Emissions Reduction Alberta ("ERA") Final Report

1. TITLE PAGE

ERA Project ID:	202101539
Project Title:	Radio Frequency Enhanced Oil Recovery - RF XL Commercial Pilot Test
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	Project End: June 30, 2023
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	June 30, 2023: 7*
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Funding:	$5,000,000 ERA
Submission Date:	January 31, 2024

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2. EXECUTIVE SUMMARY

Acceleware's commercial scale pilot in Marwayne, Alberta ("RF XL Pilot"), demonstrated the operability of the patented and patent-pending RF XL technology; an all-electric, scalable, on-demand and highly efficient heating system using radio frequency energy ("RF energy") that can be applied to economically decarbonize production of heavy oil and oil sands. RF XL may be able to displace fossil fuel reliant heating systems that are GHG intensive and costly, and RF XL can be expediently deployed and operational.

The full-scale prototype of RF XL includes a patent protected inverter ("Clean Tech Inverter" or "CTI") that converts AC or DC electricity to RF energy and a patented protected subsurface heating technology that delivers the RF energy directly to the reservoir. The CTI uses leading edge silicon carbide ("SiC") transistor technology that results in over 98 percent conversion efficiency. RF XL is the first subsurface heating system designed to operate with horizontal wells of commercially significant length. It also eliminates expensive and complex underground components that were utilized in previous trials. When compared to SAGD or other in-situ heavy oil or oil sands extraction technologies, RF XL is near-zero GHG (greenhouse gas) emissions through direct or indirect use of renewable power, requires no central processing facility so is less capital intensive, uses significantly less land, requires no fresh water or solvents and results in no residual tailings.

The project has significantly impacted the application of RF XL as a subsurface recovery technology. Key outcomes include:

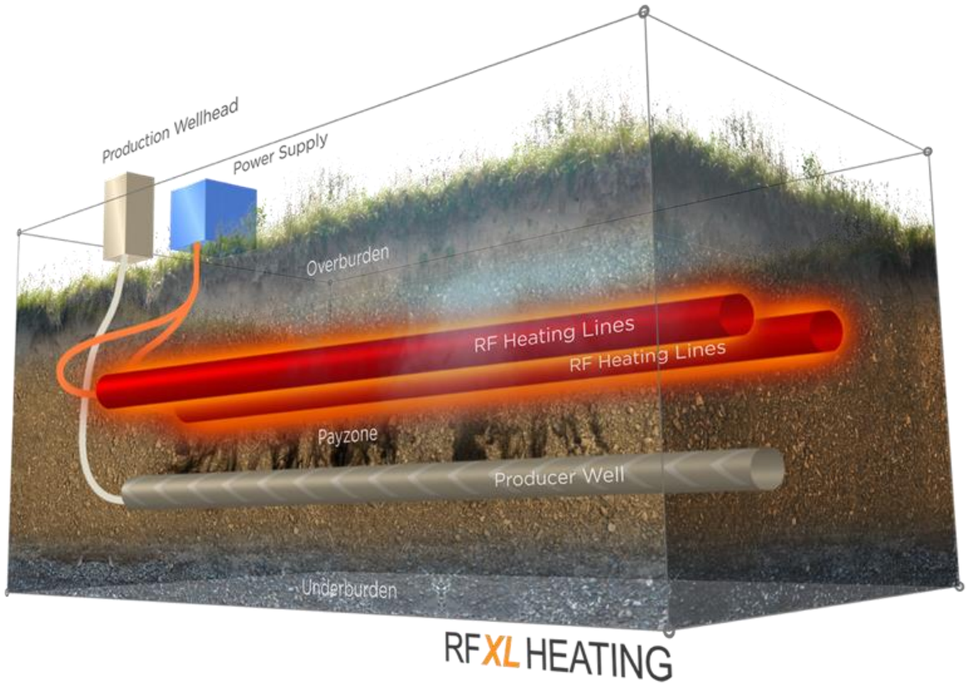
• Validation of the drilling and completion of a commercial length RF XL well pair, showing that heat can be transferred to the reservoir using this technology.

• Proving the performance of the proprietary Clean Tech Inverter (CTI) as an electrification engine that converts power into radio frequency (RF) energy.

• De-risking the limitations that have historically constrained RF heating, by proving both run life and power exceeding that achieved in any previous trial of in-situ RF heating.

Despite a lower than planned level of delivered power and resulting lower oil production, we believe the historical limitations to RF heating have been addressed through the work done on the RF XL Pilot, including activities performed during the workover. Without developing and deploying all aspects of the RF XL pilot including drilling the wells, completing a horizontal well system with RF XL components, and energizing the CTI and RF XL, we would not have advanced the technology from TRL 4 to 100% of TRL 7 and 70% of TRL 8 requirements. The RF energy generation component of RF XL is the CTI which is 100% TRL 8 and is being sought after by other industries for their industrial heating application projects. In aggregate this places RF XL at TRL 7+ as at June 20, 2023. This is described in more detail in section G. Outcomes and Metrics.

Further RF XL system performance, including high power, efficiency, and radiation patterns, has been limited due mechanical issues with the heating arms that started as soon as the wells were completed. To address the lack of high power, significant upgrades and improvements were designed, tested, and manufactured for the removable subsurface components during the workover which began November 10, 2022, and were ready for installation as of June 30, 2023. The issues also prompted the engineering team to design modifications and upgrades to the immovable subsurface components during this time. Given the highly complex nature of electrical systems, the work subsurface has required significant de-risking engineering efforts and novel scientific procedures. As of the date of this report, the subsurface upgrade work remains in progress.



3. PROJECT DESCRIPTION

RF XL is an all-electric, scalable, on-demand and highly efficient heating technology that uses RF energy to economically decarbonize production of heavy oil and oil sands.

The key goals of the project have not changed from the original objectives of the project and include the following:

- Validate the ability to drill and complete a functioning RF XL heating well, showing that the technology can generate heat to the reservoir.
- Validate system performance, high power operations, efficiency, and radiation patterns of the technology.
- Further de-risk and address limitations that have historically constrained RF heating.
- Monitor formation temperature and pressure as well as oil production levels and stability of the downhole RF XL components.
- Confirm the operation of the RF XL Inverter.

The performance metrics of the project include:

- Uptime of the CTI.
- Power delivery.
- AC to RF energy conversion efficiency.

• RF XL well length.
• Energy to oil ratio.
• Simulation accuracy using AxHeat software.

	Project Objectives	Results to Date
1.	Complete an in-ground test of the RF XL dynamic transmission line technology at full scale at a production site in Alberta.	A commercial-scale (800m horizontal) RF XL system, including the CTI, producing well and transmissions lines (vertical coax and horizontal radiating arms), has been installed and operational at a production site near Marwayne, Alberta. The project has experienced noteworthy progress over the test period.
2.	Development, construction, and testing of prototype RF generators.	The prototype RF generators (or CTI as it is now named) has been developed, constructed, and tested during the project with an uptime of > 80%, a conversion efficiency of 98% and over 95% downhole transmission efficiency, exceeding expectations. This objective is complete. The CTI is used to generate RF energy output from electricity input and has been lab tested, field tested, and CSA certified for operation. The CTI was transported to site and was operational from Mar 4, 2022, to October 4, 2022. Seven months of continuous operation was achieved, and individual CTI modules have been tested at full power. The CTI was also tested at its maximum voltage and at its maximum current.
3.	Impedance of the system matches numerical predictions, both before the RF is delivered and periodically over the course of heating.	Impedance of the system matched numerical predictions both at the 500kW field test and initially at the RF XL Pilot demonstrations to a level that is +/- 20%. Impedance at the RF XL Pilot decreased over time, indicating issues with the transmission line. Impedance of the system will continue to be compared to simulations over the course of subsequent heating.
4.	External currents at the well-head and on the surface are below industry standard levels, per Health Canada limits for electromagnetic radiation.	The external currents at the wellhead and on the surface are below industry standard levels and are within Health Canada limits for electromagnetic radiation based on the power levels demonstrated to June 30, 2023. Subsystems of RF XL have received CSA certifications. Safe levels of electromagnetic radiation will continue to be monitored and compared to electromagnetic safety standards over the course of any subsequent heating.

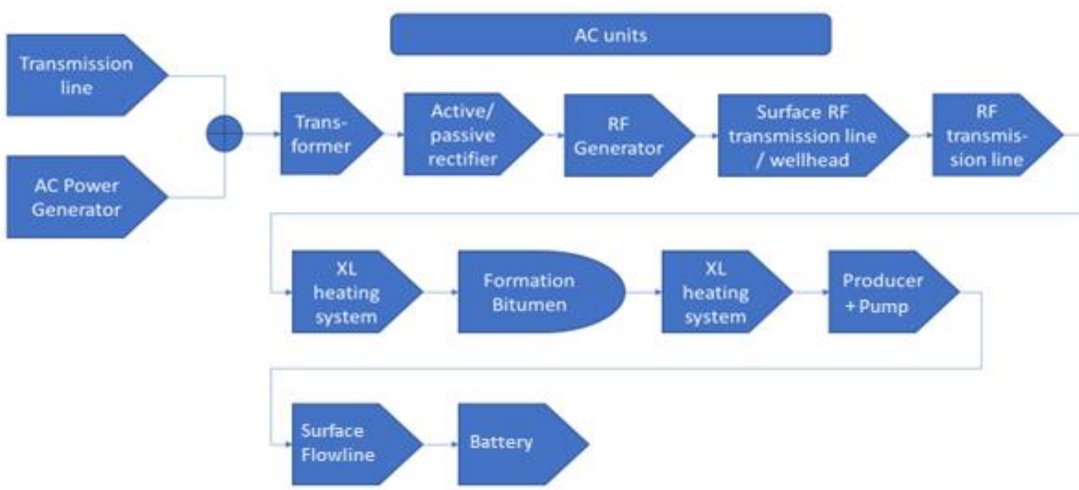
5.	Confirm economics of the technology	The economics for the capital cost of 2MW CTI, met Acceleware's target and all results to date continue to support initial economic assumptions for the energy to oil ratio. Heating results subsequent to June 30, 2023, are expected to provide further confirmation.
6.	Confirm AxHeat Software accuracy and achieve even heat distribution	Heat distribution of the RF XL Pilot to +/- 20% of test site simulations using AxHeat Software is supported by results from the RF XL Pilot to June 30, 2023. Further heating results will continue to be compared to this metric.

Table 1 - Project Objectives

4. PROJECT WORK SCOPE

Acceleware's proprietary, patent-protected Clean Tech Inverter (CTI) is an electrification engine which converts power into Radio Frequency (RF) power. Jointly developed with General Electric (GE) and using cutting edge silicon carbide (SiC) transistor technology, the CTI has delivered over 98% energy conversion efficiency at the Marwayne RF XL Commercial Test (RF XL Test).

The RF XL Test uses grid power to feed the CTI. This is connected to an upper heating well with two radiating arms. Below the heating well is a lower production well. The RF power is radiated into the producing formation, which is heated, increasing production from the reservoir. Production is then collected at the well battery.



The RF XL Test has 2 over-arching objectives:

1. To demonstrate the operability of the CTI at high power over a sustained period
2. To deploy the RF XL system downhole in a commercial-scale pilot

The development of the CTI technology was a multi-stage process. This began with significant design and laboratory testing. Following this were a series of field tests, designed to test and trouble shoot the CTI technology prior to full scale deployment. The final field test, discussed in this document, was a 500kW test. Once the 500kW field test was completed, the final design of the CTI was confirmed.

The pilot was designed to test the efficacy of the RF XL well system at a commercial scale. Two 800m long horizonal wells, one production well and one heating well, were drilled at the RF XL test site. The commercial-scale deployment of RF XL incorporated the updated CTI design as well as a specific heating well design to allow the transmission of RF power downhole through and out to the reservoir through two transmission lines connected to radiating arms. Specifically, the heating well is a two-leg multilateral well, with each of the legs designed to transmit power and therefore heat downhole. The upper portion of the heating well incorporated a coaxial transmission line structure (coax) that permits the transmission of high RF power down to the radiating arms, and prevents leakage of RF power at the surface or in the vertical section of the well. The coax and the radiating arms are designed to not only meet the electrical requirements of transmitting and radiating RF, but also to meet the mechanical rigors of deployment, the thermal requirements of heating, and the chemical issues inherent in a reservoir deployment.

The RF XL Test facility was designed to deploy the power from the CTI downhole and to manage and measure the operation of the heating well and the production from the producer well. Critical to monitoring is to accurately measure the temperature response from these operations. Acceleware's heating and production wells, all ~1450m in length (~800m horizontal) incorporate fiber optic distributed temperature sensing (DTS) in each leg for their entire length.

The Scovan designed surface facility consists of:

- Electrical building (e-house), housing the CTI and related switchgear, connected by cable to the heating wells,
- Production flow lines, test separator, and gas combustor,
- Two emulsion tanks, and
- Truck loading station.

The Marwayne Piot facility closely resembles a single well battery, with the addition of an e-house, rather than an expansive central processing facility. This demonstrates the promise of RF XL technology to significantly reduce the footprint of thermal operations.

5. TECHNOLOGY LEARNINGS

SITE

The Marwayne project is in Section 18-53-01W4 in the SE of the Cold Lake.

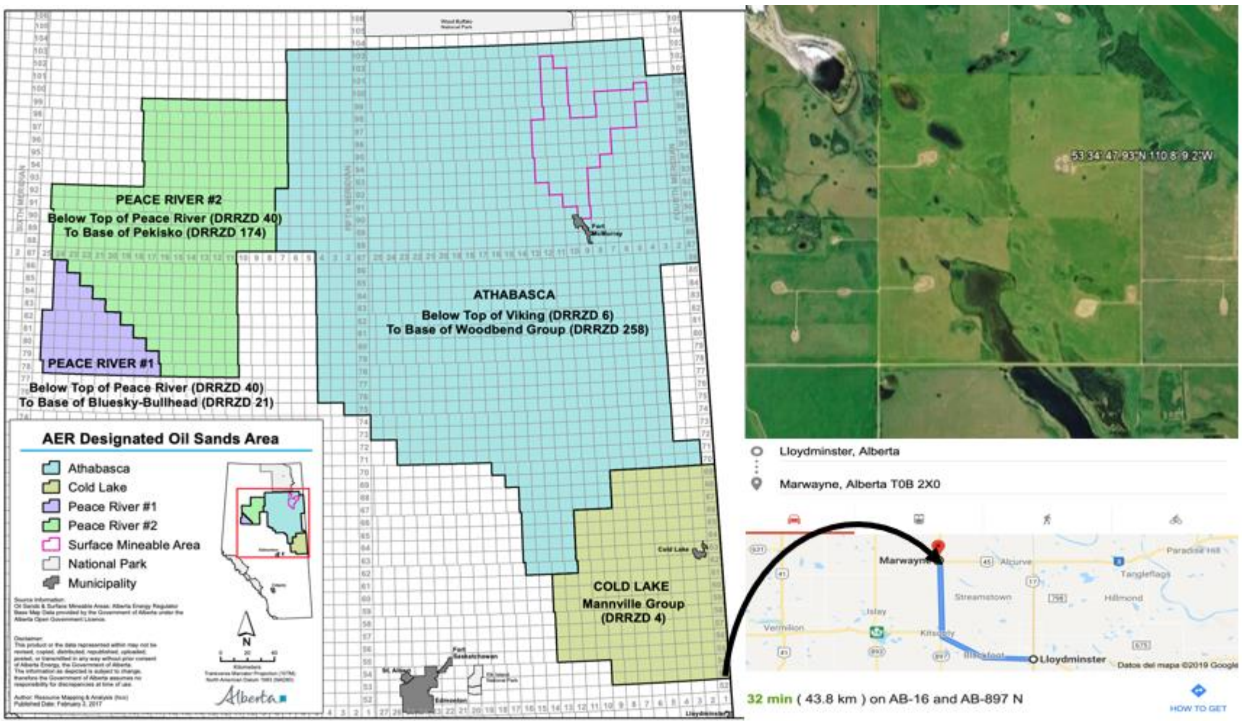


Figure 1 – RF XL Pilot Location

The site consists of the heating and production wells, production facilities, the e-house containing the CTI and an office. As there are no steam generation or water treatment facilities, it approximates the size of a cold flow production single well pad rather than that seen in thermal operations.

WELL DESIGNS

The RF XL Pilot has two wells, a production well and a multi-lateral heating well, all thermally completed.

The production well is completed similarly to a SAGD well, with a horizontal section of 800m. It is completed with a liner and production is pumped to the production facilities on surface.

The heating well was drilled with two 800m horizontal legs from a single build section. These legs are located 8-14m apart and are 5m above and centered over the horizontal production well.

The horizontal legs of the heating well were both completed with solid liners to act as radiating arms for the power. DTS fiber optics is run from the surface to the toe of the radiating arms to measure the temperature effects of RF XL. The radiating arms of the legs are electrically isolated from the upper section of the well by installing a proprietary isolation sleeve design.

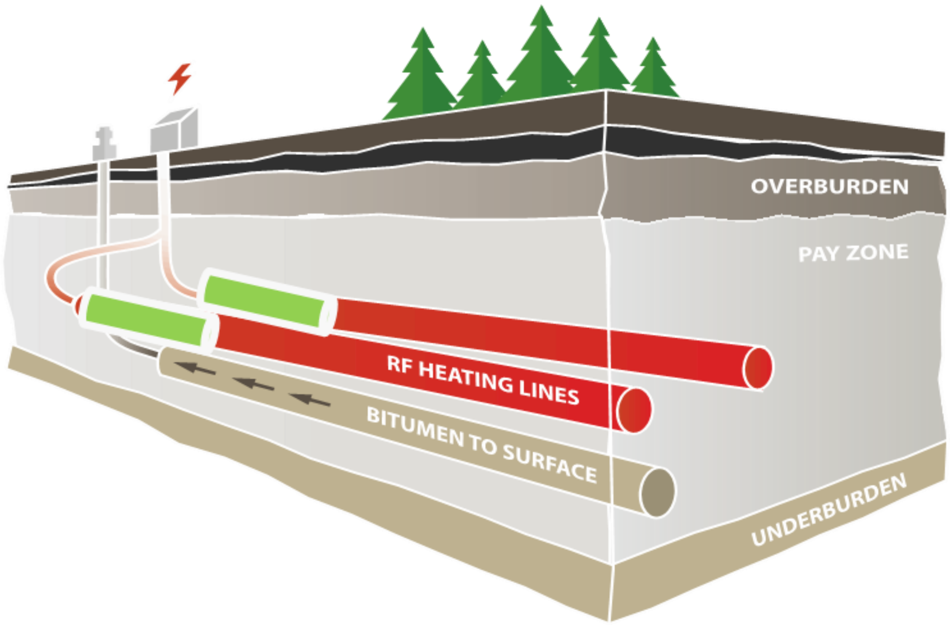


Figure 2 - Heating well design

The upper section of the well contains two proprietary coaxial transmission lines. The coax is designed to simultaneously transmit high-power RF, protect against fluid influx from the reservoir, and provide electrical ground.

FACILITIES

The RF XL Pilot surface facilities were designed by Scovan Engineering. Scovan's SAGD experience and expertise in electrical equipment design informed the design incorporating the e-house (home to the CTI). The facility itself resembles more closely a single well pad used for cold production with the absence of steam generation and water handling facilities. The image below reflects the design of the pilot. Of note, a second production tank was added to allow for more settling time prior to trucking production.

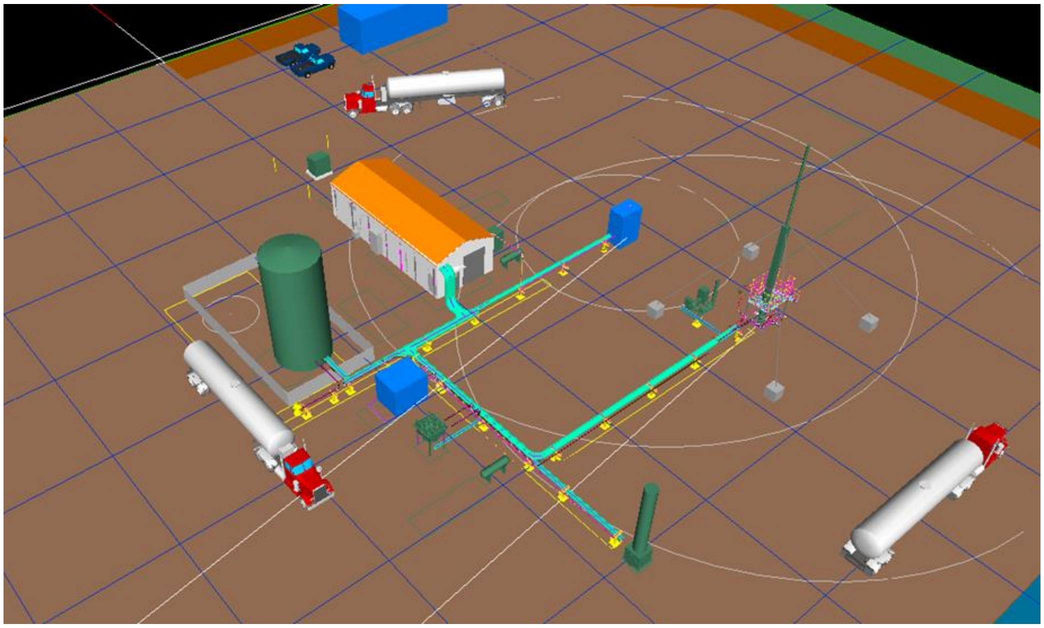


Figure 3 - RF XL Pilot Facility Design

The CTI is in the e-house indicated on the figure as the structure with the orange roof. The CTI functions as follows:

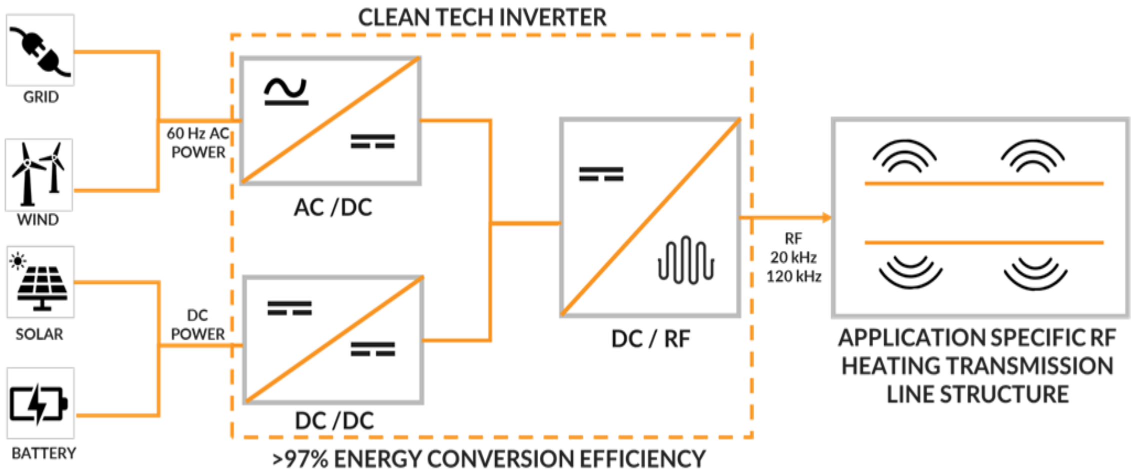


Figure 4 - CTI Functionality

The CTI deployed in Marwayne can operate using either AC or DC power inputs. As deployed, the system is connected to the AC grid (provided by ATCO) via the Acceleware designed rectifier. The operating frequency of the CTI is in the range of non-ionizing radiation and operated below the frequency of long-wave AM radio. The same design can scale from 20kW to 10MW in power, with an upper power range and frequency significantly higher than standard inverters.

Figure 5 – RF XL Pilot E-house

500kW FIELD TEST

From June 30, 2020, to July 1, 2020, a 500kW RF power test of the RF XL system was undertaken. The test aimed at verification of various system components: the operation of CTI RF power generation, the transmission lines that connect the CTI to the underground system, and the horizontal radiating arms buried near surface. This was considered a critical de-risking event prior to undertaking the RF XL Pilot.

The objectives of these tests were to:

- Deliver 500 kW of RF power to the radiating arms
- Maintain the power for a limited amount of time
- Test if the coaxial lines pressurized to 4 bars with CO_2 gas can withstand the required voltage of approximately 3000 V_{rms}, with same strength of electric field as expected in RF XL pilot

The electrical power was produced by a diesel generator at 60Hz AC current, rectified to DC, and then converted to RF frequencies by the CTI.

Figure 6- Diesel Generators with Transformers

Figure 7 - CTI

The underground radiation system impedance was measured using a vector network analyzer (VNA). As expected, in this scaled experiment the reactance was too high and resistance too low for successful RF power delivery by the CTI. To bring the impedance to a more acceptable level a matching circuit was designed and added to the excitation system of the radiating arms.

Two high power tests were performed using this experimental layout, one at 400kW and the second at 500kW.

The initial high-pressure test was successfully executed at 400 kW power level. It was used to monitor the temperature in the outer co-axial pipes as well as the other experimental components.

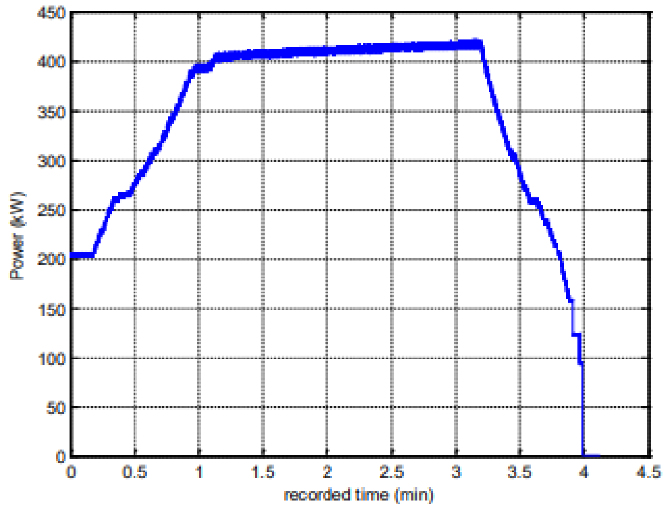


Figure 8 - 400kW test - RF Power delivered by the CTI

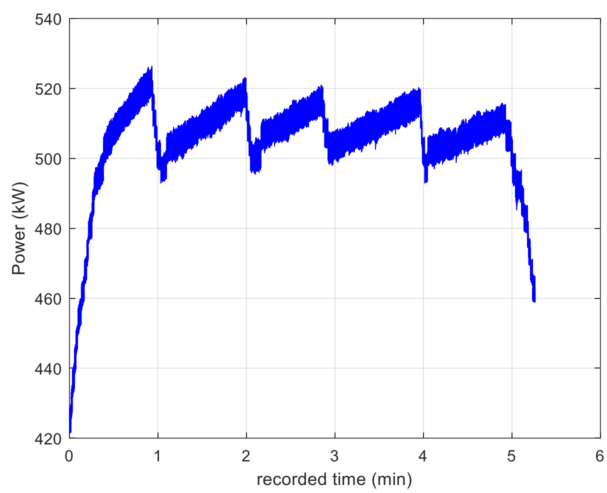


Figure 9 - 500kW test. RF power delivered by CTI

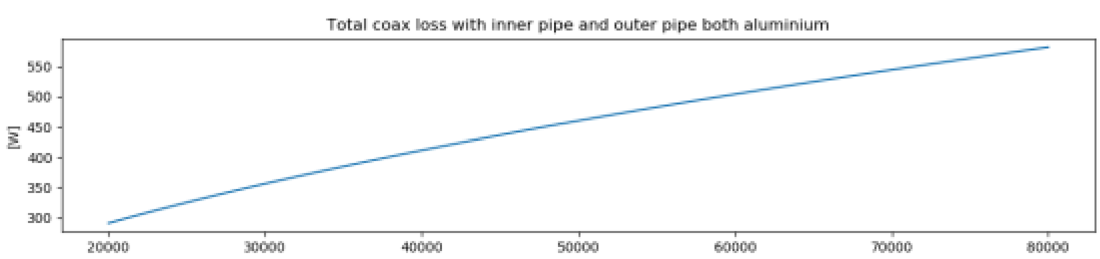


Figure 10 - 400 kW Test Coax Losses

A 500 kW test was then successfully executed. The temperatures were measured with fiber optics at critical locations of the CTI, with no components seeing temperatures >40^{o}C, meeting design requirements.

The results of the 500kW test demonstrated the efficacy of the CTI unit in converting and delivering high power DC current into RF Power and delivery of this power through co-axial cable to radiating arms. The conversion efficiency was 98%. This test was used as the model in the RF XL Pilot design.

The test used two of the eight CTI modules eventually installed and used in the RF XL pilot, confirming that each module can deliver 250kW of power, even in load conditions that were not optimal (and required a matching circuit).

The objectives of the test, were successfully achieved as described below:

1. Deliver 500 kW of RF power to the buried radiating arms.
    - The CTI was successfully able to deliver over 500kW of RF power into the underground radiating system.
2. Maintain the power for a limited amount of time.
    - High power was maintained for close to 10 minutes. The limitation was not the CTI or the underground radiating arms, or even transmission lines delivering power to the radiating arms, but rather the large inductors built for the test for impedance matching purposes. Impedance matching was required due to the short radiating arms specific to the ditch test and the high level of water table condition present because of recent rainfall.
3. Test if the coaxial lines pressurized to 4 bars with CO_2 gas can withstand the required voltage (approximately 3000 V_{rms})
    - This was successfully completed. We also performed destructive tests confirming that our high voltage modelling tools correctly predict maximum operating parameters for the coax.
4. Test and verify operation of the control system and sensors.
    - This was also successful. However, the test provided an opportunity to improve the robustness of some of the sensors, and communication lines of the control system, by to hardening their EMI tolerance. The hardened control/communication system was designed and tested and incorporated in the RF XL pilot.

RF XL PILOT OPERATIONS

The CTI was lab tested, field tested, and CSA certified for operation. It was transported to site, and was operational from Mar 4, 2022, to Nov 11, 2022. Seven months of near continuous operation was achieved, and individual CTI modules have been tested at full power. We have further improved robustness of the control system of the CTI implementing Acceleware developed and patent pending optical (fiber optics) communication system with sensors, as well as more distributed control and EMI protection. The system performed well even at maximum RF currents. The CTI was powered down on several occasions to perform downhole repairs or maintenance and to incorporate improvements to the control system and CTI sub-systems.

The power delivered to the radiating arms was generating heat in the formation as predicted by our simulations. The highest temperatures in both legs were observed around the isolation sleeve and the initial sections of the radiating arms, matching well with the expected temperature distribution from the simulations.

Heating at the production well was also observed. This heating was observed when the production well was shut in for work to be conducted on the heating well. A significant temperature increase was observed in the production well just past the ICP of the production well.

The survey below indicates where the temperature is measured on the production well relative to the ICP of the production well and the sleeves of the heating well. Of note the survey is measured in true vertical depth and the temperature measurements in measured depth, with the boxes highlighting the survey to correlate the 2 figures.

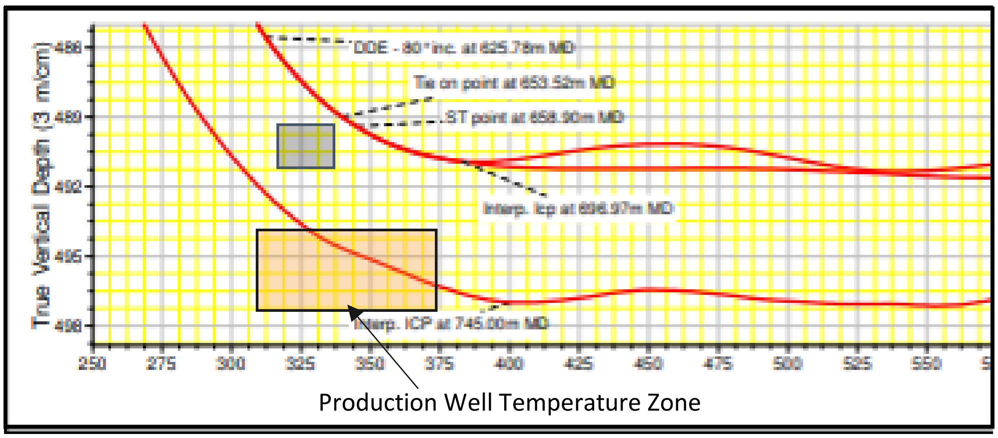


Figure 11 - Producer Well, Temperature Plot Location

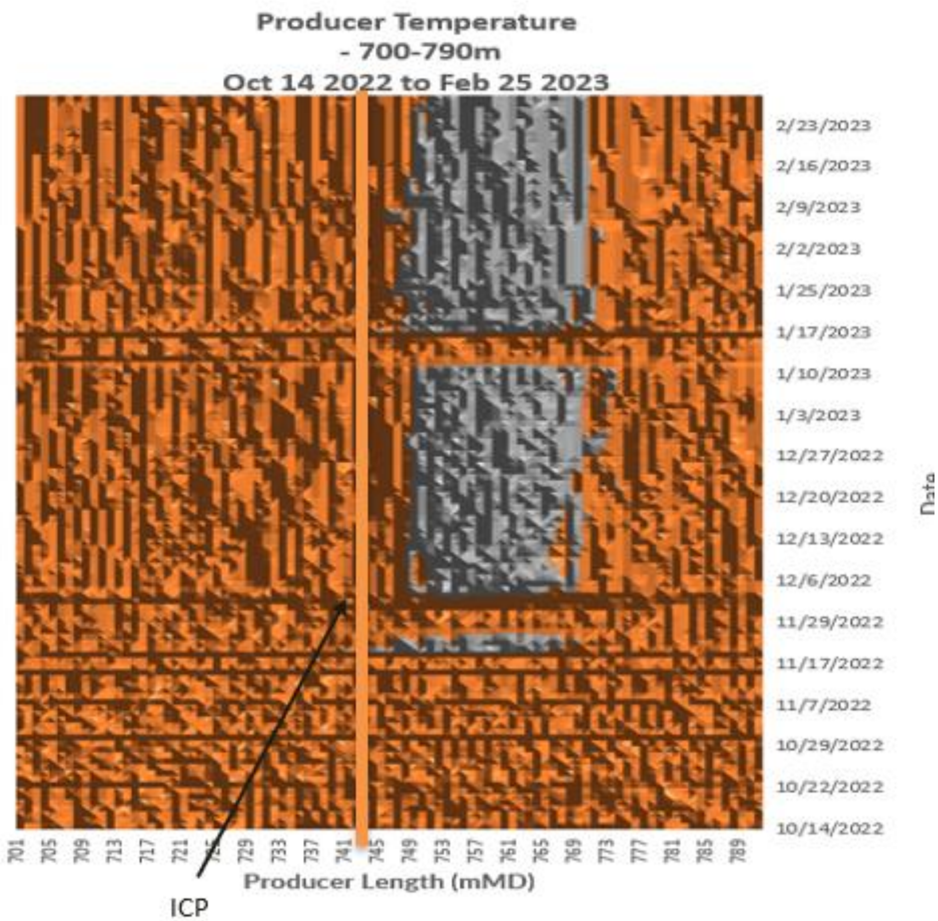


Figure 12 - Production Well Temperature Response

The temperature response in the production well was not sufficient to create a production increase. Our simulations predicted no change in production with the heat that was supplied to the system. As such, the simulation discussed will pertain to the heat observations in the heating wells at this time.

SIMULATION RESULTS

Temperature and production forecasts were created and updated for the Marwayne project. As the most significant temperature changes were observed near the sleeves of the heating well, the simulation forecasts were most relevant at this point.

Assuming a downhole pressure of 1500 kPa, the simulation predicted the temperature around the Isolation sleeve was very close to what we have observed experimentally.

During the period from April 20, 2022, to May 14, 2022, lower power was injected to the wells, but we continue to observe heating in the isolation sleeve are and into the formation.

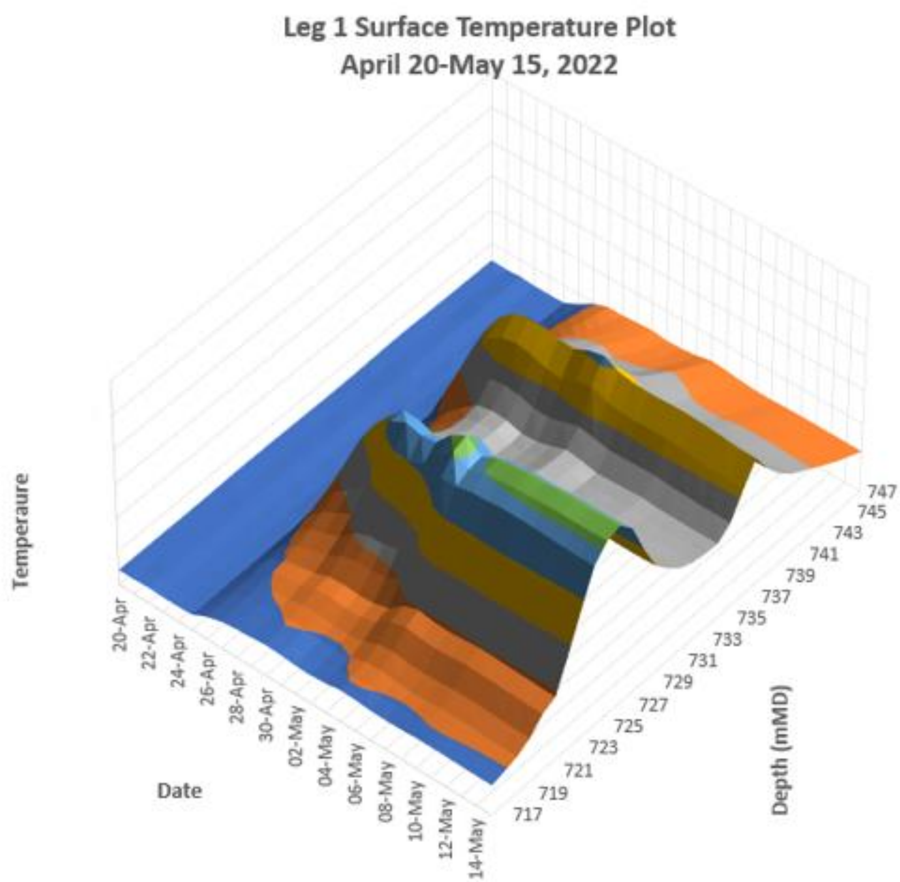


Figure 13 - April 20-May 14, Leg 1 Temperature Profile 717--747mMD

The actual temperature profile around the sleeve is consistent with the expected temperature from simulation with small differences. The temperature build-up ahead of the sleeve has a steeper slope than the temperatures on the far side of the sleeve, as heat is being transmitted past the sleeve to the radiating arm of the heating well.

With the data available, Acceleware remains confident in the predictive capabilities of the AXHeat simulation software coupled with the CMG software. With operation of the RF XL Pilot subsequent to June 30, 2023, Acceleware will continue to collect temperature, production, and pressure data and correlating these to the amount of power transmitted to the reservoir. Simulation of the continued operation will be ongoing, and the simulation forecasting will be tested, and the simulation will be updated as required, to strengthen predictability.

The objectives of operation subsequent to June 30, 2023 are to:

1. confirm AxHeat Software accuracy and
2. achieve even heat distribution.

The AxHeat Software simulations for the original field demonstration are noted below for temperature and output.

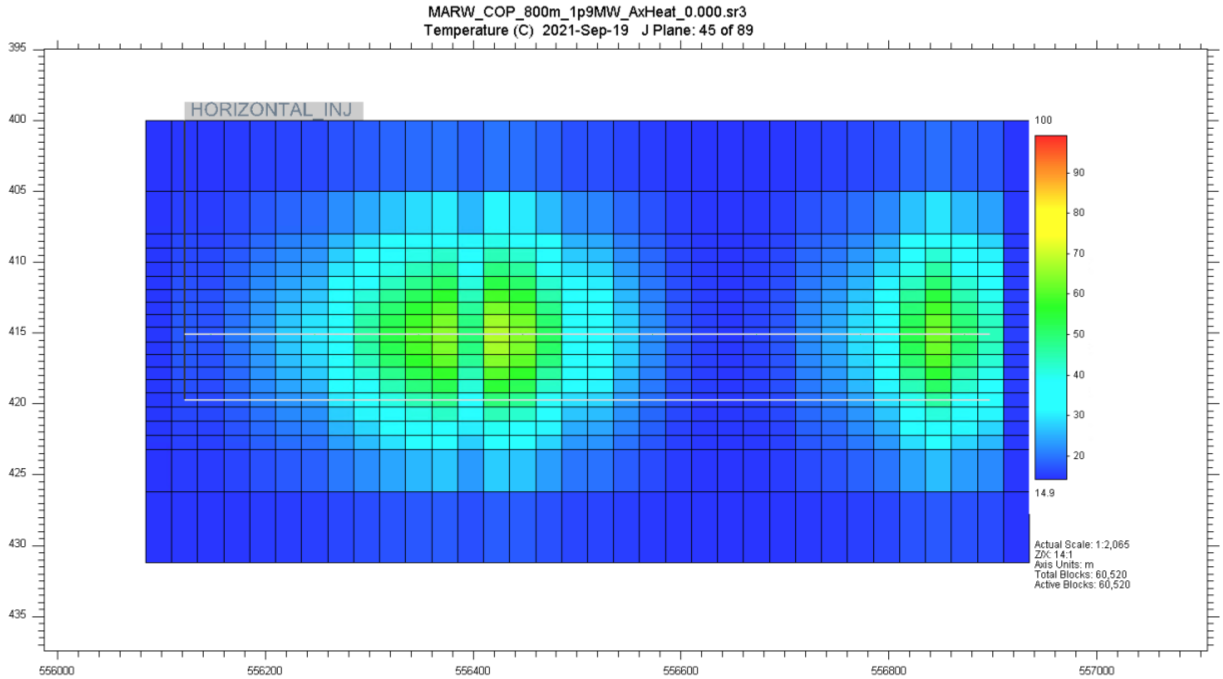


Figure 14 - Temperature Profile 2MW Along the Wells – 3 months

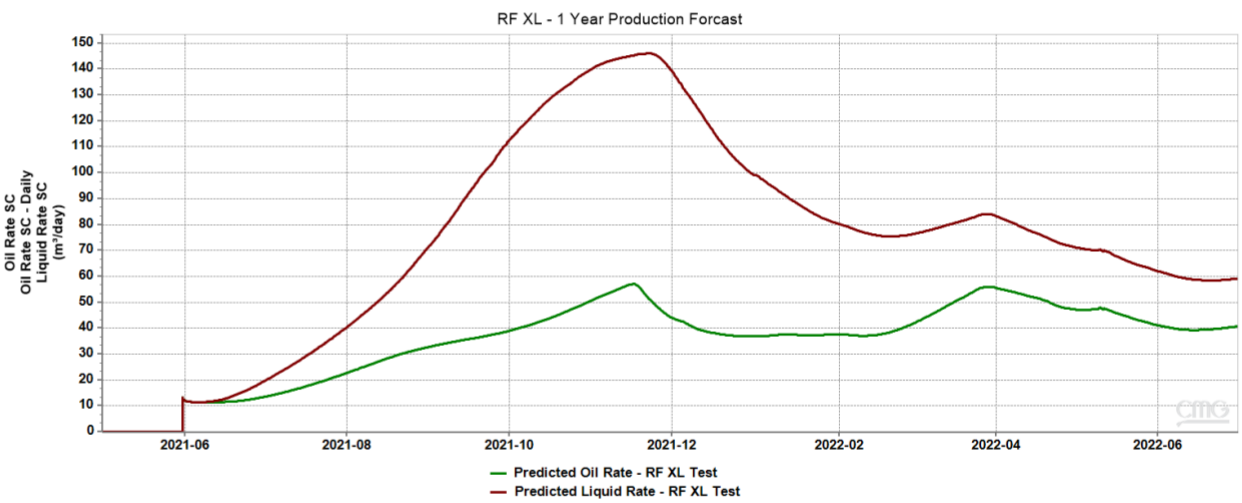


Figure 15-Simulation Output Forecast Rates – 2MW, 800m well

6. PROJECT OUTCOMES AND IMPACTS

The project has significantly impacted the application of RF XL as a subsurface recovery technology. Key outcomes include:

- Validation of the drilling and completion of a commercial length RF XL well pair, proving that heat can be transferred to the reservoir using this technology.
- Proving the performance of the proprietary Clean Tech Inverter (CTI) as an electrification engine that converts power into Radio Frequency (RF).
- De-risking the limitations that have historically constrained RF heating, by extending previous records for both run life and power.

CLEAN ENERGY METRICS:

Metric	Project Target	Commercialization / Mobilization Target	Project Actuals	Commercialization / Implementation Target Update
TRL advancement	7	9	7+	9
Field pilots/demonstrations	1	1	1	1
GHG emissions: Projected reductions from future deployment (to 2030)	n/a	14830	n/a	14830
Jobs: Actual new jobs created from project	16	n/a	22	n/a
Jobs: Projected new jobs created from future deployment	n/a	5908	n/a	5908
Patents & Records of Invention filed	23	>20	14	>20

The Clean Resources Metrics were advanced during the RF XL Pilot. TRL of the RF XL Pilot began at TRL 4 as at January 1, 2018 and moved into TRL 7 as at January 1, 2021. As at June 30, 2023, the RF XL Pilot had moved through TRL 7 such that work subsequent to June 30, 2023 will advance the technology to TRL 9.

Per the Technology Readiness Assessment Tools on the Alberta Innovates website here and the Government of Canada TRL Assessment Tool here, Level 8 notes that the actual technology is completed and qualified through tests and demonstrations, is proven to work in its final form and under expected conditions. To further decide if the technology is in TRL 8, we need to have developed the final configuration of the technology, successfully tested that configuration in an operational environment, and have documented, with plans to further develop the technology, resolutions for problems identified during operation in the 'real-world' environment. Although the RF XL Pilot has not been operated to 2MW of power (successfully tested in final configuration), the RF XL technology is developed in its final configuration, has operated on a commercial-scale basis for seven-months, and as noted in Next Steps, has several plans, options, and actions documented to resolve those limitations noted in the operational environment. As such, we have concluded that RF XL is in the final stages of TRL 8 with plans to move it into TRL 9 subsequent to June 30, 2023.

There were 22 jobs created during the RF XL Pilot compared to an estimated 16. Additional activities related to the extended time frame, changes in site location, and complexity of the workover have resulted in additional jobs in the RF XL Pilot. These jobs are primarily engineers.

Patents filed related to this work are listed in the Project Related Patent section. There were 12 patents filed prior to the start of the RF XL Pilot. Of those 12 patents, 10 were moved from filed to issued during the RF XL Pilot and the remaining two continue to be in progress. During the RF XL Pilot, there were an additional 33 patents filed with 8 of them issued and 25 still in development. There was considerable effort and cost invested in patents and this metric has been exceeded.

PROGRAM SPECIFIC METRICS:

Program Specific Metrics (Select the appropriate program metrics from the drop down list)

Metric	Project Target	Commercialization / Mobilization Target	Project Actuals	Commercialization / Implementation Target Update
$ intensity cost reduction on commercial deployment	$2.77	$2.77	tbd	$2.77
# energy intensity reduction	0.33	0.6	tbd	0.9
# of barrels of new resource unlocked	n/a	>700 billion barrels	n/a	>700 billion barrels
% Improvement of overall water use efficiency	100%	100%	100%	100%

The intensity cost reduction on commercialization and well as the energy intensity reduction of RF XL will be confirmed subsequent to June 30, 2023, however, it is still expected that the NPV per bbl for RF XL will exceed that of SAGD (using a 10% discount rate) and that there will be a reduction of energy intensity measured using GJ/bbl. The percentage improvement of the overall water use efficiency is 100% as there is no fresh water used with RF XL technology. The water use metric is an even more significant achievement for the technology in 2023 as all other recovery methods use some freshwater, create residual tailings and can result in irreparable damage to freshwater sources for communities nearby.

Analysis continues to show that RF XL could unlock over 700 billion additional barrels of oil for profitable production. The analysis will be validated subsequent to June 30, 2023.

PROJECT SUCCESS METRICS:

Project Success Metrics (Metrics to be identified by Applicant Representative)

Metric	Project Target	Commercialization / Mobilization Target	Project Actuals	Commercialization / Implementation Target Update
Uptime of RF XL Converter	>80%	>99%	94.10%	>99%
Power Delivery	2 MW	2-4 MW		
AC to RF conversion efficiency	>98% efficiency	>98% efficiency	>98%	>98%
RF XL Well Length	800m horizontal length	500 - 1500m horizontal length	800m horizontal length	500 - 1500m horizontal length
Energy Oil Ratio	tbd	1.75 - 3.75 GJ/m3	tbd	1.75 - 3.75 GJ/m3
Simulation Accuracy (AxHeat Software)	+/- 20%	+/- 10%	tbd	+/- 10%

Both the RF XL Pilot and the 500kW high power field test have created confidence in the CTI, the power delivery structure, and the AC to RF conversion efficiency.

- The uptime of the RF XL Converter was 85% in the 500kW test and 94.1% in the heating operations of the RF XL pilot from March 4, 2022, to November 11, 2022. When the downtime resulting from downhole issues was subtracted from the calculation, the actual effective uptime of the uptime of the RF XL converter was 99%, exceeding the project target and matching the commercialization target.
- The power delivery of 500kW was met in the high-power test, there was high power (though lower than planned) delivery in the operational environment (highest ever achieved) and there are plans to achieve full power subsequent to June 30, 2023.
- In both the 500 kW test and the RF XL Piot, the AC to RF conversion was >98%.
- The drilling of the RF XL well length of 800m was achieved.
- Simulation Accuracy was confirmed in the 1/20 scale test to +/- 15%. In the RF XL Pilot, the downhole heat, particularly around the sleeves of the heating well was also as predicted with simulation. There was not sufficient power in the pilot to cause significant heating in the production well, therefore, simulation of oil production and production well heating will be confirmed subsequent to June 30, 2023.

Scientific accomplishments to date include:

- RF-XL (Radio Frequency XL) RF power generation system and power delivery system de-risking Phase 1 & Phase 2;
- 2 MW Clean Tech Inverter completed and tested, AER (Alberta Energy Regulator) experimental scheme approval received, all remaining funding confirmed;
- The 500kW heating test results in June 2020 validate that the technology works as intended, however our ability to operate at higher power has been limited by downhole challenges unrelated to the core technology. Challenges have been addressed and tested in redesigns and are ready to deploy in an extended test.

- Operation of the RF XL Pilot, while less than full design power, was at the highest level ever delivered by an RF heating system to a downhole formation,
- Evidence of reservoir heating at the heating well and at the producer well, and heating profiles that conform to simulation are all evidence that RF XL operates as expected. Further evidence is expected to emerge with the extended test.
- Design refinements and de-risking tests, procurement of materials & equipment for construction; and
- Design and implementation of new fiber optics communication technology to communicate with sensors in an environment with high EMI noise.
- Development of hardened RF current and voltage sensors.

Once the RF XL system is re-installed downhole, the system will be powered back up. It is expected that heating will resume and that it will continue for a minimum of three months after power-up to show heating consistency and to produce oil at temperatures warmer than cold flow production.

PROJECT RELATED PATENTS

Patents have been issued/allowed during the RF XL Pilot (12), pending or in development during the RF XL Pilot (25) or developed and issued/allowed during the RF XL Pilot (8).

SAFETY CERTIFICATIONS

During the time when the CTI is powered up and generating RF power, a system of sensors is actively measuring stray RF fields and stray currents that could potentially be returning to the surface from the underground radiating arms over the external surfaces of the wells. These systems have fiber-optics connections with the control system and are designed to execute emergency system shutdown if any of the sensers detects anything abnormal. Over the entire time that the system was active, both the electromagnetic (RF) fields observed on the surface, and the currents measured on the wells external surfaces were at noise level, well below the industry electromagnetic safety limits.

The electrical and electronic components of RF XL system at our pilot site are in two main locations: E-House building (MCC), and the well-head enclosure. The e-house building contains power switchgear, PLCs, control systems, auxiliary equipment, as well as Acceleware's high efficiency rectifiers and CTI inverter. The electronics at the fenced/gated wellhead enclosure contains capacitor banks and high-voltage, high-power connectors. For safety, an unauthorized opening of the gate to the wellhead area triggers emergency shut down.

Acceleware devoted considerable effort and expense to receive the CSA certifications for our equipment and safety code certifications from the municipality with oversight responsibility at the RF XL Pilot site (County of Vermilion River). All equipment in the e-house received CSA certifications. Likewise, the electronic equipment in the wellhead enclosure also received CSA certifications.

Additionally, the county safety code certifications were obtained prior to operations.

7. ECONOMIC AND SOCIAL IMPACTS

The successful implementation of this technology will result in:

- Lower emissions intensity - with less than half the energy required by Steam Assisted Gravity Drainage (SAGD,) RF XL could immediately lower GHG emissions by up to 50%, producing near zero GHGs when using renewable power.
- Other environmental benefits - fresh water use can be eliminated, land use reduced, and there is no requirement for solvents.
- Greater cost competitiveness for our oil - capital and operating costs are expected to reduce by ~ 40% each.
- Additional oil recovery. With the lower capital and environmental intensity of RF XL relative to other thermal operations, operators can produce thermally in reservoirs previously considered as marginal thermal prospects and extend thermal operations in existing plants. The follow on impacts of this are increased employment, royalties to the resource owners, particularly the provinces of Alberta and Saskatchewan, and increased tax revenue both federally and provincially.
- Creation of jobs - Alberta's economy requires maintenance of existing jobs and creation of highly skilled jobs, including jobs for Indigenous peoples.
- Expanded market opportunities - RF XL could open the door to clean production of bitumen by-products such as petrochemicals, carbon fibre, and hydrogen, and increase export potential.

8. NEXT STEPS

INVESTIGATION

The conclusions of the results from the pilot to June 30, 2023 include:

- Installed and demonstrated the successful operation of Acceleware's Clean Tech Inverter with a capacity of 2MW.
- RF heating was observed downhole in both the heating and production wells as predicted by simulation corresponding to the amount of power delivered downhole.
- Mechanical issues with the coax resulted in limitations in the amount of power that could be delivered downhole, and degradation in some downhole components was observed.
- In an attempt to determine the cause of the reduced power, the DTS fiber was inadvertently severed in leg 1.

In November 2022, removable components were pulled from the heating well. On December 1, 2022 a camera and caliper run were run as far as the latch in leg 1. This, along with previous attempts at well cleanouts with gas of the well confirmed the fluid ingress.

By pulling the equipment from the well, degradation of the components was confirmed.

Figure 16- Leg 1 Image of Severed DTS Fiber at Latch

REDESIGN ACTIVITIES

Acceleware is investigating 10 alternatives for operations subsequent to June 30, 2023.

PROPOSED RESTART

The proposed restart date will vary depending on the path chosen. Broadly, restart is planned the first half of 2024. In the case of a single leg workover, the restart is likely early 2024 while the re-drill alternatives will result in a restart in mid-2024.

LONG TERM COMMERCIALIZATION PLAN

RF XL is the first of several electrification of industrial heating applications that Acceleware is commercializing since the near-term decarbonization of heavy oil and oil sands production will play a critical role in a successful energy transition. Work is also underway on the decarbonization of heavy emitting industrial heating applications including the drying of mining ore and agricultural products and the production of hydrogen via methane pyrolysis.

ACTIONS OVER THE NEXT 2 YEARS

Upon the successful completion of the Marwayne pilot Acceleware expects to deploy one or more RF XL systems with operators in Canada or internationally. Many companies have expressed interest in deploying the technology once it has been proven to operate as planned. These initial deployments will serve to further validate the potential benefits of the technology and prove that it is ready for broader deployment in the market.

POTENTIAL PARTNERSHIPS

Acceleware anticipates potential partnerships with engineering companies and service companies who could support the deployment of the systems as well as be involved in the planning, site design, and maintenance of future RF XL projects.

9. OVERALL CONCLUSIONS

Acceleware's Radio Frequency Enhanced Oil Recovery - RF XL Commercial Pilot Test has made considerable progress since January 2021, and met significant project objectives.

First among these was the demonstration of the operation of the CTI. Acceleware has demonstrated that the CTI can operate successfully at full power.

Commercial length (800m horizontal) RF XL heating and production wells were successfully drilled and completed. A facility was designed and constructed to accommodate production and an e-house was included in the facility design to house the CTI. Control software was developed to monitor the project and control the CTI.

Operational in March 2022, the project has significantly affected the application of RF XL as a subsurface recovery technology. Key outcomes include:

- Validation of the drilling and completion of a commercial length RF XL well pair, proving that heat can be transferred to the reservoir using this technology.
- Proving the performance of the proprietary Clean Tech Inverter (CTI) is an electrification engine which converts power into Radio Frequency (RF).
- De-risking the limitations that have historically constrained RF heating, by showing both run life and high power.

Completion of the heating well workover and DTS (Distributed Temperature Sensor) repair and additional field demonstration is expected to continue in the second half of 2023. The heating well workover includes changes to the downhole design of the heating well to improve the performance of the pilot. This will allow increased reservoir heating and confirm the economic impact of this technology and Ax-heat Software accuracy at higher power levels.

Once successful implementation of this technology will result in:

- At least 50 % lower GHG emissions intensity.
- Elimination of fresh water use, and reduced land use.
- Capital and operating costs reductions.
- Creation of highly skilled jobs.
- Expanded market opportunities.

RF XL could prove to be a transformative decarbonization technology for heavy oil and oil sands production. Not only can it eliminate direct GHG emissions, but it would also eliminate the requirement for fresh water and significantly reduce land footprint. This decarbonization technology can play a key role in the energy transition.

10. COMMUNICATIONS

Acceleware has presented at several events such as the Global Energy Show, COSIA events and through the CHOA and intends to further present at conferences such as these. We continue to publish and promote our story through an extensive social media and video blog program that will continue to highlight successes and accomplishments with RF XL. As we begin working with new clients to deploy the technology on their sites, we will continue to look for opportunities to publish whitepapers and present at industry conferences. We will keep sharing the results of those projects and communicate the potential benefits of the technology for other operators to the extent that our clients are willing to share project results..

Acceleware has issued more than 20 News Releases in the funding period. These can be found here on our website News Releases. In that same time, there were many social media postings and media coverage opportunities that can be found here also on our website.