GISERA
Gas Industry Social and Environmental Research Alliance

Project Order

Proforma 2021

1. Short Project Title

Methane emissions quantification of well drilling to completion processes in Beetaloo sub-basin

Long Project Title	Quantification of fugitive methane emissions related to well drilling to completion processes in the Beetaloo sub-basin, with an emphasis on the current stage of activities.
GISERA Project Number	G8
Start Date	01/04/2021
End Date	30/06/2023
Project Leader	Cindy Ong

2. GISERA State/Territory

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

3. Basin(s)

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

4. GISERA Research Program

- ☐ Water Research
- ☒ Greenhouse Gas Research
- ☐ Social & Economic Research
- ☐ Biodiversity Research
- ☐ Health Research
- ☐ Agricultural Land Management Research
- ☐ Other

5. Project Summary

Objective

The objective of this research is to:

a) quantify the fugitive methane emissions from well construction and completion activities (including well drilling, hydraulic fracturing, stimulation and completion) from unconventional shale petroleum exploration in the Beetaloo sub-basin by conducting long-term continuous monitoring at well sites.

b) Compare actual measured results with estimated results to verify the adequacy of existing calculated emission estimates. This is a unique opportunity to capture industry operations while they are underway and accurately determine the level of fugitive methane emissions associated with well construction and completions. The actual use case will be emissions related to well construction operations (from well drilling to well completion), which as they are undertaken during the current stage of gas exploration in the Beetaloo sub-basin.

c) An additional outcome of the project is demonstration of the use of autonomous emission monitoring stations[1] (AEMS) to continuously measure the emissions related to natural gas activities and infrastructure and other background sources of methane and, recommendations for the most appropriate technologies balancing the technical requirements and cost. The benefit of AEMS will enable ongoing monitoring in the Beetaloo sub-basin in an accurate and cost-effective manner. Hence, additional work will be conducted in this project to determine the optimal number of AEMS needed to provide representative sampling of the gas activities and infrastructure across the sub-basin and elsewhere in the NT. This appraisal will include the different emission sources that may be encountered and, investigate the most cost-effective solutions to be employed and, whether the deployment of a network of AEMS is practical.

Description

Fugitive methane emissions from unconventional shale well drilling and completion has continued to be a main focal point for a number of interested stakeholders. Providing evidence-based data on the fugitive emission levels during unconventional shale development activities is crucial for understanding the impacts of industry's operations broadly. Importantly, understanding whether current emission estimation calculations align with actual emission levels is required to ensure that estimates of emission levels of onshore gas developments are accurate. An important secondary goal is to develop approaches to detect unplanned emission in a timely manner to mitigate significant elevation of the methane emission intensity of the region. Moreover, it is known that emissions may vary significantly over time due to changing operating activities and conditions and other factors. Hence, continuous monitoring provides a means to capture these changes in emission profiles.

A potentially effective way of obtaining these data is to collect measurements via autonomous emissions monitoring stations (AEMS) such as the one shown on Figure 1 which, provides continuous concentration measurements in real-

[1] AEMS is a generic term used to describe monitoring systems/packages that automates the collection of gas concentration data.

time. However, as there could potentially be quite a number of wells being drilled, some important questions need to be answered. These include:

1) The numbers and locations of AEMS that would allow for representative measurements of the region with sufficient accuracy to inform decision making. In addition, there are options of the more traditional permanent fixed AEMS or mobile AEMS deployed on a rotational basis. The value of these options will be evaluated;

2) The optimal combination of technologies to meet the technical and challenging operating environments in a cost effective manner; and

3) If numerous AEMS are deployed, then they will have to be operated as a network effectively. Therefore, a good understanding of the potential maintenance requirements and costs of maintaining such autonomous networks will be beneficial.

The answers to these questions will help inform further decisions if such autonomous networks will be operationally viable options or if alternative means such as the more traditional estimations coupled with screening and validation of the estimations are sufficient.

Figure 1: An autonomous emission monitoring station (AEMS) developed by CSIRO Energy. This photograph shows a recent trial at an industry site in the Beetaloo sub-basin. A drill rig can be seen in the background.

This project will consist of two parts. The first part will address the urgent need to collect methane concentration and flux data to quantify fugitive methane emissions from drilling and completion operations, particularly given that some stages of operations (such as the flowback stage) identified from overseas research suggest that there could be significant sources of emissions (Howarth, Santoro et al. 2011). This part of the project is time critical as future drilling and completion activities are planned in March/April 2021. If this window of opportunity is missed a unique set of Australian measurements will not be possible until potentially 2022+.

In this first part, to ensure that we capture the opportunity, we propose to start the project by careful manual tracer (the 'gold standard') flux measurements (Feitz, Schroder et al. 2018) accompanied by the deployment of the current AEMS (AEMS-C) developed by CSIRO (shown on Figure 1) at two newly proposed well sites (which will be agreed through consultation with industry and NT Government).

Although the use of manual methods are sufficient in the short term, the deployment of AEMS that can replicate the 'gold standard' and provide continuous flux measurements for an extended period of time is useful for comprehensively collecting measurements at these sites because 1) a time series over an extended period would be advantageous for assessing the impacts of gas operations and, 2) the drilling and completions process is usually over a longer period than manual methods can be sustained making continuous manual sampling challenging and cost prohibitive. Therefore, an extension of AEMS-C to include flux measurement capabilities (automating the 'gold standard' manual measurements) is planned for the project. These extended AEMS (AEMS-CF) is expected to be completed in 6 months[2] (for the first and a second to follow 6 weeks later), after which, they will replace the AEMS-C in the field.

The manual measurements and the AEMS-CF (which collects flux measurements via the tracer method) is a proven method which will provide accurate flux measurements (Feitz, Schroder et al. 2018) of the local infrastructure on a well pad area. These measurements will provide ideal inputs for the development of specific emission factors. Besides meeting the primary aim of acquiring accurate data for industry-related fugitive methane emissions, the collection of the data via AEMS (either via the AEMS-C and AEMS-CF) provide the additional benefit of demonstrating the use of autonomous systems for the online delivery of continuous methane concentration data and, provide insights into the systems that may be suitable for long term automated online monitoring as recommended in Recommendation 9.5 of the Northern Territory Scientific Inquiry into Hydraulic Fracturing. However, for long term monitoring the configurations and the output required may not be the same as those required for emission quantitation. For example, for long term monitoring in a remote location where power consumption, maintenance of a complex system and overall infrastructure and running cost may be more limiting, a simpler AEMS configuration (similar to the AEMS-C) together with simplified atmospheric modelling may suffice. Hence, the data collected from the AEMS-CF will also be used to simulate/model a simpler AEMS configuration relying solely on the concentration, meteorological measurements and simplified atmospheric modelling and inversion methods (such as Windtrax; http://thunderbeachscientific.com/windtrax.html). The use of the two methods will allow us to determine just how accurate these two methods are for the job of measuring fugitive methane emissions.

[2] Note the lead time for delivery of the components from the USA is up to 10 weeks.

Mobile AEMS which can be readily reused/redeployed are an ideal solution for short term operations such well drilling and completion. In the long term when more permanent gas infrastructures are established, some questions that needs to be answered are 'How many AEMS are required; Where do you locate them; Do they need to be permanently located or will a set of roving AEMS suffice; What are the infrastructure and running costs?' Therefore, the second part of this project will address the numbers, locations and optimal cost-effective configuration of the AEMS to enable effective monitoring of the industry's fugitive emissions over the long term. Specifically, we will address questions related to 1) the number and location of AEMS required to comprehensively capture the industry's potential methane emissions from the entire Beetaloo sub-basin ; 2) based on the current state of the art technology, the optimal combination of components to provide operationally viable and cost-effective AEMS. Beside the optimal combination of technologies and costs, there is an additional question of whether permanent or mobile AEMS deployed on a rotational basis is suitable as an operational solution. Together with the results from the comparison of the tracer method and the simpler AEMS and atmospheric modelling method, we will answer the question 'Is it feasible to use AEMS for long-term monitoring of fugitive emissions in remote sites at gas industry operations?'

Need & Scope

Submissions made during public hearings and community forums related to the NT Scientific Inquiry into Hydraulic Fracturing indicated community concerns about the potential impacts of GHG emissions from the industry operations. This project seeks to address these stakeholder concerns by providing evidence-based information on the magnitude of fugitive methane emissions that may be produced through each stage of well drilling and completion operations. This will require characterisation of the baseline levels pre-drilling and, monitoring throughout the operations until the end of well completion activities. Research conducted in the USA indicates that some operations such as completions (especially flowback after hydraulic fracturing) may be a significant source of emissions. Because the shale industry is new in Australia, there is no local/Australian data to verify this or quantify the amounts that may be produced. As a consequence, USA data such as the American Petroleum Institute (API) Compendium of GHG (https://www.api.org/~/media/files/ehs/climate-change/2009_ghg_compendium.ashx) are often used to define the emission factors that will be applied to quantify emissions even though the relevance and transferability of those emission factors to the Beetaloo sub-basin is unknown.

This proposal seeks to firstly provide quantitative data for pre-drilling baseline and acquire data throughout the entire well drilling and completions (including hydraulic fracturing) process to quantify fugitive methane emissions produced from each stage of the different operations. Where possible, the research will also attempt to differentiate exploration related emissions from those that are likely to be representative of broader development activities (such as completions, flowback management and condensate storage). As some of the activities may potentially be over a considerable length of time but has a finite duration (for example, drilling generally may take 45-90 days, stimulation range from 10-21 days and completions may take 2-5 days with 24 hour operations), the deployment of mobile AEMS is being proposed to make sure that any emissions are comprehensively captured and when the activities are completed the AEMS can be reused/redeployed to another new site.

An important outcome of the project is critical data which may be used to develop Australian emission factors for estimating the emissions from such operations. As such, effort will be made to ensure that the measurements will be aligned and sufficient to meet the requirements of the NGERS framework. This development will also demonstrate the value of AEMS that could be used to close off the gaps in the establishment of continuous AEMS as described in recommendation 9.5 of the NT Scientific Inquiry into Hydraulic Fracturing to provide real-time decision-making tools for managing emissions. Specifically, the project will demonstrate the concept of an interactive network providing near real-time concentration measurements and near-real-time emission flux of the area local to the industry's development/infrastructure.

Relevant State/Territory Government independent reviews

https://frackinginquiry.nt.gov.au/

Submissions made during public hearings and community forums related to the NT Scientific Inquiry into Hydraulic Fracturing indicated community concerns about the potential impacts of GHG emissions from the industry operations. Eight recommendations were provided to address these concerns, two of which (recommendations 9.4-9.5) related to ongoing monitoring and, reporting of methane concentration levels at any new gasfield development. The recommendations related to GHG monitoring were:

> ***Recommendation 9.4***
> *That baseline and ongoing monitoring be the responsibility of the regulator and funded by the gas industry.*
>
> ***Recommendation 9.5***
> *That all monitoring results must be made publicly available online on a continuous basis in real time.*

This project will address the need for continuous real time data from Recommendation 9.5. The developments and findings from this project will complement a project currently being developed with the NT government to establish pre-development regional-scale baselines and monitoring program under the NT SREBA framework. Currently, the delivery of real-time monitoring data is yet to be developed for/by the NT government. This project will provide real-time online methane concentration, ethane concentration and weather data via a live link available from the GISERA website.

Methodology

Part 1: Quantification of emissions related to drilling, stimulation, hydraulic fracturing and completions of new wells

At least 2-5 wells per year are expected to be constructed in the Beetaloo sub-basin starting in the dry season (March/April) in 2021 and, potentially more in 2022 and years subsequent to that to support exploration. This provides the opportunity to collect baseline data before construction and, subsequently to record the emissions profile during the well drilling through to completions process.

To capture this opportunity, we propose in the initial stages, to manually collect baseline and then flux measurements at two new well sites where drilling and completions operations are to be undertaken (access to be provided by industry) using the tracer method at selected key points during the operations to capture critical flux measurements for the first new wells starting in March/April 2021. Where no pre-existing well exists, pre-construction soil flux measurements from a series of flux chambers placed across the well pad to establish the baseline value prior to the commencement of drilling and completion activities will be undertaken. Concurrently, we propose the deployment of AEMS-C at the selected well sites to collect methane, ethane concentrations and associated meteorological data. The AEMS-Cs will be deployed after the well pad has been cleared for new wells or, before the commencement of the operations at pre-existing well pads to allow pre-operations data to be included in the measurements. The measurements will continue until the finalisation of well completions. The acquisition of both methane and ethane is important as some exploration wells at the Beetaloo sub-basin are expected to encounter significant ethane compositions, which may be useful in the future as an indicator of emissions from exploration activities. The AEMS-C will be placed downwind of the well at the predicted prevailing wind direction (based on BoM climate data) to maximise emissions data capture.

It is important for data that will be used for emission factor developments to be of a high quality and aligned to the NGER framework. To date, the tracer method has been proven to provide the highest accuracy. However, continuous manual collections spanning the entire well drilling and completions operations which could be months in length will be too resource and cost prohibitive. To enable continuous flux measurements using the tracer method, we proposed the extension of the current CSIRO AEMS (AEMS-C) to enable automated tracer measurements. This would involve 1) building of a complete AEMS-CF system including a) the incorporation of 2 gas analysers (to be purchased) in order to measure the methane, ethane and the tracer, acetylene, b) developing a tracer release system; c) extending the calibration capabilities to include the tracer gas, and, d) extending the current software to cater for the new data streams and, 2) upgrading one of the current AEMS-C to the AEMS-CF requiring the incorporation of an additional analyser (to be purchased) in order to measure the tracer and other upgrades as described in 1 b, c and d.

The first extended AEMS (AEMS-CF) is expected to be completed in 6 months after which it will be deployed in the field as soon as practicable. The next AEMS-CF will be upgraded from the AEMS-C retrieved from the field and is expected to be completed in 6 weeks after the first AEMS-CF is complete and, it will take the place of the other AEMS-C.

It is anticipated that data will be collected at 6 to 8 sites across different time periods for the duration of the project. At each deployment period, two sites will be selected for the AEMS-CF deployment and data will be collected from the start of the operation till the well completion is finalised. Each deployment period is expected to be up to six months in length. After the well completion is finalised, the AEMS-CFs will be redeployed to the next two selected sites (will be agreed through consultation with industry and NT Government) for further data collection. The data collected from this use case will be used to determine the baseline of the well pads before activities occur and for the quantification of these emission sources, which, will not only help in understanding the potential impact but, potentially lead to the definition of Australia specific emission factors for these sources. As there is potential for these flux measurements to be used to determine Australian emission factors, then comparisons of estimates of flux using current calculations is included as an essential part of the work. The support of the industry to access these estimations of flux would be required for any site proposed for measurement.

Flux measurements from the tracer method having high accuracies are ideal for the development of emission factors. However, when deployed for long term monitoring in a remote location such as the Beetaloo sub-basin, operational deployment of AEMS particularly in remote, extreme locations requires a balance between accuracy, cost and maintenance complexity. Therefore, we will investigate as part of this project the trade-offs of these different aspects using only the methane dataset acquired from the AEMS-CF to simulate a simplified system with less components, reducing cost but potentially higher uncertainties. Specifically, the methane data (without the tracer gas measurement) together with the associate meteorological data will be used to undertake simplified atmospheric modelling and inversion (Windtrax, suitable for local dispersion within 1 km. Although the model caters for local scale dispersion, note that monitoring systems such as the AEMS-C and the monitoring system deployed for the GISERA Characterising the regional fluxes of methane seepage in the Surat Basin, Queensland Project Number G1 (Luhar, Etheridge et al. 2018) have the capability to detect sources further than 1 km. Their footprint is a function of the height of the gas intake, metrological conditions and surrounding environments. For example, the AEMS-C being trialed at the CSIRO Perth site was able to detect methane and ethane from fires approximately 40 km away) to estimate the flux local to the well pad. In this component, the estimated flux calculated from the tracer method be used as a calibration dataset at the initial stages and validation of the flux measurements. In addition, the calculated flux estimation sourced from the industry will also be compared to the data from the manual measurements as well as the modelled results to understand the applicability of the flux estimations.

Part 2: Determining the numbers and locations of AEMS and cost

Mobile AEMS are an ideal solution for temporary operations such as well drilling and completions which are usually relatively short term (months) operations. In the long term, if more permanent gas infrastructures are required, for longer term monitoring, a usual route would be to use permanently deployed or fixed AEMS. However, there is also a possibility that mobile AEMS deployed on a rotational basis at different sites may suffice. Here, the question would be how many of such AEMS whether permanent or mobile are required and their location to be representative of gas infrastructure expected across the Beetaloo sub-basin. Therefore, an aspect that we will investigate in this part is the optimal number and location of AEMS required. Statistical modelling methods together with emission source information from GISERA Baseline measurement and monitoring of methane emissions in the Beetaloo sub-basin Project Number G5 (Ong, Day et al. 2019) and the NT SREBA project will be used to determine the optimal number and location of AEMS. Some factors that will be considered for this include the expected gas infrastructures and operations, meteorological/climatic patterns, geology, terrestrial/landscape, natural and other anthropogenic sources.

Although the technology was state of the art at the time, one of the lessons learnt from the GISERA Characterising the regional fluxes of methane seepage in the Surat Basin, Queensland Project Number G1 (Luhar, Etheridge et al. 2018) was that significantly lower power consumption and independence from mains/grid power is a crucial next step, particularly for remote/new area deployments. In recent years, improvements in technology have significantly reduced power consumption, size and weight of methane analysers, and some cost reduction. Indeed, CSIRO has taken advantage of some of these improvements and undertaken strategic research to prototype an off-the-grid, solar-powered AEMS, which has been ruggedised for the extreme outback environments to ensure the stability of measurements. This prototype will be used in part 1 of this project to expedite the measurements of the well drilling, stimulation and completion activities in a timely manner. However, a different or modified solution may be required for longer term monitoring. The outstanding challenge that needs to be addressed for the operational deployment of numerous AEMS is the cost of some of the components. To address this, we will undertake a review of the most relevant technologies' technical capabilities and cost structure to understand the optimal cost-effective solutions and cost savings that may be realised with the scale of production.

6. Project Inputs

Research

Industry members have expressed strong interest in this project to address stakeholder concerns, understand the emissions from wells drilling and completions and the long-term continuous monitoring technology. Any AEMS system that we eventually recommend for the localised monitoring close to infrastructure is best hosted/operated by the industry in the long term.

The NT government (Tania Paul & Alaric Fisher, Department of Environment, Parks and Water Security) is interested in developing AEMS to be part of a network for the Beetaloo sub-basin.

The Commonwealth Government Department of Industry, Science, Energy and Resources (Rob Sturgiss) will be interested in the results for the quantification of emissions from the drilling, stimulation and completion (including hydraulic fracturing) operations.

CSIRO has developed a prototype mobile AEMS as part of an internal project led by Cindy Ong. This project will build on that research refining and extending the capabilities of the AEMS to include automated flux measurements.

There is potential to extend the type of gas that will be measured by the AEMS to put the AEMS for multiple purposes. An example is an extension to collect carbon monoxide, which could be useful for providing additional information related to bushfires, which could inform climate change and land management practices for the land managers/traditional owners in other applications.

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Cindy Ong	62 days	Emission and remote sensing research	25	CSIRO
Mederic Mainson	70 days	Instrumentation/Engineering	10	CSIRO
Jelena Markov	70 days	Geophysics and modelling	5	CSIRO
Charles Heath	66 days	Chemist	10	CSIRO
Dave Downs	14 days	Technician	20	CSIRO
Data 61 statistician	10 days	Statistician	15-20 years	CSIRO

Subcontractors (clause 9.5(a)(i))	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Stuart Day	24 days	Emission research	35	One Key Resources

Budget Summary

Source of Cash Contributions	2020/21	2021/22	2022/23	2023/24	2024/25	% of Contribution	Total
GISERA	**$118,145**	**$282,496**	**$124,037**	**$0**	**$0**	80%	**$524,678**
- Federal Government	$31,382	$75,038	$32,947	$0	$0	21.25%	$139,367
- Santos	$49,828	$119,143	$52,313	$0	$0	33.74%	$221,283
- Origin	$30,585	$73,131	$32,110	$0	$0	20.71%	$135,826
- Pangaea	$6,350	$15,184	$6,667	$0	$0	4.30%	$28,201
Total Cash Contributions	**$118,145**	**$282,496**	**$124,037**	**$0**	**$0**	**80%**	**$524,678**

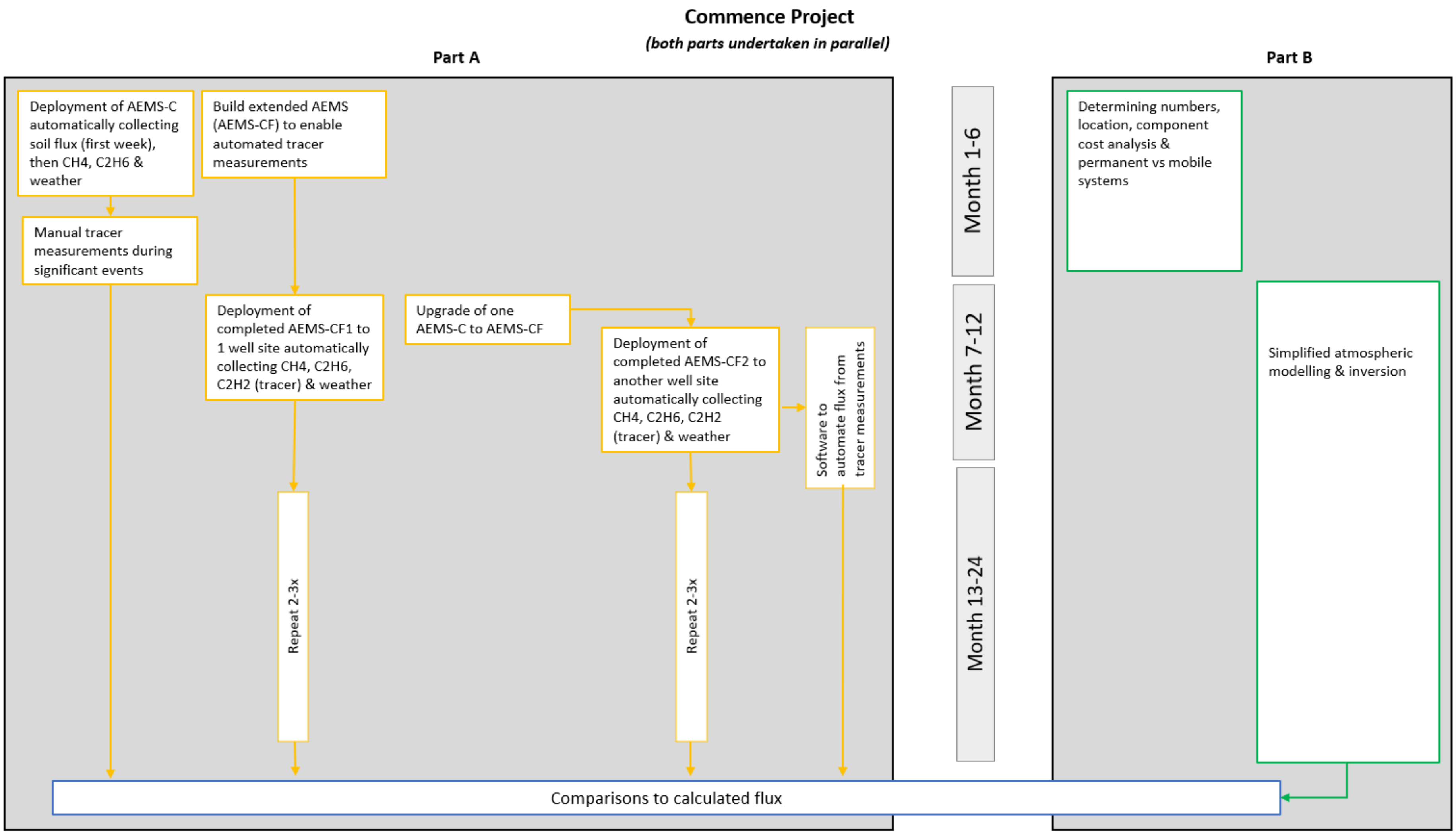
Source of In-Kind Contribution	2020/21	2021/22	2022/23	2023/24	2024/25	% of Contribution	Total
CSIRO	$29,536	$70,624	$31,009	$0	$0	20%	$131,169
Total In-Kind Contribution	**$29,536**	**$70,624**	**$31,009**	**$0**	**$0**	**20%**	**$131,169**

TOTAL PROJECT BUDGET	2020/21	2021/22	2022/23	2023/24	2024/25	-	TOTAL
All contributions	$147,681	$353,120	$155,046	$0	$0	100%	$655,847
TOTAL PROJECT BUDGET	**$147,681**	**$353,120**	**$155,046**	**$0**	**$0**	**100%**	**$655,847**

7. Project Impact Pathway

<table>
<tr><th>Activities</th><th>Outputs</th><th>Short term Outcomes</th><th>Long term outcomes</th><th>Impact</th></tr>
<tr>
<td>Part 1: Quantification of emissions related to hydraulic fracturing of new wells</td>
<td>• Temporal data related to baseline and quantification of emissions from 6 new wells collected over the entire drilling and completions process and related report documenting the results.
• A quantitative comparison between tracer method and simplified atmospheric modelling/inversion</td>
<td>• Baseline and monitoring data satisfying NT hydraulic fracturing inquiry recommendations 9.3 Demonstration of real-time methane concentration data, satisfying NT hydraulic fracturing inquiry recommendations 9.4 & 9.5
• Enables decision-making on practical and cost-effective solutions for future deployment of AEMS</td>
<td rowspan="2">• Inform regulators and policy-makers on the development of NGERS emission factors related to well completions.
• Enhance industry's and regulators' knowledge and emissions monitoring practices.
• Improve community awareness and evidence-based decision making of emissions impacts in the Beetaloo sub-basin.
• Enhance industry and regulators' ability to monitor and mitigate GHG impacts.</td>
<td rowspan="2">Environmental Impact
• The monitoring data enables improved emission management and hence reduction in greenhouse footprint
Social Impact
• Potential for training and deployment of local NT and indigenous communities in the management of the AEMS thereby generating greater income, jobs and wealth for regional communities
Economic Impact
• Enables licence to operate leading to stable and reliable domestic energy supply and regional wealth generation
• Meeting environmental obligations leading to sustainable Australian onshore gas industry
• The operational deployment of AEMS will require consultants/operators to undertake management and data processing and delivery which can lead to job creation.
• The technologies developed could have export potential to other resources-based countries</td>
</tr>
<tr>
<td>Part 2: Determining the numbers and locations of AEMS and cost</td>
<td>Report documenting analysis performed to determine the optimal numbers and locations of AEMS and review of current state-of-the-art instrumentation and related cost analysis for AEMS</td>
<td>• A guidance document on the optimal numbers and locations of AEMs.</td>
</tr>
</table>

8. Project Plan



Project Schedule

ID	**Activities / Task Title** (should match activities in impact pathway section)	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Baseline flux chamber measurements, initial manual tracer & calibration and validation data	Cindy Ong	April 2021	March 2022	None
Task 2	Monitoring station deployment, extension and maintenance	Cindy Ong	April 2021	March 2023	None
Task 3	Comparisons between flux measurements from tracer method and atmospheric modelling and inversion	Cindy Ong	July 2022	March 2023	Task 1
Task 4	Determining the numbers and locations of AEMS and cost	Cindy Ong	July 2021	June 2022	Task 1
Task 5	Project Reporting	Cindy Ong	April 2021	March 2023	None
Task 6	Communicate findings to stakeholders	Cindy Ong	April 2023	June 2023	Tasks 1-5

Task description

Task 1

TASK NAME: Baseline flux chamber measurements, initial manual tracer & calibration and validation data

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: 12 months (Apr21-Mar22)

BACKGROUND: It is important to capture the baseline flux before operations commence to define the reference levels from which the impacts can be estimated. This pre-operational baseline will be captured using flux chamber measurements of the wellpad after clearing or before the commencement of operations if it is an existing well. In addition, to ensure high quality measurements, flux measurements of key operations will be collected manually using the tracer method.

TASK OBJECTIVES: 1) To collect comprehensive soil flux data pre-commencement of the hydraulic fracturing operations; 2) Manually collect comprehensive flux measurements using the tracer method at key points during the hydraulic fracturing processing to expedite the data collection at the initial stages and for calibration and validation of the results from the AEMS.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: 1) The initial results will be documented in a section of an overall report in Task 5 6 months from commencement of the hydraulic fracturing process documenting the baseline soil flux levels and initial results from the hydraulic fracturing process; 2) The results overall report from the hydraulic fracturing process from the first two wells where manual tracer measurements were made will be reported in a section of an overall report in Task 5 12 months from the commencement of the work.

Task 2

TASK NAME: Monitoring station deployment, extension and maintenance

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: 24 months (Apr21-Mar23)

BACKGROUND: It is important to collect temporal data throughout the hydraulic fracturing process to ensure that emissions impacts can be captured accurately. The extended length of time (months) for the whole operation from commencement to well completion requires automated techniques to be deployed. CSIRO has developed 2 AEMS which are deployable immediately for the continuous measurement of methane and ethane. However, flux measurements are also essential. The most reliable method of obtaining flux is via the tracer method. Extension of the AEMS with additional instrumentations is required to enable this capability.

TASK OBJECTIVES: 1) At the start of the project, to deploy 2 current AEMS (AEMS-C) at 2 new well sites to initially capture methane and ethane concentrations only; 2) To develop an extended AEMS (AEMS-CF) with tracer capabilities and to extend one of the AEMS-C in readiness for the subsequent new wells; 3) Deploy the 2 AEMS-CF as soon as the systems are completed and tested and subsequently to 2 new wells each time with the aim of collecting methane concentration and flux for a total of 6-8 new wells during the project

TASK OUTPUTS AND SPECIFIC DELIVERABLES: 6 monthly interim reporting in a section of overall report (Task 5) documenting the results from the AEMS deployments, that is, the concentration and flux measurements recorded, highlighting significant events.

Task 3

TASK NAME: Comparisons between flux measurements from tracer method and atmospheric modelling and inversion

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: 21 months (Jul22-Mar23)

BACKGROUND: Simplified AEMS with fewer components, lower power consumption and lower maintenance and overall cost is potentially feasible if atmospheric modelling methods are used with the methane concentration and meteorological measurements. However, the compromise is a potentially higher level of uncertainties. The data from the extended AEMS could be used to simulate a simplified system and atmospheric modelling and inversion methods tested for estimating flux related to the industry's operations.

TASK OBJECTIVES: To 1) To test simplified atmospheric modelling methods such as Windtrax for the estimation of flux of the local area, and potentially optimised the methods for the use case; and, 2) to compare the results from the atmospheric modelling methods with the results from the tracer method

TASK OUTPUTS AND SPECIFIC DELIVERABLES: 6 monthly report documenting the progress of the atmospheric modelling work and final report documenting the final results and comparisons in a section of overall report as outlined in Task 5.

Task 4

TASK NAME: Determining the numbers and locations of AEMS and cost

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: 12 months (Jul21-Jun22)

BACKGROUND: The number of AEMS that are required and their location to be representative of regions such as the entire Beetaloo sub-basin and, the different sources of emissions within it is unknown. To operationally deploy AEMS in the remote locations such as the Beetaloo sub-basin, a solution balancing the cost and the quality of the data needs to be found.

TASK OBJECTIVES: To 1) determine the optimum number and location of AEMS required to be representative of regions such as the entire Beetaloo sub-basin and, the different sources of emissions within it; 2) undertake a review of the most relevant technologies' cost structure to understand the optimal cost-effective solutions and cost savings; comparison of the value of fixed versus mobile monitoring solutions; 4) estimation of operational maintenance and running costs;

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Report documenting analysis performed to determine the optimal numbers and locations of AEMS and review of current state-of-the-art instrumentation and related cost analysis for AEMS, comparisons of mobile versus fixed AEMS solutions and estimation of operating maintenance and running cost to be included in a section of the overall reporting as outlined in Task 5 in order to understand the practicality of an operational system.

Task 5

TASK NAME: Project Reporting

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: 24 months (Apr21-Mar23)

BACKGROUND: Information from this project is to be made publicly available after completion of standard CSIRO publication and review processes.

TASK OBJECTIVES: To ensure that the information generated by this project is documented and published after thorough CSIRO Internal review.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: 1) Preparation of a final report outlining the scope, methodology, scenarios, assumptions, findings and any recommendations for future research; 2) Following CSIRO Internal review, the report will be submitted to the GISERA Director for final approval; and 3) Provide 6 monthly progress updates on Tasks 1, 2, 3 & 4 to GISERA office.

Task 6

TASK NAME: Communicate findings to stakeholders

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: 2 months (Apr23-Jun23)

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

TASK OBJECTIVES: Communicate findings to stakeholders through meetings, knowledge transfer session, factsheet and journal article, in collaboration with GISERA Communications officers.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Communicate results to GISERA stakeholders according to standard GISERA project procedures which will include:

1) Knowledge Transfer session with Government/Gas Industry
2) Presentation of findings to Community members/groups
3) Preparation of article for GISERA newsletter

4) Revision of project factsheet to include final results (a factsheet is developed at project commencement and another will be done at completion)

5) Peer reviewed scientific manuscript ready for submission to relevant journal (optional)

Project Gantt Chart

		2020-2021			2021-2022												2022-2023											
Task	**Task Description**	**Apr-21**	**May-21**	**Jun-21**	**Jul-21**	**Aug-21**	**Sept-21**	**Oct-21**	**Nov-21**	**Dec-21**	**Jan-22**	**Feb-22**	**Mar-22**	**Apr-22**	**May-22**	**Jun-22**	**Jul-22**	**Aug-22**	**Sept-22**	**Oct-22**	**Nov-22**	**Dec-22**	**Jan-23**	**Feb-23**	**Mar-23**	**Apr-23**	**May-23**	**Jun-23**
1	Baseline flux chamber measurements, initial manual tracer & calibration and validation data	■	■	■	■	■	■	■	■	■	■	■	■															
2	Monitoring station deployment, extension and maintenance	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
3	Comparisons between flux measurements from tracer method and atmospheric modelling and inversion				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
4	Determining the numbers and locations of AEMS and cost				■	■	■	■	■	■	■	■	■	■	■	■												
5	Project Reporting	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
6	Communicate findings to stakeholders																									■	■	■

9. Technical Reference Group

The project will establish a Technical Reference Group (TRG) aimed at seeking peer-to-peer technical advice on contextual matters and to discuss research needs as well as outputs as the project progresses. The TRG will include the project leader and a group of different stakeholders as appropriate which may include:

- Origin Energy representative (e.g. Matt Kernke)
- Santos representative (e.g. Paul Wybrew)
- Commonwealth Department of Industry, Science, Energy and Resources (e.g. Rob Sturgiss)
- NT Government representative

10. Communications Plan

Stakeholder	**Objective**	**Channel** (e.g. meetings/media/factsheets)	**Timeframe** (Before, during at completion)
Regional community / wider public	To communicate project objectives and key messages from the research	Fact sheets (including development of one at commencement of project which will explain in plain English the objective of the project – this will be updated periodically as project progresses). Project progress reported on GISERA website to ensure transparency for all stakeholders including regional communities. Media release (optional)	From commencement of project and with updates as they come to hand. As required At completion
Government	Briefing on research being undertaken and progress	Engagement during project	During
Gas Industry	Quantify the fugitive methane emissions from HF operations. Determine the optimal number of AEMS needed to provide representative sampling of the gas infrastructure	Presentation of findings at joint Gas Industry/Government Knowledge Transfer Session	At Completion

Stakeholder	**Objective**	**Channel** (e.g. meetings/media/factsheets)	**Timeframe** (Before, during at completion)
Government	Advice provided to senior bureaucrats / ministers / policy makers	Presentation of findings at joint Gas Industry/Government Knowledge Transfer Session	At Completion
Community stakeholders	Presentation of research findings	Presentation of findings at via workshop/briefing	At Completion
Regional community/wider public, government, scientific community and industry	To report on key findings	Public release of final report	At project completion
Traditional Owner communities	To explore collaboration opportunities for environmental monitors to be involved on a voluntary basis.	Engagement with indigenous Rangers where appropriate to determine interest/availability on a voluntary basis	Ongoing

11. Budget Summary

Expenditure	2020/21	2021/22	2022/23	2023/24	2024/25	Total
Labour	$24,891	$247,204	$131,110	$0	$0	$403,205
Operating	$17,560	$41,720	$20,200	$0	$0	$79,480
Subcontractors	$5,230	$14,196	$3,736	$0	$0	$23,162
Equipment	$100,000	$50,000	$0	$0	$0	$150,000
Total Expenditure	**$147,681**	**$353,120**	**$155,046**	**$0**	**$0**	**$655,847**

Expenditure per task	2020/21	2021/22	2022/23	2023/24	2024/25	Total
Task 1	$22,310	$91,885	$0	$0	$0	$114,195
Task 2	$125,371	$125,761	$46,715	$0	$0	$297,847
Task 3	$0	$45,588	$44,972	$0	$0	$90,560
Task 4	$0	$55,908	$0	$0	$0	$55,908
Task 5	$0	$33,978	$40,823	$0	$0	$74,801
Task 6	$0	$0	$22,536	$0	$0	$22,536
Total Expenditure	**$147,681**	**$353,120**	**$155,046**	**$0**	**$0**	**$655,847**

Source of Cash Contributions	2020/21	2021/22	2022/23	2023/24	2024/25	Total
Federal Govt (21.25%)	$31,382	$75,038	$32,947	$0	$0	$139,367
Santos (33.74%)	$49,828	$119,143	$52,313	$0	$0	$221,283
Origin Energy (20.71%)	$30,585	$73,131	$32,110	$0	$0	$135,826
Pangaea (4.3%)	$6,350	$15,184	$6,667	$0	$0	$28,201
Total Cash Contributions	**$118,145**	**$282,496**	**$124,037**	**$0**	**$0**	**$524,678**

In-Kind Contributions	2020/21	2021/22	2022/23	2023/24	2024/25	Total
CSIRO (20%)	$29,536	$70,624	$31,009	$0	$0	$131,169
Total In-Kind Contributions	**$29,536**	**$70,624**	**$31,009**	**$0**	**$0**	**$131,169**

	Total funding over all years	Percentage of Total Budget
Federal Government investment	$139,367	21.25%
Santos investment	$221,283	33.74%
Origin investment	$135,826	20.71%
Pangaea investment	$28,201	4.30%
CSIRO investment	$131,169	20.0%
Total Expenditure	**$655,847**	**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	Baseline flux chamber measurements, initial manual tracer & calibration and validation data	GISERA	Apr-21	Mar-22	2020/21	$91,356
Task 2	2.1	Monitoring station deployment, extension and maintenance	GISERA	Apr-21	Mar-23	2022/23	$238,278
Task 3	3.1	Comparisons between flux measurements from tracer method and atmospheric modelling and inversion	GISERA	Jul-22	Mar-23	2022/23	$72,448
Task 4	4.1	Determining the numbers and locations of AEMS and cost	GISERA	Jul-21	Jun-22	2021/22	$44,726
Task 5	5.1	Project Reporting	GISERA	Apr-21	Mar-23	2022/23	$59,841
Task 6	6.1	Communicate findings to stakeholders	GISERA	Apr-23	Jun-23	2022/23	$18,029

12. Intellectual Property and Confidentiality

<table>
<tr><td rowspan="4">Background IP (clause 11.1, 11.2)</td><td>Party</td><td>Description of Background IP</td><td>Restrictions on use (if any)</td><td>Value</td></tr>
<tr><td>CSIRO</td><td>Design of Autonomous Emission Monitoring Station Version C (AEMS-C)</td><td></td><td>$200,000</td></tr>
<tr><td>CSIRO</td><td>Design of Autonomous Emission Monitoring Station Version CF (AEMS-CF)</td><td></td><td>$200,000</td></tr>
<tr><td>CSIRO</td><td>Background knowledge related to emissions quantification methodology, analysis & interpretation</td><td></td><td>$350,000</td></tr>
<tr><td>Ownership of Non-Derivative IP (clause 12.3)</td><td colspan="4">CSIRO is the owner of Non-Derivative IP. The agreement does not cater for joint ownership of Non-Derivative IP.</td></tr>
<tr><td>Confidentiality of Project Results (clause 15.6)</td><td colspan="4">Project Results are not confidential.</td></tr>
<tr><td>Additional Commercialisation requirements (clause 13.1)</td><td colspan="4">Not Applicable</td></tr>
<tr><td>Distribution of Commercialisation Income (clause 13.4)</td><td colspan="4">All income derived from commercialisation of the project IP is owned by CSIRO.</td></tr>
<tr><td rowspan="5">Commercialisation Interest (clause 1.1)</td><td colspan="2">Party</td><td colspan="2">Commercialisation Interest</td></tr>
<tr><td colspan="2">CSIRO</td><td colspan="2">100%</td></tr>
<tr><td colspan="2">Origin</td><td colspan="2"></td></tr>
<tr><td colspan="2">Santos</td><td colspan="2"></td></tr>
<tr><td colspan="2">Pangaea Resources</td><td colspan="2"></td></tr>
</table>

13. References

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