CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT

1. PROJECT INFORMATION:

Project Title:	**Zero Emission CHOPS Monitoring Project**
Emissions Reduction Scope/Description:	Electricity generation using microgrid incorporating photo-voltaic systems and battery storage systems to reduce GHG intensity
Applicant (Organization):	Saskatchewan Research Council (SRC)
Project Completion Date:	May 2023

2. EXECUTIVE SUMMARY:

For the Zero Emission (ZE) CHOPS (cold heavy oil production with sand) site, SRC has conducted a site energy assessment by installing energy meters and climate stations (data loggers), generating data for a microgrid design. A microgrid is a self-sufficient power system that generates electricity using renewable sources like solar and wind, providing reliable energy in remote areas or during emergencies when the main grid is unavailable. A microgrid design incorporates other renewable generation, increases energy efficiency, and reduces greenhouse gas (GHG) emissions. In addition, the gathered data was analyzed for other optimization opportunities.

The site's energy consumption is primarily driven by eight 60 kW production tank heaters and two 10 kW room heaters, four well-head motors rated at 43 kW each which run progressive cavity pumps, a single 7.5 kW room heater, and a lighting panel/heat trace system. The peak load of the site is found to be 192 kW. The ZE CHOPS site currently receives its power from a 450-kW gas generator and a 150-kW utility service line Energy meters. A climate station and data loggers were installed in the site to monitor and assess energy usage. The data collected from these devices helped to identify energy efficiency opportunities and informed microgrid design decisions. This study evaluates three microgrid configurations to better understand the benefits of implementing such a system at the ZE CHOPS site. The primary finding of the study is that the best the best microgrid option from an economic standpoint is a power system with 450kW gas generator + 150 kW utility where the surplus energy produced can be sold to the utility. This system has a levelized cost of energy (LCOE) of -$0.0256/kWh, where the negative value indicates profit. The GHG intensity of this system is higher than that of Alberta's utility grid. To reduce the GHG emission, renewable energy could be added to the energy mix which will potentially increase the LCOE. The peak load on site can be reduced by integrating a smart digital controller to the tank heaters to maintain consistent variable heating control rather than coarse power levels.

Tank samples were collected and sent to the SRC's analytical laboratory for density and viscosity measurement. The analysis confirms that the current temperature setpoint of 80°C is reasonable to maintain the required fluid viscosity for delivering produced oil to trucks and to account for potential heater fouling, poor tank mixing, or cooling. The site has multiple, innovative design features to monitor and mitigate GHG emissions. Future sites may consider additional instruments and equipment such as well casing flow meters, methane monitors/detectors, and back-up treatment of produced gas via a combustor.

This comprehensive energy assessment for the ZE CHOPS site provides valuable insights into the feasibility of implementing power systems to meet the site's energy needs while minimizing energy bills. By carefully evaluating energy consumption patterns, climatic conditions, and potential energy management strategies, the producer can improve the energy efficiency and reliability of existing power systems.

3. KEY WORDS

Microgrid modeling, site load assessment, GHG emission reduction, energy usage optimization, process optimization.

Natural Resources Canada | Ressources Naturelles Canada

4. APPLICANT INFORMATION:

Applicant (Organization):	Saskatchewan Research Council
Address:	Bay 2D, 820 51st Street East, Saskatoon, SK, Canada, S7K 0X8
Applicant Representative Name:	Aman Mogos
Title:	Research Engineer
Applicant Contact Information:	306-221-5977 | aman.mogos@src.sk.ca

5. LEAD CONTRIBUTING PARTNER INFORMATION:

Organization:	N/A
Address:	
Representative Name:	
Title:	

6. PROJECT PARTNERS

Funding for this project is made possible through PTAC's CanERIC program, funded by Alberta Innovates and NRCan, and by the Saskatchewan Ministry of Energy and Resources, and Innovation Saskatchewan. In-kind contributions are provided by the producer and the Saskatchewan Research Council (SRC).

A. INTRODUCTION

Sector Introduction

A microgrid is a self-contained system of energy generation, delivery, and consumption that may run alone or in tandem with the larger power grid. Load optimization in a microgrid seeks to balance energy supply and demand while avoiding energy waste and enhancing overall efficiency. This may be accomplished through a variety of strategies, including, energy storage systems, and smart grid technology. Microgrids can play an essential role in lowering GHG emissions in addition to load optimization. Microgrids can minimize dependency on fossil fuel-based generation, which contributes significantly to greenhouse gas emissions, by incorporating renewable energy sources such as solar or wind power. Energy storage devices can help store extra renewable energy for use during peak demand, lowering greenhouse gas emissions even more. Using smart heating control systems in the oil and gas sites can also help minimize energy usage and hence greenhouse gas emissions in microgrids. Overall, microgrids provide a more sustainable and effective method of managing energy generation and distribution while also aiding in the mitigation of climate change effects. As a result, they are rapidly becoming a popular choice for communities, corporations, and governments seeking to move to a more sustainable energy system.

This study presents a comprehensive energy assessment and microgrid analysis for the Zero Emission CHOPS site. The primary objectives of this study include assessing existing electrical loads, increasing energy efficiency, decreasing site energy costs, and identifying operational optimization opportunities.

Project Specific Information

As part of CanERIC's mandate, data collection and analysis are key to ensuring that projects are relevant to the broader CanERIC member audience and that successes are reproducible. Thus, SRC as a part of CanERIC Industry Solutions Committee member was invited to propose test work projects related to the site.

SRC identified an opportunity to collect data relevant to operational optimization and eventual implementation of renewable energy solutions and electricity generation from methane sources on-site. Within this scope of work, SRC installed a climate station to determine the site's solar resource and wind resource which can be used when sizing renewable energy solutions. The climate station also recorded ambient conditions such as temperature, relative humidity, barometric pressure, and rainfall. The climate station employed a flexible data logger platform that also recorded the site's electrical consumption via revenue-grade energy meters supplied by SRC to monitor and record electrical loads, voltage, frequency, and power factor for individual site loads. The climate station also incorporated a camera to view the site and aid in troubleshooting.

Of specific interest, this project aimed to characterize primary site electrical loads and methods of operation, identify opportunities for efficiency optimization related to both site operations and tank temperature settings, and to determine the comparative benefit of operating the site using a combination of photovoltaics, battery and gas generation versus grid electricity.

B. METHODOLOGY

As an initial stage, SRC installed energy meters and data loggers in two buildings on site to track and record individual load consumption. The collection of data makes it possible to continuously monitor and assess how much energy is used at the site and promote best practices for energy management and conservation. This in turn helps to properly apply energy efficiency actions in the future. The data collection framework used at the main and small buildings are shown in Figure 1 and Figure 2, respectively. These include Wattnode Multi-Circuit Meter (MCM)s; their installed locations are indicated in Figures 3 and 4, respectively.

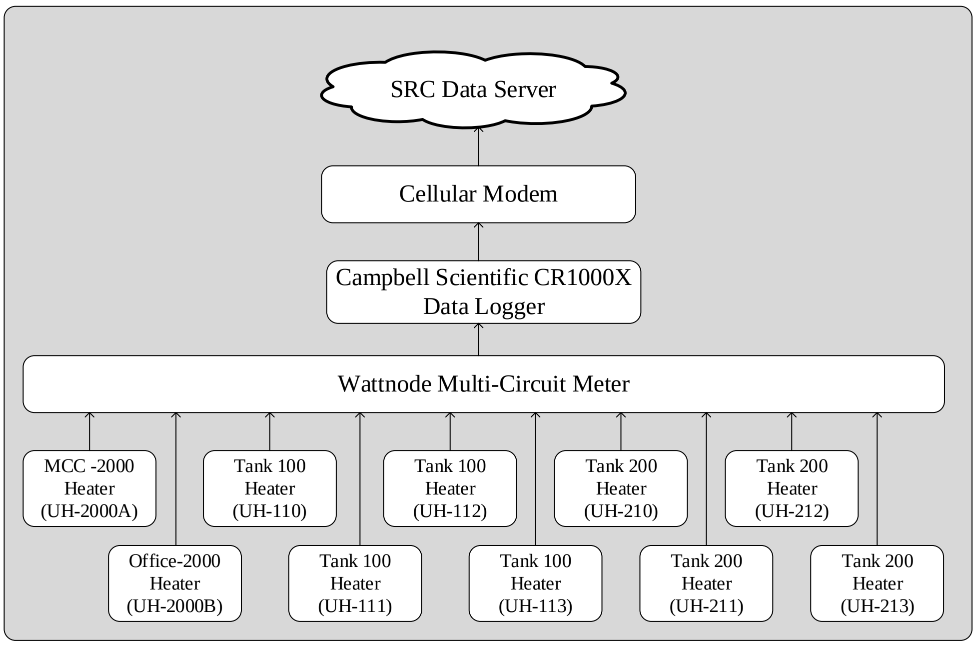

Figure 1 – Framework of Data Acquisition on the Main Building (For MCM installation refer Figure 3)

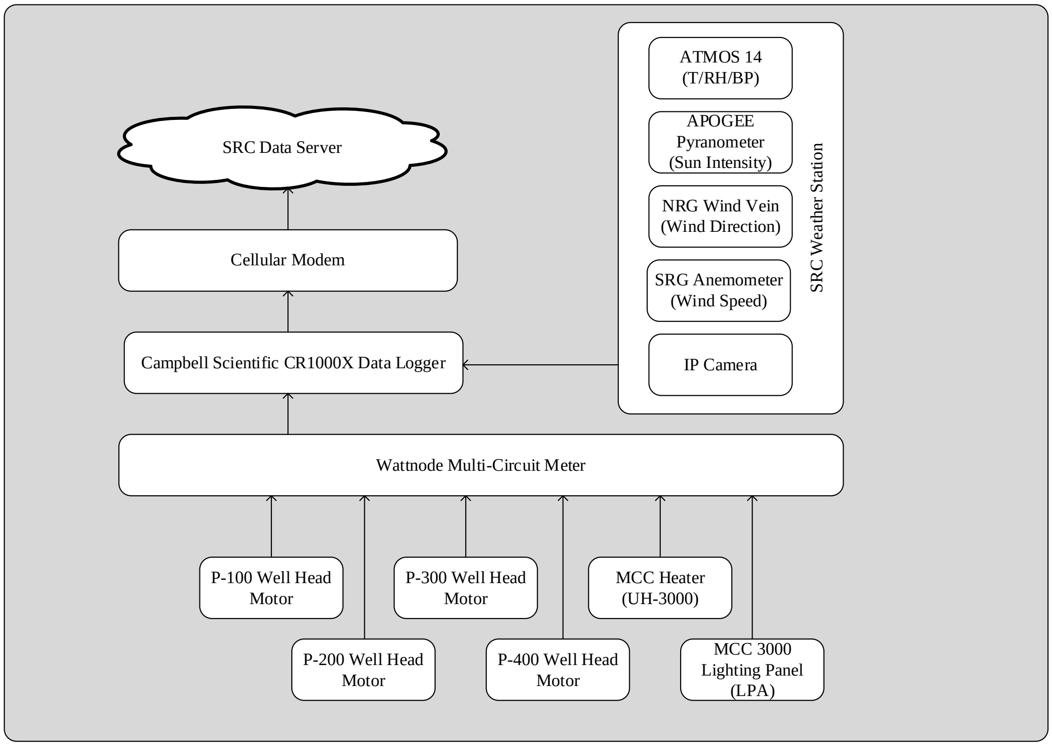

Figure 2 – Framework of Data Acquisition on the Small Building (For MCM installation refer Figure 4)

The physical location of the Wattnode multi-circuit meter (MCM) installed in the site are shown in Figure 3 and Figure 4.

Figure 3 – MCM in the Main Building

Figure 4 – MCM in the Small Building

SRC also installed a climate station with an IP camera to view the site and aid in troubleshooting. The physical location of the installed climate station is shown in Figure 5.

Figure 5 – SRC Weather Station (Please refer the top-right part of Figure 2)

The data loggers and modems installed on site allows a wireless connection of the MCMs and climate station with the SRC data server. This allows for remote monitoring and analysis of the site's energy usage and environmental conditions, which enables informed decision-making on microgrid design, optimization, and operating strategies. SRC collected electricity consumption data along with climatic data for the site during the months of February and March. While one year of data is generally recommended for modeling an efficient microgrid, SRC has employed data analytics to correlate the energy consumption with the ambient temperature, effectively extrapolating the available data to represent an entire year. In addition, samples of the separated oil were sent to SRC’s analytical laboratory for density and viscosity measurement.

C. PROJECT RESULTS AND KEY LEARNINGS

The major energy users on site are the tank heaters. These two tanks are heated to increase the density difference between the heavy oil (992.61 kg/m3 at 20°C) and produced water (1,000 kg/m3), so that they will more easily separate. The heavy oil is also heated to reduce the viscosity so that it can be loaded into trucks. Samples of the separated oil were sent to SRC's analytical laboratory for density and viscosity measurement. Results are presented in Table 1 and Figure 6.

Table 1 – Density and Viscosity of Produced Oil

T (°C)	Dynamic Viscosity (cP)	Density (kg/m3)	Kinematic Viscosity (cSt)
20	33158	992.61	33405
40	3405	981.19	3470
50	1877	975.26	1925
80	285.8	956.24	299

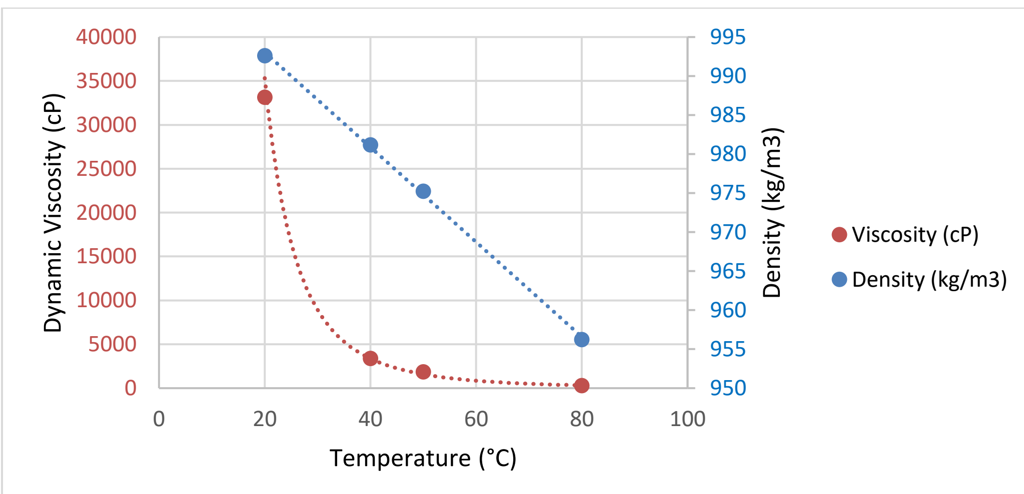

Figure 6 – Density and Dynamic Viscosity of Produced Oil

As can be seen in Figure *7*, the kinematic viscosity is well-represented by a two-parameter exponential model: $Viscosity = Ae^{\frac{B}{T}}$. Based on the curve-fit equation in Figure 7, a temperature of 74.5°C is required to reach a viscosity of 350 cP (350 cP is the pipeline specification for oil, which should be more than adequate for loading oil from the tanks to trucks). Temperature set points for both tanks are currently controlled at 80°C. No changes to heater set point are recommended following this analysis.

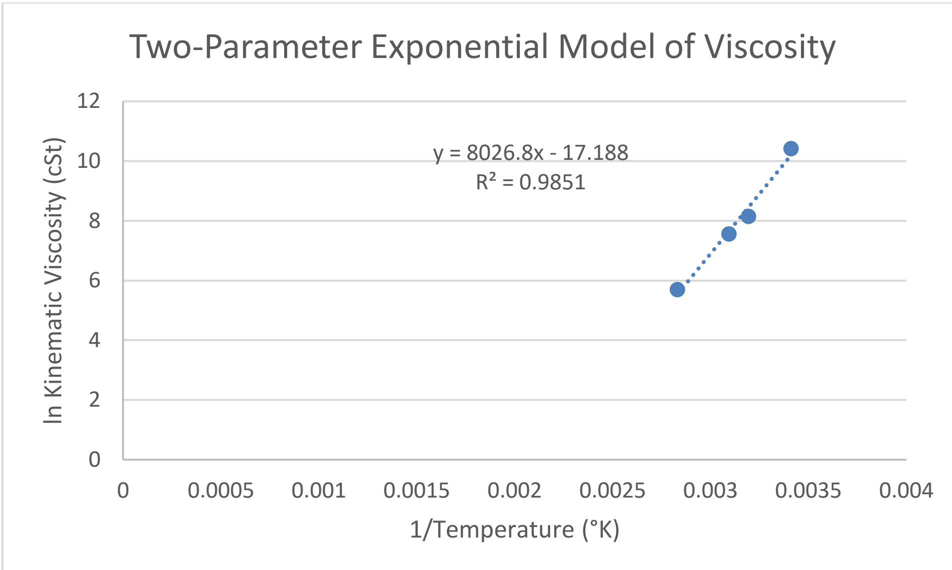

Figure 7 – Two-Parameter Exponential Model of Viscosity (natural log of viscosity vs inverse temperature)

Gas Production and Tank Temperature

The zero emissions CHOPS site has multiple design features to eliminate both carbon dioxide and methane emissions. The new equipment, that was installed as part of the zero emission project, minimizes methane venting/leaks, and carbon dioxide and uncombusted methane exhaust emissions are avoided by using electrical power instead of gas-fired heating and mechanical power. The site is well-instrumented to monitor gas capture. A future consideration is back-up treatment of produced gas via a combustor in the event of operational/equipment issues.

The tank level and tank temperature data were provided by and analyzed by SRC. Figure 8 and Figure 9 shows tank level and tank temperature for the group tank and test tank, respectively.

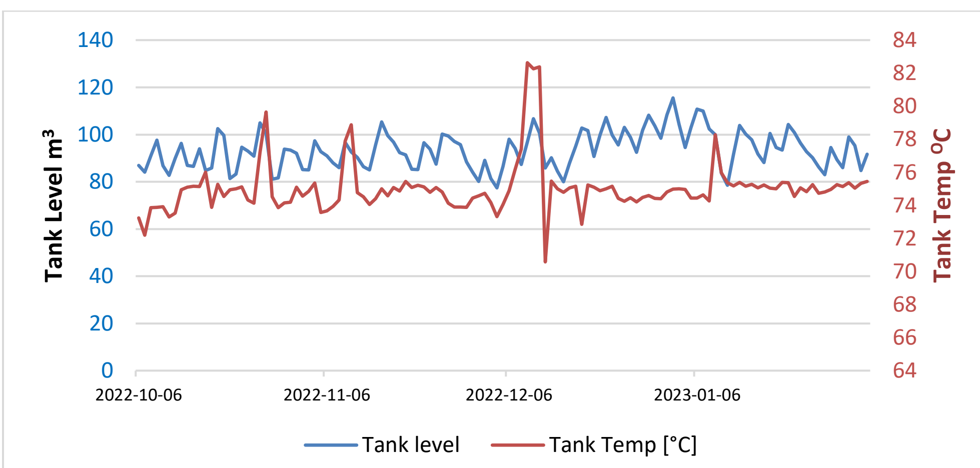

Figure 8 – Group Tank Temperature and Tank Level

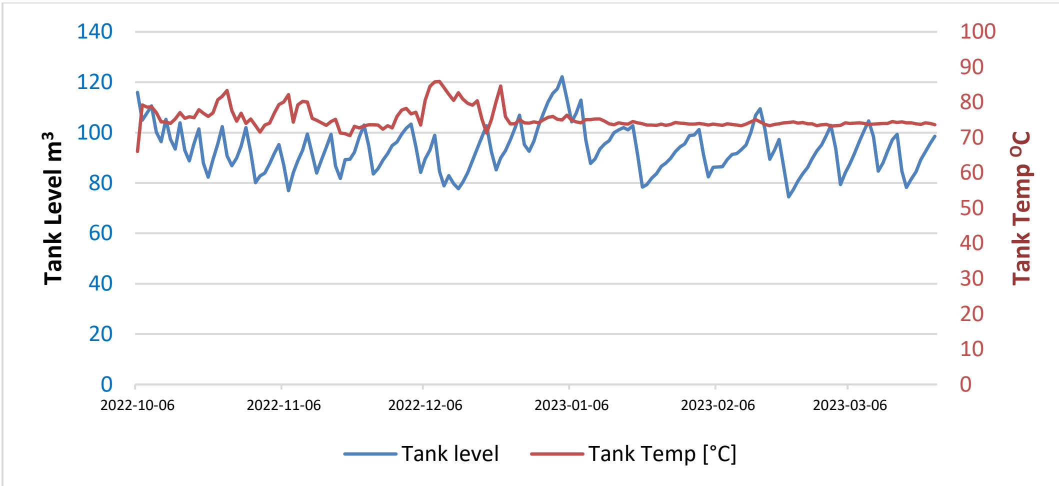

Figure 9 – Test Tank Temperature and Tank Level

The tank temperatures are always at their optimal ranges no matter the tank level. As such, no further working optimization is advised at the moment.

Microgrid Assessment

Currently the load is fed with two different power sources: one from a utility and the other from a 450-kW generator. The utility grid capacity is 150 kW which is fixed and not able to support the entire site alone. The microgrid designed will be an integrated solution for meeting peak load demands, ensuring energy resiliency, and enabling the sale of surplus energy to the utility grid. The combination of renewable energy sources, energy storage, and advanced control and monitoring equipment makes this microgrid a sustainable and efficient power solution. The conceptual diagram of the microgrid is shown in Figure 10.

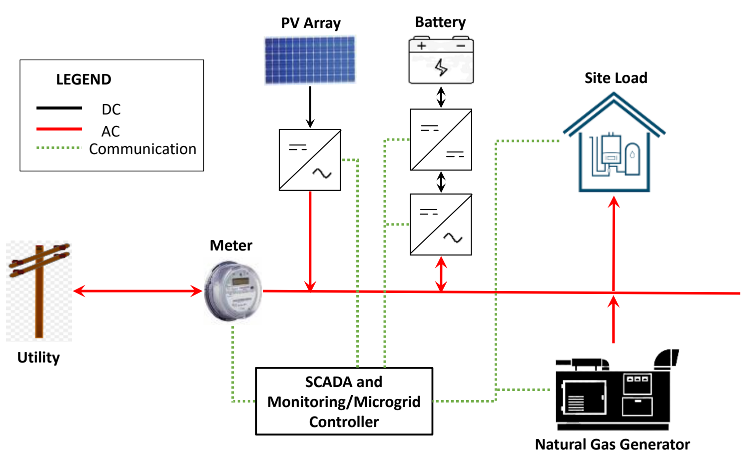

Figure 10 – Conceptual Technology Layout

The microgrid analysis identified the best option from an economic point of view to serve the site load. This study evaluated three microgrid configurations to better understand the benefits of implementing such a system at the ZE CHOPS site. The first case, referred to as "Case I," examines the lowest net present value (NPV) when energy cannot be sold to the utility. The CHOPS site has been previously altered as part of the zero-emission project to improve efficiency and reduce GHG emissions. This optimized site is Case I (Base Case) in this analysis. The second case, "Case II", assesses the lowest NPV when it is possible to sell surplus energy back to the utility. The final case, “Case III”, assesses the lowest NPV of the site if the utility interconnection were disconnected. Note that Case I is the site’s existing power system and it is considered as a base case for Case II and III.

The primary finding of the study is that the best economic option with the NPV is Case II, which is an existing system (450-kW gas generator + 150-kW utility) where the surplus energy produced can be sold to the utility. This system has a levelized cost of energy (LCOE) of -$0.0256/kWh, where the negative value indicates profit. Despite this case being economically sound, the GHG intensity is substantially higher than that of Alberta’s utility grid’s GHG emissions intensity in 2020 (590 CO_2e/kWh). To reduce the GHG emissions, renewable energy could be added to the energy mix which will potentially increase the LCOE. This best economic case could also shorten the operation life of the gas generator as it will run 24/7 all the year round. To analyze the benefit of renewable energy in reducing GHG intensity, a 100-kW solar PV forcibly incorporated into the Case III microgrid and the GHG intensity was reduced by 10.3%.

One key observation was made regarding the capacity of the generator. The minimum load ratio of the modelled generator was 35%. For a 450-kW generator, this equates to 157 kW. If the site load is below this limit, the fuel consumption remains unchanged. The average load at site was measured to be 120.7 kW and the peak load was 191.7 kW. This means the generator is typically operating below its minimum load threshold and thus consuming excessive fuel. One option to reduce fuel consumption, thus lowering the GHG intensity, at site would be to right-size the generator for the site loads. SRC recognize that there may be load expansion in the future, and this may be the reason the 450-kW generator was chosen for the site.

D. PROJECT AND TECHNOLOGY KEY PERFORMANCE INDICATORS

Organization:	Current Study	Commercial Deployment Projection
Project cash and in-kind cost ($)	$164,000 cash; $77,000 in kind	N/A
Technology Readiness Level (Start / End):	TRL 9	TRL 9
GHG Emissions Reduction (kt CH4/yr):	N/A	N/A

Estimated GHG abatement cost ($/kt CH4)	N/A	N/A
Jobs created or maintained:	N/A	N/A

E. RECOMMENDATIONS AND NEXT STEPS

The recommendations are follows:

- Include additional features to monitor gas capture and fugitive methane equipment leaks such as a flow meter/totalizer on the combined or individual well casing gas or methane monitors/detectors at key site locations which alarm in the event of a fugitive equipment leak.
- Implement back-up treatment of produced gas via a combustor in the event of operational/equipment issues.
- Integration of the existing field instrumentation into SRC datalogger networks to enhance data collection and analysis.
- Optimize sizing of the on-site natural gas generator and incorporate more green energy to further reduce GHG emissions.
- Implement smart digital controllers to the tank heaters to maintain consistent variable heating control rather than coarse power levels to reduce energy consumption on site.
- Implement a smart mechanism to optimize tank temp with level to save energy consumption.