PROJECT SUMMARY AND OUTCOMES

FACILITY OF THE FUTURE

The “Cenovus Facility of the Future Project” demonstrated and deployed several different low to no-emission technologies within our Conventional oil and gas assets to help measure and understand capabilities and limitations as well as develop operational familiarity.

Prepared by Cenovus Energy as part of the Methane Consortia Program

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Project Summary

The "Cenovus Facility of the Future Project" demonstrated and deployed several different low to no-emission technologies (currently being developed/marketed by Subject Matter Experts [SMEs]) within our Conventional Business Unit oil & gas assets. Through this project, Cenovus was able to understand any related capabilities and limitations, while building operational familiarity/comfort with utilizing the various technologies.

This project provided the SMEs access to Cenovus candidate sites to test/trial their technologies under real-world conditions. This is an arrangement that SMEs often struggle with arranging, as producers are often reluctant to pilot/trial new technologies within active operations due to higher capital costs, performance uncertainty, and the resulting risk to operational reliability.

The results from this project are being shared with Alberta's innovation ecosystem and this will allow the ecosystem to expand and strengthen as producers gain awareness of what technologies are available. Also identified through this project would be each technology's limitations and capabilities allowing the SME and the innovation community to confirm the "gap/problem statements" and adapt designs to better meet the needs of the end-users.

Full-scale deployment of smart, strategic, cost-effective methane management technology (such as the technology this project implemented) is required for a sustainable oil & gas production. As we look to the future, it will be imperative to manage and eliminate emissions emitted from operations as Canada seeks to be a global "energy provider of choice."

Technology Summary

The low- to no-emission technologies implemented in this Project are novel to Cenovus and have not been widely implemented at-scale within Cenovus or the Canadian upstream oil & gas sector, to-date. These technologies are namely, electric instruments & pumps, instrument air, and remote on-site power generation.

The key focus of this project for Cenovus was to eliminate vented methane emissions from natural gas-driven pneumatic equipment on standard well site separator packages. This required the use of either electrically driven equipment or an alternative gas, i.e. instrument air. All this equipment would require an additional source of power generated on site.

Cenovus selected a three-well pad to trial various technologies. It was decided to trial two standard well site separator packages using electric alternatives and one instrument air package that would be suitable to power the pneumatic equipment of our standard package. Table 1 includes the equipment that was selected for trial.

Table 1: Equipment selected for trial

Component	Electric Package A	Electric Package B	Instrument Air Package
Inlet control valve actuator	Bettis RTS FL-05	Rotork CVL1000 FA07	CVS 667 Size 70 c/w Fisher i2P-100
Back-pressure control valve	Fisher D4e	Rotork CVL1500 FA07	Fisher D4 c/w Fisher i2P-100
Level controller (x2)	Fisher L2e	Norriseal 1001A electric	Fisher L2
Level control valve actuator (x2)	Fisher D3e	Rotork CML 750 FA05	Fisher D3

Electric Chemical Injection Pump(s)	LCO Crossfire (x1)	Flomore Ecoflo35 (x2)	Trido Electric Chemical Injection Pump (x2)
Instrument Air Compressor	N/A	N/A	Trido Electric Instrument Air Compressor
Power source	Qnergy PowerGen 5650		

Cenovus also trialed the Argus Automatic Multi-Pig Launching Package. This eliminates the need to routinely open a standard pig barrel, which involves venting pressurized natural gas to the atmosphere. The auto-launcher unit was solar powered.

Purchase and Installation Process

Cenovus engaged with numerous providers of equipment that would be suitable within the trial and identified a few vendors that could satisfy the constraints of the design. Cenovus engaged with technical representatives from each vendor to ensure that the equipment being proposed would be suitable in all aspects of the application, including process design, power demand, maintenance requirements, operability, reliability, and cost.

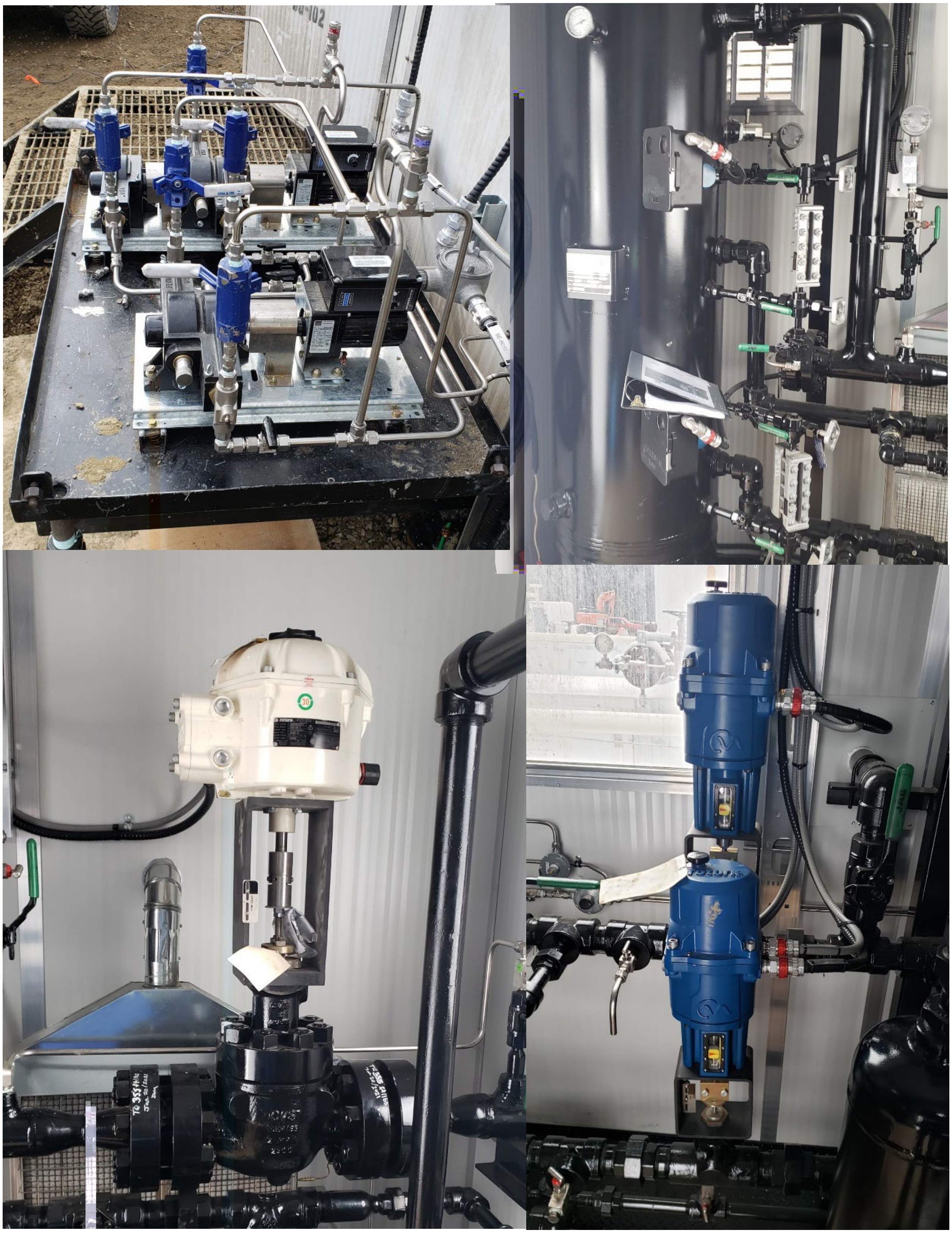
Table 2 summarizes the vendors that Cenovus worked with to provide each trial component.

Table 2: Equipment vendors for trial technologies

Vendor(s)	Equipment Provided
Spartan Controls	Electric Package A
CVS Controls / Rotork	Electric Package B (except Electric Chemical Injection Pump)
Zimco Instrumentation	Flomore Ecoflo35
Trido Industries	Trido Instrument Air Compressor and Chemical Injection Pumps
Protek Safety and Controls Ltd.	Qnergy PowerGen 5650
Argus Machine Co. Ltd.	Argus Automatic Multi-Pig Launching Package

The installation was managed by Cenovus with the support of the various vendors. On-site programming and commissioning support was provided by vendors for the majority of the components.

Figures 1-4: Electric Package A – [clockwise from top left] (1) LCO Crossfire electrical chemical injection pump, (2) Fisher D3e level control valves, (3) Fisher L2e level controllers, (4) Bettis RTS FL-05 inlet control valve actuator



Figures 5-8: Electric Package B – [clockwise from top left] (5) Flomore Ecoflo 35 electrical chemical injection pumps, (6) Norriseal 1001A electric level controllers, (7) Rotork CML 750 FA05 level control valve actuators, (8) Rotork CVL1000 FA07 inlet control valve actuator

Figures 9-11: Instrument Air Package – [clockwise from top left] (9) Trido electric air compressor package, (10) Trido electric air compressor, (11) Trido electric chemical injection pump

Figure 12: Qnergy PowerGen 5650

Figure 13: Argus Auto-launcher

Project Schedule

Q1-Q2 2020: Cenovus conducted a technology assessment to research viable options and collaborated with industry partners and peers to select equipment for trial.

Q3-Q4 2020: Cenovus partnered with vendors and technology manufacturers to complete detailed design.

Q1 2021: Cenovus installed trial equipment.

Q2 2021: Cenovus monitored and collected data on operating trial equipment.

Emission Profile

Summary of GHG mitigated due to the project

This project may mitigate 1,860 TCO2e/yr of GHG emissions from Cenovus operations in the first year. This is calculated based on a combination of measurements and calculations, including the metered instrument air volume consumed and chemical injected, and the calculated vent reduction using the automatic pig launcher system. See Appendix 1 for more details on the GHG calculations for this project.

Over a 10-year period, the estimated emissions abated will decline year-over-year due to declining well production, resulting in lower chemical consumption and less frequent actuation of pneumatic control devices. The GHG abatement profile is shown in Table 3.

Table 3: Project GHG Abatement Summary

Year	1	2	3	4	5	6	7	8	9	10	Total
Annual Project GHG Emissions Abated (TCO2e)	1,872	1,512	1,222	990	803	652	531	433	354	290	**8,658**

Abatement Cost

The following table summarizes the costs of the project. Note that these costs are incremental costs only and do not include costs associated with the components that are also used in the baseline, natural-gas driven design (e.g. RTU, process piping, etc.). Similarly, the Instrument Air Package did not include costs associated with the pneumatically driven controllers and actuators, as this was assumed to be part of the baseline cost.

Table 4: Project Cost Summary

Project segment	Cost
Electric Package A	$ 110,493
Electric Package B	$ 114,014
Instrument Air Package	$ 51,833
Automatic Pig Launcher	$ 139,696
Total	**$ 416,036**

The abatement costs of this project are expected to be $48.05/TCO2e abated over the next 10 years.

Conclusion

Project learnings

- There are numerous approaches to designing a well site with zero vented emissions and a variety of factors to consider when making a decision, including:
  - The quantity of equipment on site, particularly power-consuming devices,
  - Availability and quality of fuel gas for power generation,
  - Remoteness of the location and required autonomy and redundancy of any power systems and critical components,
  - Process design constraints and suitability of different equipment,
  - Emission sources that must be abated, which could include pneumatics, tank vents, pig traps, compressor seal vents, etc.

  As with any design, there are pros and cons to each approach (such as instrument air vs. electrification) and to each component (e.g. cost vs. features).
- The bulk of emissions reductions on standard well sites are driven by elimination of chemical injection pumps. This is because most pneumatic controllers today are low-bleed and vent much less than the previous high-bleed iterations. As such, it is important to focus on vent emissions abatement from pneumatic chemical injection pumps, particularly on newer wells with higher production rates and higher chemical consumption.

  Production batteries with hydrocarbon storage tanks are often another significant source of vented emissions, but tank vent abatement was not investigated as part of this project.
- A higher and more consistent frequency of pigging provided by the auto-launcher has resulted in significant production uplift from maintaining the pipeline clear of liquids. However, the auto-launcher portion of the project contributed the least to the overall GHG reduction, while imposing a significant cost.

Technology learnings

- In this project, it was observed that the electrical packages typically consumed more power than the instrument air package under the same operating conditions. Electric chemical injection pumps demanded the most power of all the electric devices.
- In this project, the manufacturer specifications for power demand are often much higher than actual. Cenovus worked with the vendors to determine the appropriate power supply requirements. However, since this was the first installation of most of this equipment in this application for Cenovus, some conservativeness was applied. As a result, Cenovus was able to revert to running on solar power during spring/summer months with Qnergy generator as a backup.
- Although running with solar power alone seems to be plausible, sizing a solar power system remains the biggest challenge, particularly through the winter months. Slight variations in electric equipment type and operating conditions can have drastic impacts on power demand, and thus require a large number of solar panels and batteries.
- The electric actuators are typically slower moving than the pneumatic equivalent. This was particularly noticed on the separator level control valves that are snap-acting open and close.
- Many electric chemical injection pumps are not well-suited to replacing pneumatic injection pumps in the early life of a well due to the high injection pressures and rates required. Cenovus trialed only pumps that claimed to meet this requirement. The top performing electric chemical injection pumps were the Trido and LCO Crossfire.

- It is important to closely monitor the performance of the auto-launcher and the effectiveness of the pigs. With some declining upstream pressures, there were some sealing issues with the pigs and it took time for pressure to build sufficiently to send the pigs. Some softer pigs will be trialed to help alleviate this. It was also observed that the pigs typical i91(\)Tj0.227 Td27 9 Td.5Tw rgT1 13Tf1.708 0 10.58 Td6494Tw

Appendix

GHG Abatment Calculation Summary

Instrument Air Consumption	5.8	m3/d
Natural Gas Equivalent	7.5	m3/d
GHG Reduction	41.7	TCO2e/yr
Est. Annual Decline	10%	per year

Chemical Consumption	150	L/d
Bruin 5100 Baseline NG Consumption	92.64	SCF/gal
Natural gas saved	104.1	m3/d
GHG Reduction	579.6	TCO2e/yr
Est. Annual Decline	20%	per year

Auto Launcher Vent Reduction	45.4	m3/month
GHG Reduction	8.3	TCO2e/yr

10 Year GHG Reduction	1	2	3	4	5	6	7	8	9	10	Total
Control Devices	41.7	37.5	33.7	30.4	27.3	24.6	22.1	19.9	17.9	16.1	271
Chemical Injection Pumps	579.6	463.7	370.9	296.8	237.4	189.9	151.9	121.6	97.2	77.8	2587
Total Per Well	621.3	501.2	404.7	327.1	264.7	214.5	174.1	141.5	115.2	93.9	2858
Total Pad (3 Wells)	1863.8	1503.5	1214.1	981.4	794.2	643.6	522.2	424.4	345.5	281.8	8574
Auto Launcher	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	83
Total	**1,872**	**1,512**	**1,222**	**990**	**803**	**652**	**531**	**433**	**354**	**290**	**8,658**