Minister for the purpose of the Fund, and
b) administrative expenses incurred in relation to the Fund or Coal Innovation NSW (CINSW), and
c) payments directed or authorised to be paid from the Fund by or under this or any other Act or law.

2) Any money paid into the Fund on the condition that it is to be used only for a specified purpose, including any proceeds of the investment of that money in the Fund, is only payable from the Fund for the specified purpose and a proportionate share of the administrative expenses payable from the Fund.

Under the Administrative Arrangements (Administrative Changes – Public Service Agencies) Order 2019, dated 2 April 2019, the Department of Planning and Environment (DPE) was abolished with effect from 1 July 2019 and its status as an employing and a reporting entity ceased. DPE's functions were transferred to the newly formed Department of Planning, Industry and Environment (DPIE). Subsequently, under the Administrative Arrangements (Administrative Changes – Regional NSW and Independent Planning Commission) Order 2020, dated 2 April 2020, person employed in the Regions, Industry Agriculture and Resources Group in DPIE were transferred to Department of Regional NSW. These administrative changes will have no financial impact other than the transfer of staff allocated to administer the Fund's activities being transferred to new Departments.

1. Summary of significant accounting policies (cont'd)

(b) Basis of preparation

This financial report is a special purpose financial report that has been prepared in order to account for the transactions of the Fund under the Act.

This financial report has been prepared in accordance with the significant accounting policies disclosed below. Such accounting policies are consistent with the previous period unless stated otherwise.

The statement of net assets and the statement of income and expenditure have been prepared on an accruals basis and based on historic costs and do not take into account changing money values or, except where specifically stated, current valuations of non-current assets.

All amounts are rounded to the nearest one thousand dollars and are expressed in Australian currency.

(c) Research and development expenses (Contractors and Professional expenses)

The Fund engages contractors to conduct work for site preparation, drilling, engineering, project management research activities and peer review of research results. This activity is classified as in the research phase for the project and no expenses have been capitalised. An asset will not be recognised until clear and quantifiable future benefit is established. However, there is acknowledgement that any grant is from the Fund and any future economic benefits (assets) arising out of it may belong to NSW Government and/or the research partner.

The Fund engaged Deloitte Access Economics to undertake a cost-benefit analysis of CO_2 storage for NSW this financial year.

(d) Accounting for the Goods and Services Tax (GST)

Income, expenses and assets are recognised net of the amount of GST, except that the:

- amount of GST incurred by the Fund as a purchaser that is not recoverable from the Australian Taxation Office is recognised as part of an asset's cost of acquisition or as part of an item of expense and
- receivables and payables are stated with the amount of GST included.

(e) Income recognition

Income is measured at the fair value of the consideration or contribution received or receivable. Additional comments regarding the accounting policies for the recognition of income are discussed below.

Interest Revenue

Interest income is recognised using the effective interest rate method. The effective interest rate is the rate that exactly discounts the estimated future cash receipts over the expected life of the financial instrument or a shorter period, where appropriate, to the net carrying amount of the financial asset.

(f) Receivables

Trade receivables and other receivables that have fixed or determinable payments that are not quoted in an active market are classified as receivables. Receivables are measured at amortised cost using the effective interest method, less any impairment. Changes are recognised in the net result for the year when impaired, derecognised or though the amortisation process.

Short-term receivables with no stated interest rate are measured at the original invoice amount unless the effect of discounting is material.

1. Summary of significant accounting policies (cont'd)

(g) Payables

Payables represent liabilities for goods and services provided to the Fund and other amounts. Short-term payables with no stated interest rate are measured at the original invoice amount where the effect of discounting is immaterial.

(h) Personnel services

The Fund does not have any employees and received administrative, secretarial support and operational assistance from DPIE and DRNSW during the year. The Fund had an arrangement with the Departments to reimburse the Departments for personnel services expenses and other costs incurred on behalf of the Fund.

2. Cash receipts and payments

	Actual 2020 $'000	Actual 2019 $'000
Opening cash balance	**76,535**	**82,164**
Cash receipts:		
The Fund is authorised to receive amounts in accordance with Section 6 of the Act.		
(1) (a) the proceeds of the investment of money in the Fund	510	1,196
(b) all money directed or authorised to be paid into the Fund by or under this or any other Act or Law		4
BAS receipt	476	329
Cash payments:		
Payments from the Fund are in accordance with Section 7 of the Act.		
(1) (a) payments approved by the Minister for the purpose of the Fund	(3,680)	(5,610)
(b) administrative expenses incurred in relation to the Fund or CINSW	(1,387)	(1,548)
Closing cash balance	**72,454**	**76,535**

3. Events after the reporting period

As at 30 June 2020, the Fund assessed the impact of COVID-19 on the fair value of its financial assets. This was based on historical sales information, expectation of macroeconomic conditions and outlook at the time of assessment. Given continued uncertainty of the COVID-19 factor, it is possible that post 30 June 2020 there may be some new evidence that impacts this fair value assessment materially.

There are no other known events that would impact on the state of affairs of the Fund or have a material impact on the financial statements.

End of audited financial report.