Australia's National
Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Project Order

Short Project Title

Review of beneficial reuse and end-use options for brine

Long Project Title	Review of beneficial reuse or end-use options for brine from the Narrabri Gas Project (NGP) region
GISERA Project Number	W.32
Start Date	01/02/2023
End Date	29/02/2024
Project Leader	Prashant Srivastava

GISERA State/Territory

- ☐ Queensland
- ☒ **New South Wales**
- ☐ Northern Territory
- ☐ South Australia
- ☐ Western Australia
- ☐ Victoria
- ☐ National scale project

Basin(s)

- ☐ Adavale
- ☐ Amadeus
- ☐ Beetaloo
- ☐ Canning
- ☐ Western Australia
- ☐ Carnarvon
- ☐ Clarence-Morton
- ☐ Cooper
- ☐ Eromanga
- ☐ Galilee
- ☐ Gippsland
- ☐ Gloucester
- ☒ **Gunnedah**
- ☐ Maryborough
- ☐ McArthur
- ☐ North Bowen
- ☐ Otway
- ☐ Perth
- ☐ South Nicholson
- ☐ Surat
- ☐ Other (please specify)

GISERA Research Program

- ☒ **Water Research**
- ☐ Health Research
- ☐ Biodiversity Research
- ☐ Social & Economic Research
- ☐ Greenhouse Gas Research
- ☐ Agriculture Research
- ☐ Land and Infrastructure Management Research
- ☐ Other (please specify)

1. Project Summary

The Narrabri Gas Project (NGP) was granted development consent by the NSW government in 2020. The project will lead to the large volumes of saline 'produced water' requiring treatment for beneficial reuse of the water, such as irrigation, livestock watering and dust suppression etc. Treatment of produced water by a reverse osmosis (RO) water treatment facility will generate a large volume of brine by-product. The NGP and associated activities/processes including the production of produced water and brine have been a cause for concern in the local community. Development conditions for the management of produced water include maximising the beneficial reuse of brine and salt and disposing of salt that cannot be beneficially reused or other end-use options. This is in addition to community concerns relating to the potential environmental impacts of highly saline produced water and brine. To address the community concerns, all the potential options for management of brine need to be evaluated appropriately and presented to stakeholders.

This project aims to review beneficial reuse or end-use options for brine from the NGP region. The project objectives are to:

1. Collate existing data and knowledge on brine in the NGP region;

2. Undertake a review of existing and emerging innovative technologies and solutions for beneficial reuse or end-use options for brine;

3. Conduct techno-socio-economic analysis (identify pros and cons) for the options identified in objectives 1 and 2 above; and

4. Communicate and engage with key stakeholders about the beneficial reuse or end-use options for brine.

2. Project description

Introduction

Santos has been granted approval to extract coal seam gas (CSG) from the Narrabri region in NSW located in the Gunnedah Basin. Exploratory and appraisal wells will produce highly saline 'produced water' requiring treatment through a reverse osmosis (RO) process, which is highly effective in removing salt from solutions with up to 99% reduction in total dissolved solids (TDS) concentrations. The RO treatment includes forcing solution under pressure through a membrane to remove ions from the solution with the formation of a purified permeate solution and a concentrate solution, or brine,

containing the membrane-rejected salts. The waste brine can vary in concentrations/composition of salts, metals, TDS, and other contaminants that will influence its reuse and other end-use options, which are socially, environmentally and economically acceptable. The NGP and the associated activities/processes including the generation of large quantities of brine as a result of CSG extraction activities have been a cause for concern in the local community.

Previous research found that perceptions of community resilience to CSG development in the Narrabri and the surrounding region were relatively low - 60% of respondents indicating they believed their community would adapt or transform into something better (Walton et al., 2018). To help maintain the well-being and function of communities, it is important to provide impacted communities with information on the environmental impacts associated with gas extraction. Therefore, a thorough assessment including the pros and cons of all potential options for the management of brine needs to be conducted and shared with the community.

The brine produced through the RO process can be diverted to storage ponds, concentrated via passive evaporation through to salt crystallisers or enhanced evaporation systems, which require additional energy inputs. Brine can be used as a feedstock for chemical production, such as sodium hydroxide. The concentration of brine to produce salt containing minimal to no liquid can make it considerably easier for beneficial reuse opportunities arising from a solid salt material. The primary salts present in produced water include sodium bicarbonate ($NaHCO_3$), sodium carbonate (Na_2CO_3) and sodium chloride (NaCl) and each of these can be used for a range of industrial applications, such as the production of glass, detergents, animal feeds and sodium hydroxide through to mine site rehabilitation (Hayes, 2020).

The Development Consent for the NGP published by the Independent Planning Commission of NSW has a preference for undertaking beneficial reuse options where this is feasible, although the disposal of brine or salts produced from brines is also an (undesirable) option as long as this meets regulatory requirements, such as using suitably licenced waste management facilities (NSW DPIE, 2020). Ultimately, the extent of beneficial reuse for brine or salt needs to consider a range of factors to examine the feasibility of the proposed options, such as technical, economic, social, environmental and safety factors.

Prior Research

The use, disposal, and reuse of water associated with oil and gas (O&G) production has been a topic of interest to O&G operators, regulators, water users, and researchers for decades. A number of reviews have been undertaken to assess various options for brine/salt management, that have highlighted both beneficial reuse and disposal options.

Previous studies have also considered the beneficial reuse and disposal of CSG brines in Australia, with a number of technically viable options identified (APPEA 2018, Hayes 2020, Khan and Kordek 2014, Ly 2013).

Beneficial reuse options for brine include:

- Selective salt recovery (SSR) of high purity salts (Na_2CO_3, $NaHCO_3$, NaCl) for industrial applications
- High-value algae cultivation
- Acid mine drainage neutralisation
- Recovery of critical raw minerals (e.g., Ca, Mg and K)
- Mining of precious and other important metals (e.g., Li, Rb, In, Ga, Sc, V, Cs)
- Harvesting energy (e.g., osmotic power or blue energy or salinity gradient power)

Since these recent assessments of brine management, it is likely that some of the options that were previously not considered commercially viable have become feasible in the last 12 months. For example, carbonates can be used for renewable energy storage or synthetic production of nitrates for renewable energy heat transfer applications (Geyer et al. 2022, Bell et al. 2019). Natural sources of nitrates and other elements critical in the manufacturing of goods are concentrated in other countries and sovereignty over resources has become an increasingly important issue. In addition, there is a general policy push towards including circular economy issues in all areas of the economy and management of wastes, which is likely to increase the feasibility of beneficial reuse options.

Need & Scope

There is increasing interest from O&G stakeholders in beneficial end-use or reuse options for brines due to their large production volumes that can be difficult to treat and manage in a cost-efficient and sustainable manner. Brine waste reuse and recycling strategies can provide several benefits, such as reducing wastewater discharge volumes or allowing facilities to increase production volumes while staying within discharge permit limitations. Additionally, some facilities have seen net cost savings by supplementing freshwater demand with waste brine, especially in regions where access to source water may be costly and unreliable.

The production of brine from water purification must meet the environmental, social, and economic needs of the projects and therefore must ensure community concerns are addressed, environmental harm is minimised, and technical and economic feasibility is achieved. A range of available options are available for brine management. For example, salt encapsulation represents an environmentally sound option that also addresses many community concerns. Salt encapsulation, however, requires considerable capital for setting up and ongoing maintenance of storage areas is considerable relative to other options.

Objective

The aim of this project is to review beneficial reuse or end-use options for brine from the NGP region. The project objectives are to:

1. Collate existing data and knowledge on brine and salt management in the NGP region;
2. Undertake a review of existing and emerging innovative technologies and solutions for beneficial reuse or end-use options for brine;
3. Conduct techno-socio-economic analysis (identify pros and cons) for the options identified in the objectives 1 and 2 above; and
4. Communicate and engage with key stakeholders about the beneficial reuse or end-use options for brine.

Methods

Task 1 of this project will collate all relevant literature relating to brine and salt management in the NGP. Relevant information relating to technical, regulatory, economic, social and environmental aspects of brine reuse will be considered. In addition, an assessment of existing and emerging technological innovations that can be applied to brine or salt for future management strategies, particularly in the context of the identified salt composition expected to be produced in the NGP. This will be undertaken in consultation with national and international brine treatment organisations, such as Hydroflux Pty Ltd (Australia), ThyssenKrupp Uhde GmbH (Germany), Salttech (The Netherlands), Memsift Innovations Pte Ltd (Singapore), and Thermosift Engineering Pvt Ltd (India).

Task 2 will be to conduct techno-socio-economic analysis of identified promising technology/management interventions/options for the beneficial reuse or end-use options for brine from the NGP region. This will involve an assessment of technical merits and demerits of each identified option. In addition, the social and economic impact of each option will be evaluated.

Task 3 will involve communication and engagement with selected local stakeholders. The project will undertake three workshops to inform and engage key community stakeholders to understand their perspectives and priorities in relation to produced water and brine. These insights will be used to inform the technical, social and economic assessments of each potential brine beneficial reuse or end-use option.

A short virtual workshop will take place at the beginning of the project (within the first 2 months), to inform selected community stakeholders of the project aim, scope, methods, timing and expected outcomes, and engage with stakeholders around their perceived information and communication needs. A second and longer workshop will discuss the proposed technical, social and economic

frameworks that will be used to evaluate each of the potential brine beneficial reuse or end-use options. This workshop will be undertaken within the first six months of the project and the feedback from stakeholders used to refine the technical, social and economic assessment frameworks.

A third and final workshop with key community stakeholders will then be organised at project completion – with the aim of a face-to-face session if possible (a virtual option can be included as an alternative). This workshop will cover the communication of project outcomes and key messages, with engagement and discussion around any ongoing or future work.

The key community stakeholders would typically comprise representatives from peak agricultural and farming bodies, regional Landcare groups, local government, relevant local leaders or community members, and local Indigenous perspectives.

Task 4 will include communication across the duration of the project via progress reports, factsheets, final reporting, presentations and research papers. A Knowledge Transfer Session involving government and industry representatives will also be held prior to project completion.

3. Project Inputs

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principal area of expertise	Years of experience	Organisation
Dr Prashant Srivastava	90 days	Soil and water chemistry, risk assessment and remediation	>20	CSIRO Environment
Dr Mike Williams	20 days	Soil and water chemistry, risk assessment and remediation	>15	CSIRO Environment
Dr Anu Kumar	20 days	Water chemistry, risk assessment and remediation	>25	CSIRO Environment
Dr Andrea Walton	5 days	Socio-economic analysis	>20	CSIRO Environment
Dr Rod McCrea	35 days	Socio-economic analysis	>20	CSIRO Environment
Dr Nawshad Haque	5 days	Techno-economic analysis	>20	CSIRO Energy
Timothy Lai	25 days	Techno-economic analysis	>2	CSIRO Energy

Subcontractors (clause 9.5(a)(i))	Time Commitment (project as a whole)	Principal area of expertise	Years of experience	Organisation
N/A				

Budget Summary

Source of Cash Contributions	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
GISERA	$59,694	$185,604	$0	$0	76%	$245,298
- Federal Government	$44,771	$139,203	$0	$0	57%	$183,974
- NSW Government	$10,996	$34,190	$0	$0	14%	$45,187
- Santos	$3,927	$12,211	$0	$0	5%	$16,138
Total Cash Contributions	**$59,694**	**$185,604**	**$0**	**$0**	**76%**	**$245,298**

Source of In-Kind Contribution	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
CSIRO	$18,851	$58,612	$0	$0	24%	$77,463
Total In-Kind Contribution	**$18,851**	**$58,612**	**$0**	**$0**	**24%**	**$77,463**

TOTAL PROJECT BUDGET	2022/23	2023/24	2024/25	2025/26	-	TOTAL
All contributions	**$78,545**	**$244,216**	**$0**	**$0**	**-**	**$322,761**
TOTAL PROJECT BUDGET	**$78,545**	**$244,216**	**$0**	**$0**	**-**	**$322,761**

4. Communications Plan

Stakeholder	**Objective**	**Channel** (e.g., meetings/media/factsheets)	**Timeframe** (Before, during at completion)
Regional community stakeholders / wider public including landholders and traditional owners	To communicate project objectives and key messages from the research	A fact sheet at the commencement of the project explaining in plain English the objective of the project. Project progress report on the GISERA website to ensure transparency for all stakeholders including regional communities. Virtual workshop with key community stakeholders (e.g., representatives from peak agricultural and farming bodies, regional Landcare groups, local government, relevant local leaders, community members, and local Indigenous representatives.), to explain the project objectives and key messages and to receive feedback and to understand their concerns and interests. A second and longer workshop to discuss proposed technical, social and economic frameworks being used to evaluate each of the potential brine beneficial reuse or end-use options. The feedback from stakeholders will be used to refine the technical, social and economic assessment frameworks. Presentation of research findings to regional community stakeholders as above to present of research results.	At the commencement of the project Ongoing Within 2 months of the commencement of project Within the first six months of the project At completion of project.
Gas Industry	Industry adopts methods for improving understanding of the options for brine beneficial reuse or end-use	Fact sheet and project report Presentation of findings at joint Gas Industry/Government Knowledge Transfer Session	At project completion
Government	The advice provided to senior bureaucrats / ministers / policymakers	Fact sheet and project report Presentation of findings at joint Gas Industry/Government Knowledge Transfer Session	At project completion

Stakeholder	**Objective**	**Channel** (e.g., meetings/media/factsheets)	**Timeframe** (Before, during at completion)
Regional community/wider public, government, scientific community and industry	To report on key findings	Public release of the final report Plain English factsheet summarising the outcomes of the research. Preparation of article for GISERA newsletter and other media outlets as advised by GISERA's communication team	At project completion At project completion
Scientific Community	Provide scientific insight into the latest opportunities for brine and salt management	Manuscripts for submission to journals Conference presentations	At project completion

In addition to project-specific communications activities, GISERA has a broader communications strategy. This strategy incorporates activities such as webinars, roadshows, newsletters and the development of other communications products.

5. Project Impact Pathway

Activities	Outputs	Short term Outcomes	Long term outcomes	Impact
Review of literature and existing and emerging innovative technologies and solutions for beneficial reuse or end-use options for brine	A review of and potential approaches to brine or salt beneficial reuse and end-use, applicable to the NGP. Scientific journals will also be reviewed to find technologies for brine and salt management that may not have been previously considered. A review of existing and emerging innovative technologies and solutions for beneficial reuse or end-use options for brine will be undertaken.	Greater awareness of beneficial reuse or end-use options for brine from the NGP region Satisfied and confident stakeholders	This project will assist the stakeholders in the decision-making with respect to the beneficial reuse or end-use options for brine from the NGP. A cost-effective, socially acceptable and environmentally-friendly solution to the brine issue. Satisfied and confident stakeholders	Environmental impacts: • Reduction of salt entering the environment Social impacts: • Community confidence in appropriate reuse options for a waste product • Providing opportunities for employment in beneficial reuse Economic impacts: • Cost-effective solution • Ongoing savings or profits from brine
Techno-socio-economic analysis	A techno-socio-economic assessment of identified options for brine reuse and end-use will be undertaken.			
Information sharing with the community stakeholders	Three workshops will be organised to inform and engage key community stakeholders to understand their perspectives and priorities in relation to produced water and brine, and to communicate project outcomes.			
Communication	• GISERA Communications will develop a plain English factsheet at project commencement. • Completed fact sheet(s) with key findings for distribution via the GISERA website and at community engagement events. • Final report with detailed outcomes will be prepared. • Manuscripts will be prepared for submission to scientific journals.			

6. Project Plan

Project Schedule

ID	Activities / Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Review of literature and existing and emerging innovative technologies and solutions for beneficial reuse or end-use options for brine	Prashant Srivastava	February 2023	August 2023	-
Task 2	Techno-socio-economic analysis	Prashant Srivastava	September 2023	November 2023	Tasks 1, 2
Task 3	Communication and engagement with selected local stakeholders	Prashant Srivastava	February 2023	February 2024	Tasks 1, 2, 3
Task 4	Communication and reporting	Prashant Srivastava	February 2023	February 2024	Tasks 1, 2, 3

Task description

Task 1: Review of literature and existing and emerging innovative technologies and solutions for beneficial reuse or end-use options for brine

OVERALL TIMEFRAME: February 2023 – August 2023

BACKGROUND: Task 1 will involve a detailed review of literature and existing and emerging approaches to beneficial reuse and end-use of brine, which could be applicable to the NGP. A wide range of literature including publicly accessible reports and web-based resources related to CSG extraction in Australia or globally will be reviewed. Scientific journals will also be reviewed to find potential options for brine reuse and end-use, and salt management that may not have been previously considered.

TASK OBJECTIVES:

1) Review previous work as published in reports, journals, and web-based resources; and
2) Use this information to inform Tasks 2, 3 and 4.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: A draft report that comprehensively reviews previous work will be prepared. This information will feed into later tasks and the results will be discussed in detail in the final report.

Task 2: Techno-socio-economic analysis

OVERALL TIMEFRAME: September 2023 – November 2023

BACKGROUND: A techno-socio-economic analysis (pros and cons) of identified technology/management interventions/options for the beneficial reuse or end-use options for brine from the NGP region will be conducted. This will involve an assessment of technical merits and demerits of each identified option. In addition, the social and economic impact of each option will be evaluated.

TASK OBJECTIVES: The objectives of the project report will be to:

1) Provide an overview of technical merits and demerits of current and emerging technologies
2) Conduct techno-socio-economic assessment (pros and cons) of identified technology/management interventions/options

TASK OUTPUTS AND SPECIFIC DELIVERABLES: A draft report detailing the techno-socio-economic assessment of identified technology/management interventions/options; that will feed into the final report.

Task 3: Communication and engagement with selected local stakeholders

OVERALL TIMEFRAME: February 2023 – February 2024

BACKGROUND: Three workshops will be organised to inform and engage key community stakeholders to understand their perspectives and priorities in relation to produced water and brine.

TASK OBJECTIVES:

- First workshop aims at informing selected community stakeholders of the project aim, scope, methods, timing and expected outcomes, and engaging with stakeholders around their perceived information and communication needs.
- Second workshop will discuss and refine the proposed technical, social and economic frameworks that will be used to evaluate each of the potential brine beneficial reuse or end-use options.
- Third workshop will communicate project outcomes and key messages.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: The feedback from the workshops will be considered and incorporated into the final report.

Task 4: Communicate project objectives, progress and findings

OVERALL TIMEFRAME: Full duration of project (February 2023 – February 2024)

BACKGROUND: Communications of GISERA research are an important component of outreach and dissemination of findings to diverse audiences.

TASK OBJECTIVES: Communicate project objectives, progress and findings via factsheet(s), reports, presentations and journal article(s), in consultation with GISERA Communications officers. A knowledge transfer session will be organised with key stakeholders at the completion of the project.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Communicate project objectives, progress and results to GISERA stakeholders according to standard GISERA project procedures which may include, but not limited to:

1) Knowledge Transfer session with Government/Gas Industry.
2) Two project factsheets: A factsheet, hosted on the GISERA website, will be developed at the commencement of the project, and another that will include peer-reviewed results and implications will be developed at completion of the project.
3) A quarterly report.
4) A consolidated report (from tasks 1, 2 and 3) outlining the scope, methods, findings and any suggestions/options for future research.

5) Following CSIRO ePublish review, the consolidated report will be submitted to the GISERA Director for final approval.
6) Following CSIRO ePublish review, a manuscript based on the report will be submitted to an appropriate journal.

Project Gantt Chart

		2022/23					2023/24							
Task	**Task Description**	**Feb 23**	**Mar 23**	**Apr 23**	**May 23**	**Jun 23**	**Jul 23**	**Aug 23**	**Sep 23**	**Oct 23**	**Nov 23**	**Dec 23**	**Jan 24**	**Feb 24**
1	Review of literature and existing and emerging innovative technologies and solutions for beneficial reuse or end-use options for brine													
2	Techno-socio-economic analysis													
3	Communication and engagement with selected local stakeholders													
4	Communication and reporting													

7. Budget Summary

Expenditure	2022/23	2023/24	2024/25	2025/26	Total
Labour	$69,545	$226,216	$0	$0	$295,761
Operating	$9,000	$18,000	$0	$0	$27,000
Subcontractors	$0	$0	$0	$0	$0
Total Expenditure	**$78,545**	**$244,216**	**$0**	**$0**	**$322,761**

Expenditure per task	2022/23	2023/24	2024/25	2025/26	Total
Task 1	$64,933	$48,023	$0	$0	$112,956
Task 2	$0	$140,069	$0	$0	$140,069
Task 3	$0	$28,340	$0	$0	$28,340
Task 4	$13,612	$27,784	$0	$0	$41,396
Total Expenditure	**$78,545**	**$244,216**	**$0**	**$0**	**$322,761**

Source of Cash Contributions	2022/23	2023/24	2024/25	2025/26	Total
Federal Govt (57%)	$44,771	$139,203	$0	$0	$183,974
NSW Govt (14%)	$10,996	$34,190			$45,187
Santos (5%)	$3,927	$12,211	$0	$0	$16,138
Total Cash Contributions	**$59,694**	**$185,604**	**$0**	**$0**	**$245,298**

In-Kind Contributions	2022/23	2023/24	2024/25	2025/26	Total
CSIRO (24%)	$18,851	$58,612	$0	$0	$77,463
Total In-Kind Contributions	**$18,851**	**$58,612**	**$0**	**$0**	**$77,463**

	Total funding over all years	Percentage of Total Budget
Federal Government investment	$183,974	57%
NSW Government investment	$45,187	14%
Santos investment	$16,138	8%
CSIRO investment	$77,463	24%
Total Expenditure	**$322,761**	**100%**

Task	Milestone Number	Milestone Description	Funded by	Start Date (mm-yy)	Delivery Date (mm-yy)	Fiscal Year Completed	Payment $ (excluding CSIRO contribution)
Task 1	1.1	Review of literature and existing and emerging innovative technologies and solutions for beneficial reuse or end-use options for brine	GISERA	Feb-23	Aug-23	2022/2023	$85,847
Task 2	2.1	Techno-socio-economic analysis	GISERA	Sep-23	Nov-23	2023/2024	$106,452
Task 3	3.1	Communication and engagement with selected local stakeholders	GISERA	Feb-23	Feb-24	2023/2024	$21,538
Task 4	4.1	Communication and reporting	GISERA	Feb-23	Feb-24	2023/2024	$31,461

8. Intellectual Property and Confidentiality

Background IP (clause 11.1, 11.2)	**Party**	**Description of Background IP**	**Restrictions on use (if any)**	**Value**
				$
				$
Ownership of Non-Derivative IP (clause 12.3)	CSIRO			
Confidentiality of Project Results (clause 15.6)	Project Results are not confidential.			
Additional Commercialisation requirements (clause 13.1)	Not Applicable			
Distribution of Commercialisation Income (clause 13.4)	Not Applicable			
Commercialisation Interest (clause 13.1)	**Party**		**Commercialisation Interest**	
	CSIRO		Not Applicable	

9. References

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