Final Project Report (Revision 1)

Reporting Period: Nov 1, 2018 to March 31, 2020

Project Title: Energy Intensity Reduction through FCDs and NCG
Agreement Number: E0160359

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Project Partners: N/A
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Project Schedule			***Cost Status***		
(1)	____	Project on schedule	(1)	____	Cost on budget
(2)	____	Project delayed	(2)	____	Cost overrun
(3)	____	Project cancelled	(3)	Yes	Cost underrun
(4)	Yes	Project complete			

Contents

List of Tables and Figures

1 Executive Summary

Athabasca Oil Corporation ("Athabasca") successfully reduced energy intensity associated with mature Steam Assisted Gravity Drainage (SAGD) well pairs through Non-Condensable Gas (NCG) co-injection at the Leismer facility, located near Conklin, Alberta.

As recovery from a mature SAGD well pair increases, the steam-to-oil ratio (SOR) can increase due to increasing heat losses and a higher energy intensity. NCG co-injection reduces the energy intensity by replacing steam volumes in the developed steam chamber while maintaining oil production. Two milestones were involved in the execution of this project. The first was to make well and pad modifications. Flow orifices on the injection wells were upgraded to allow NCG injection and measurement. As NCG is injected some of that gas is expected to be produced back at surface. To accommodate higher gas volumes, an evaluation of the Bornemann multiphase pumps was done on each of the four pads. One of the Bornemann pumps was rebuilt to manage the increased gas rates. Operation of the three other Bornemann pumps on other pads were optimized to tolerate any NCG returns. This portion of the project was under budget since only one of the four Bornemann pumps were upgraded. With modifications made, the second milestone of NCG co-injection started June 2019.

From June 2019 to March 2020, the SOR for Pads 1 to 4 was reduced 25% from 4.5 to 3.25. This achievement is more than the initial project target of 10%. Furthermore, the project success metric was achieved earlier than the target December 2021, as stated in Schedule A. There has been 4,804 e3m3 of NCG injected.

With NCG, a total of 245,725 m3 of steam has been saved to date. This equates to a reduction of approximately 32,500 tonnes of CO_2 emissions and 22 tonnes of NO_x emissions. With continued SOR reduction on Pads 1 to 4, the estimated emissions reduction over the next 10 years is 722,500 tonnes CO_2. This does not include emissions reduction if NCG is expanded to other approved wells in the Leismer property. The successful application of NCG co-injection to reduce SOR while maintaining oil production will be shared with industry through Athabasca's normal reporting methods.

2 Project Description

2.1 Introduction and Background

Athabasca proposed to reduce energy intensity associated SAGD well pairs through two technologies at their Leismer facility. The two technologies proposed were FCDs and non-condensable gas co-injection (NCG), which will reduce the SOR at a well level leading to a lower greenhouse gas energy intensity. FCDs were installed in five new well pairs that were brought into service during Q2 to Q3 2019. NCG was deployed in up to 17 additional well pairs on existing pads across the field beginning in Q2 to Q3 2019. FCDs and NCG technologies can be implemented on a well-by-well basis and used as a tool to improve the SOR on challenging wells that historically operate with higher energy intensities.

1. Flow Control Devices (FCDs):
Athabasca piloted FCDs at its two SAGD operations, Leismer and Hangingstone. Based on the early success of the pilots, Athabasca proposed to pursue installation of FCDs on five new well pairs, within a new development area known as Pad 7. FCDs allow oil to be more efficiently produced from a well pair for a given unit of steam injected, thereby improving the energy intensity of the well. Based on the pilots, FCDs decreased the SOR by more than 10% on a well pair basis.

2. Non-Condensable Gas Co-injection (NCG):
Athabasca has piloted NCG co-injection at their Leismer facility from 2015-2018, varying from 1-5 well pairs. Based on the early success of the NCG pilot, Athabasca would like to further pursue implementation of the technology at their Leismer asset. NCG co-injection would lead to reduced water usage, reduced fuel gas consumption, and lower greenhouse gas emissions by more than 10% on a well pair basis.

The final outcomes report for FCD technology was submitted April 3, 2020. This report will outline NCG achievements, conclusions and future recommendations.

2.2 Technology Description

In an idealized system, SAGD is a process that incurs thermal efficiency losses once the steam chamber has maximized vertical conformance and is conductively interacting with the reservoir top. The reservoir top is often associated with non-reservoir facies that results in less efficient deployment of latent heat. NCG co-injection is a means to decrease the overall energy intensity of a well pair and optimize the SOR.

The principle behind NCG co-injection is the injected methane gas moves to replace the void space left behind by the drained emulsion and condensed steam. The chamber pressure is maintained because the gas does not condense. For SAGD well pairs interacting with the overburden, the methane concentrates at the top of the reservoir, thus aiding in the reduction of heat losses to the overburden, while also driving steam migration and bitumen mobilization in the lateral direction.

Commonly, NCG serves as a means to maximize mature well performance, however, NCG can be implemented throughout the life of a SAGD well pair and at varying concentrations relative to steam. Coupling steam with NCG is referred to as wind-down and serves as a precursor to blow-down, which is the complete replacement of steam with NCG, to maintain chamber pressure and capture less economic reserves. Figure 1 captures the theoretical application of NCG within a single well pair system.

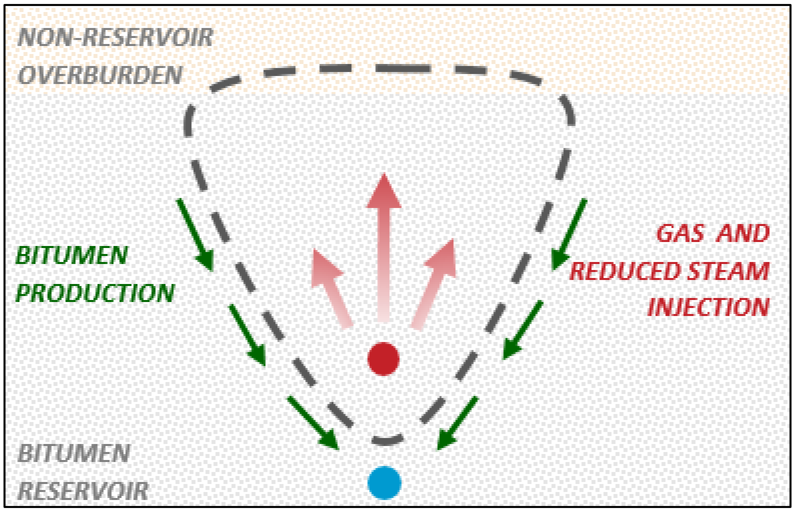

Figure 1 NCG Process

Based on the Leismer pilot thus far, NCG co-injection has lowered the SOR by 10-15% resulting in less steam requirements, reduced water usage, reduced fuel gas consumption, and lower greenhouse gas emissions. NCG co-injection began at Leismer in 2015 and by the end of 2016, two well pairs were on NCG co-injection as indicated in Figure 2 below. Based on the success of those two well pairs, L4P4 and L4P5, three more well pairs from Pad L4 were placed on NCG co-injection in late 2017 although those results were impacted by facility outages and subsequent artificial lift failures.

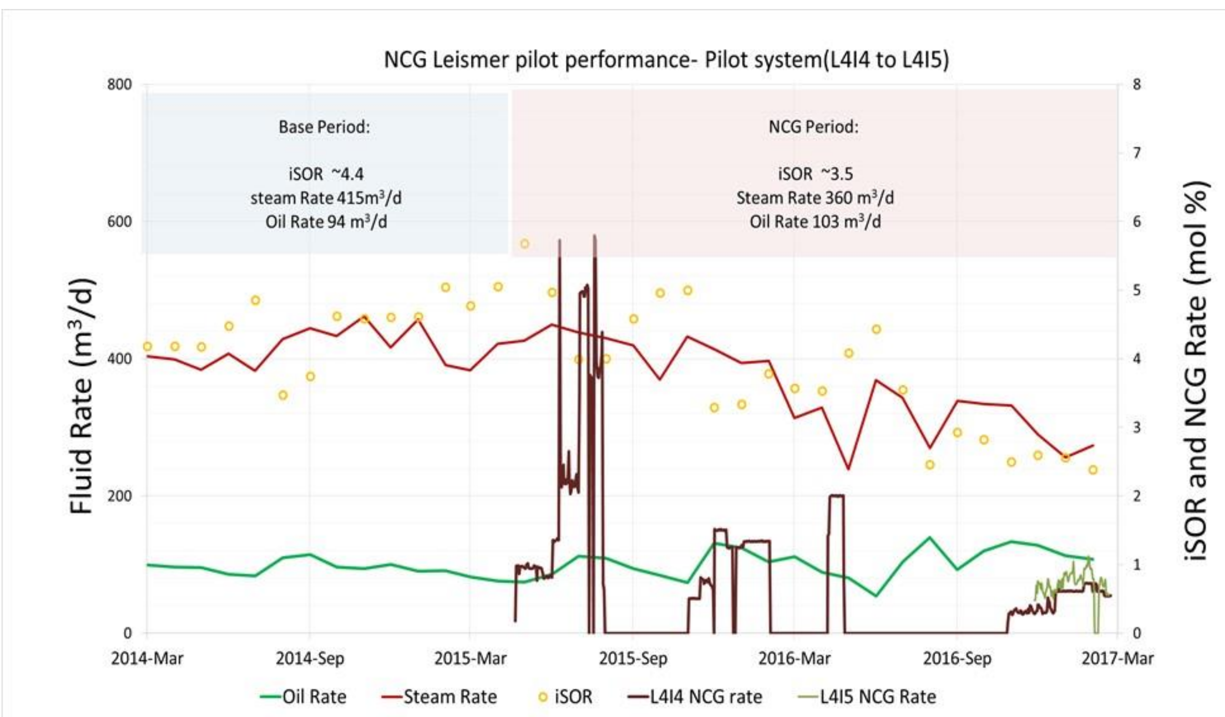

Figure 2 Results from NCG Co-Injection Pilot at Leismer

A summary of NCG application at other projects can be seen in Table 1. This shows that Athabasca's Leismer NCG pilot was consistent with results from other operators.

Table 1 Industry NCG Analogues

Operator (Project Area)	**Timing of Implementation** (Years after Start-Up)	**Operating Strategy**	**Corresponding Concentration** (mol%)	**Gas Reservoir Retention**	**Performance Observations** (Positive, Neutral, Negative)
MEG (Christina Lake, A1-A3)	Early Life (~3 Years)	Well Long	1.0 – 10.0	65 – 85 %	↑Oil Rate, ↓SOR (40%) ↓Water Retention
MEG (Christina Lake, PadV: V1-V6)	Early Life (~3 Years)	Well Long	0.75 – 5.0	0 – 25%	↓SOR (15-20%) ~Oil Rate
Connacher (Great Divide, Pad 101N)	Mid-Life (~4 Years)	Well Long	1.0 – 3.5	80 – 90%	↓SOR (10-15%) ~Chamber Pressure, Oil Rate
AOC (Leismer, L4-4)	Mid-Life (~5 Years)	Steam Long	0.2 – 2.0	70 – 85%	↓SOR (10%) ~Chamber Pressure, Oil Rate
JACOS (Hangingstone, HS1-A & B)	Mid-Life (~6 Years)	Steam Long	1.0 – 3.0	~92.5%	↑Oil Rate, ↓SOR (10%) ~Chamber Pressure
Devon (Jackfish1, Pad A)	Late Life (~7 Years)	Well/Steam Flexibility	1.0 – 2.0	~90%	↑Oil Rate ~Chamber Pressure ↓Intermittent Operation
Suncor (MacKay River, Pattern A)	Late Life (~8 Years)	Well/Steam Flexibility	0.75 – 1.5	~75%	↑Production from IHS ~Chamber Pressure, SOR, Oil Rate

Specifically, NCG application in Leismer has mirrored that of Greenfire Hangingstone (formerly JACOS), with similar benefits. NCG application in HS1-A and HS1-B is similar relative to the single-well pilot in Leismer, L4P4. Despite Leismer's prominent basal McMurray feature, the operating strategy and operational timing are similar. Both assets operate with a steam long scenario without the deployment of infill wells for the locations of NCG application. NCG co-injection commenced approximately 6-years after start-up with similar concentrations. Both assets demonstrate an equivalent iSOR reduction, with pairs A and B showing two separate intervals of sustained iSOR reduction. Figure 3 captures the benefits of a molecular concentration of approximately 2% to maintain chamber pressure and allow for steam reductions without impairment to oil.

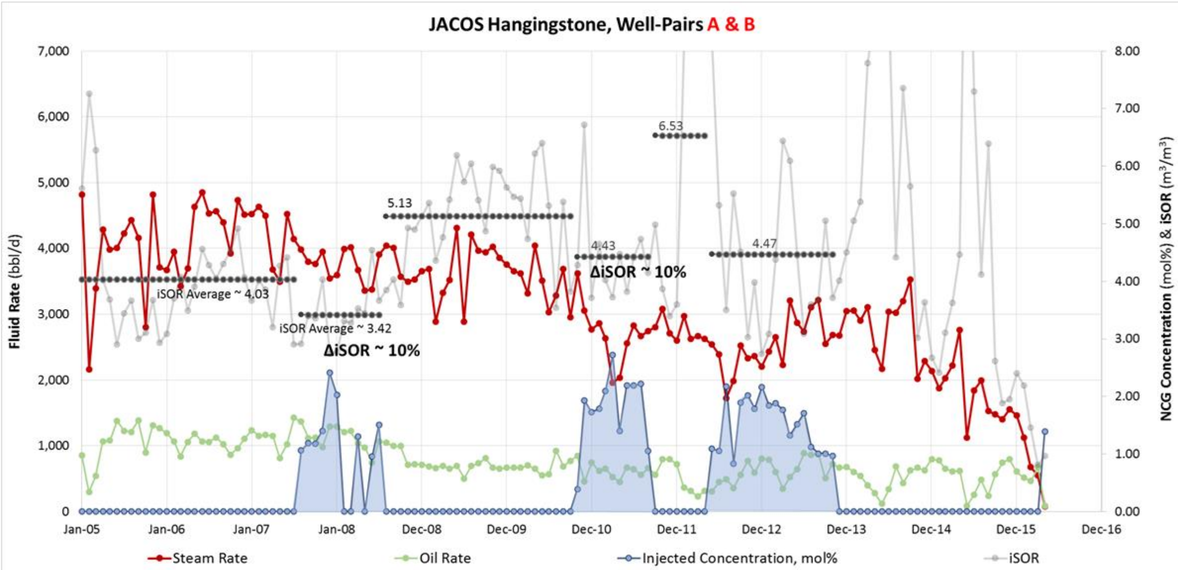

Figure 3 Application of NCG at JACOS Hangingstone HS1

Alternative technologies to NCG are solvent co-injection which also reduces the SOR intensity of SAGD operations as light end components (e.g. butane, pentane, etc.) are co-injected with steam. Solvent co-injection operations are more capitally intensive compared to NCG operations.

2.3 Project Goals

The main project goal for NCG co-injection was to decrease the energy intensity of mature SAGD pairs on Pads 1 to 4. The expected results are based on analysis of the first two Leismer NCG pairs piloted in 2015-2016.

Table 2 Success Metric for NCG Project (from Schedule A)

Success Metric	Project Target	Commercial Target	Prior Achievements
NCG GHG SOR Reduction	> 10%	> 10%	> 10%, Pad L4 actuals
NCG and FCD oil production	No negative impact	No negative impact	No negative impact

2.4 Work Scope Overview

The NCG work scope included two milestones. The first milestone was well modifications to allow NCG co-injection with steam and pad modifications to increase surface gas handling from NCG returns (milestone 5 from Schedule A). The second was to inject NCG for SOR reduction (milestone 6 from Schedule A). The scope of work for each milestone is outlined in this section.

2.4.1 NCG Injection – Injection Well Modifications

In order to inject NCG downhole, well modifications were made. One of these changes was on the injection wells which requires flow orifices to be changed as this will impact the flow characteristics and gas velocity into the reservoir. These modifications were completed internally in April 2019.

In addition to the injector well orifice change, the initial work scope included upgrades to the Bornemann pumps on Pads 1 to 4 to handle NCG returning from the reservoir. The Bornemann multiphase pumps on Pads 1 to 4 were running near design limit and, once NCG was co-injected into the reservoir, was suspected they would not be able to handle the additional load capacity and, subsequently, would not be able to transfer the fluid back to the Central Processing Facility (CPF). A thorough evaluation of each pumps' performance led to optimized operation on three of the four pumps which has allowed Athabasca to produce the NCG gas returns with existing equipment. There was one exception where the Bornemann pump was re-built. The work scope included design specifications required for the rebuild, hydraulic modelling and vibration analysis and prediction. Operation of all Bornemann pumps will be continually monitored and the need for any future upgrades will be determined on a case by case basis.

2.4.2 NCG Injection – Gas Handling

Depending upon the reservoir response, the total amount of NCG injected into the reservoir will vary from approximately 40,000 to 100,000 m3/d. On a well pair basis, this would be ~ 3,000 to 5,000 m3/d of gas and 30% of the injected gas is expected to be recycled. The project budget assumed a natural gas price of $1.66/GJ including transport costs (AECO $1.50/MMBtu).

3 Outcomes and Learnings

3.1 Project Outcomes

Modifications to the injector flow orifices to allow NCG co-injection was completed across all pads by April 2019. The installation allows proper injection and metering of the NCG. This equipment will be considered in future well designs so future retrofits would not be required.

One of four Bornemann multiphase pumps to increase gas handling at the pads was re-built, whereas the upgrade of the other three Bornemann pumps has been deferred. The operating conditions of the pumps are being optimized which has allowed NCG returns to be sent to the CPF. The upgrade of the pumps will be re-evaluated on an as needed basis pending optimized operation and volumes of increased produced gas. This portion of pad modifications was completed on schedule and under budget compared to schedule A.

With modifications complete, gas injection started as per Table 3:

Table 3 NCG Pad Start Dates

Pad	NCG Start Date
1	June 2019
2	October 2019
3	June 2019
4	November 2019 (restart date)

Since June 2019, continuous NCG co-injection and steam reductions were made as shown in Figure 4. NCG is added for voidage replacement as reservoir pressure decreases, total fluid continues to be removed and less steam is injected. NCG injection is active on 22 wells and was approaching a total rate 35,000 m3/d at the end of March 2020. Total NCG will exceed 40,000 m3/d as energy intensity is continually lowered. The total volume of NCG injected to date is 4,804 e3m3 at a cost under budget compared to the original estimate from Schedule A. The difference in cost is due to the fact that Athabasca was able to achieve its success metric of 10% SOR reduction ahead of the December 2021 project end date at lower NCG volumes. With NCG co-injection, the total volume of steam that has been removed from Pads 1 to 4 since June 2019 to present is approximately 245,700 m3 shown by the shaded area in Figure 4. This saved steam volume resulted in less fuel gas being consumed.

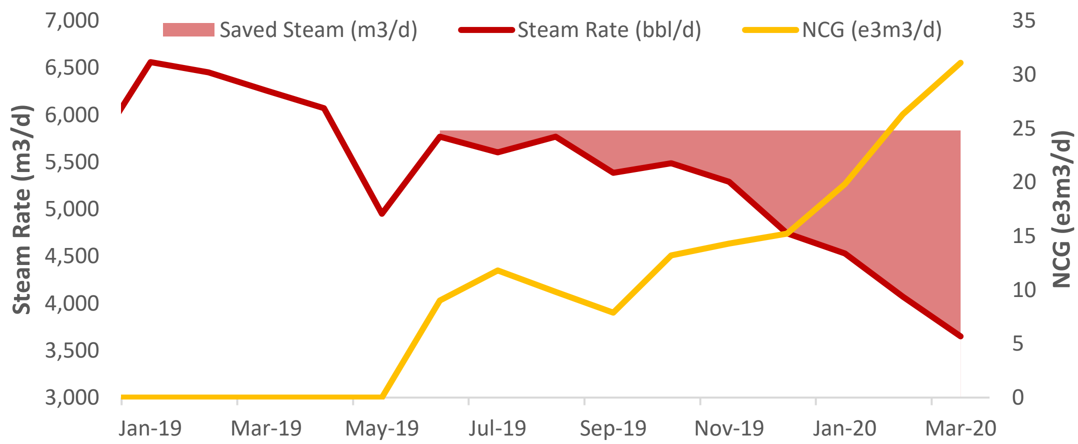

Figure 4 Pads 1 to 4 2019 – Present Steam and NCG Injection Rates

Figure 5 shows the SOR improvements that have been achieved. Total SOR for Pads 1 to 4 crested over 4 m3/m3 in February 2019 and continued to rise. A peak SOR of 4.5 was observed in October 2019 prior to more aggressive NCG co-injection and SOR reduction. As of March 2020, the SOR has been reduced to 3.25. This 25% SOR reduction is more than twice the original project goal of >10% SOR reduction. The rate of SOR reduction is limited by the water balance at the central processing facility. As steam is reduced, less produced water is required for steam generation therefore there is excess produced water that must be disposed of. The current SOR equates to a total steam for Pads 1 to 4 near 3,650 m3/d. Figure 5 also shows that steam rates for these pads has not been this low since 2011.

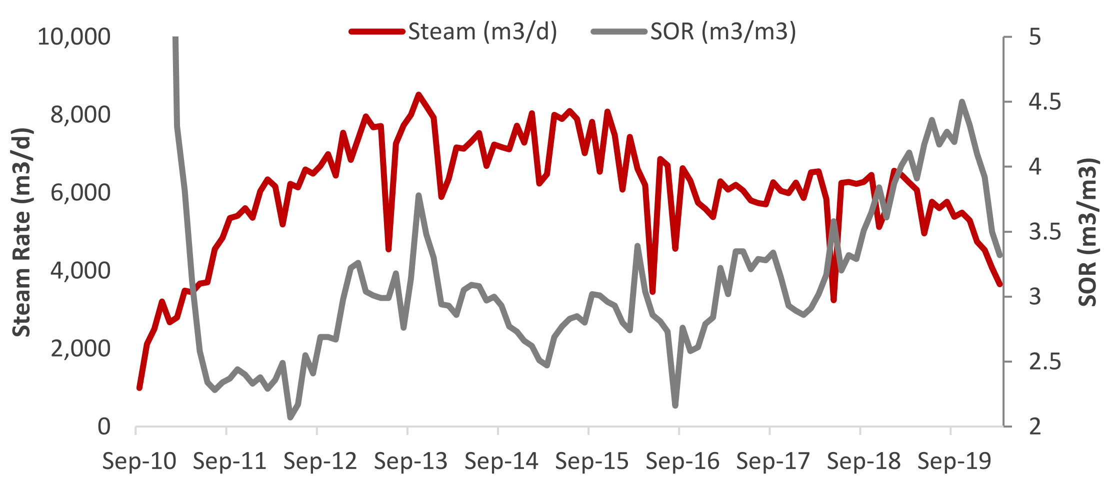

Figure 5 Pads 1 to 4 Historical Steam and SOR

Figure 6 shows the historical oil rates from the pads, which demonstrates that oil rates have not been impacted by the NCG co-injection and SOR reductions. Oil rates continue to follow a decline similar to the decline observed prior to NCG.

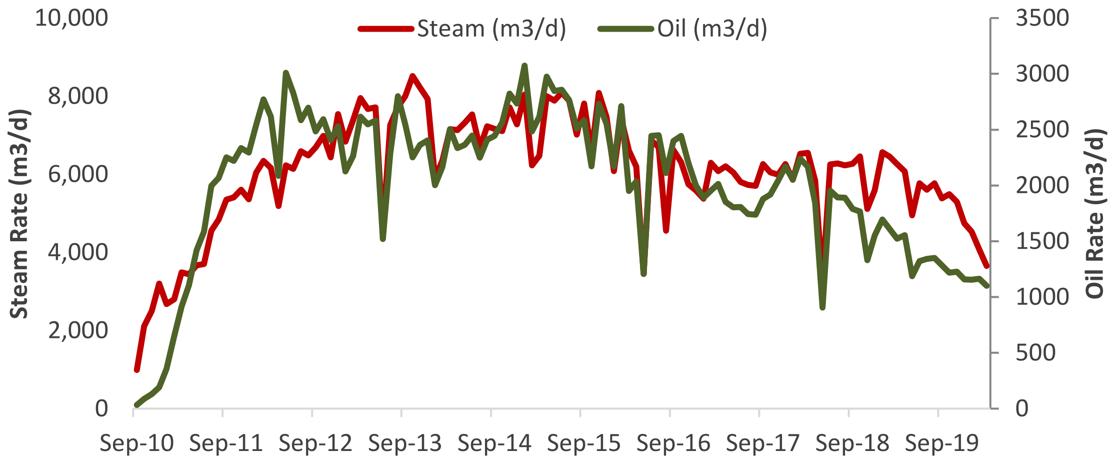

Figure 6 Pads 1 to 4 Historical Steam and Oil Rates

3.2 Important Lessons Learned

Athabasca's NCG co-injection project was successful at reducing SOR at mature pads. Some of the key lessons learned are:

- NCG can be injected at Leismer with modification to its existing facilities
- Energy intensity and SOR can successfully be reduced with NCG co-injection and steam reductions
- Reduced steam generation lowers fuel gas consumption
- Oil production is maintained during NCG co-injection
- Steam reductions can result in excess produced water at the CPF

4 Greenhouse Gas Reductions and Benefits

4.1 Qualitative discussion about the GHG benefits resulting from the completed project, including immediate benefits and potential future impacts

The approximately 245,700 m3 of steam saved from June 2019 – March 2020 resulted in less fuel gas consumed in the steam generators. This saved steam volume equates to a GHG emissions reduction of approximately 32,500 tonnes of CO_2 emissions and 22 tonnes of NO_x emissions. In the first 10 months of NCG, Athabasca has achieved 60% of the original 3-year target of 57,000 tonnes. As SOR reductions are maintained on Pads 1 to 4 with NCG co-injection, the reduced emissions will continue to accumulate.

4.2 Quantification of expected annual GHG benefits projected over a ten-year period, including both direct impacts from implementation of the project and future impacts based on market adoption

Without NCG, the SOR for mature SAGD wells would continue to increase as shown in Figure 7. NCG allows mature SAGD to continue at lower energy intensity and SOR. Athabasca's current forecasts with lower SOR shows a potential total of 5,400,000 m3 of steam saved over the next 10 years on Pads 1 to 4. This would result in a GHG emissions reduction of 722,500 tonnes of CO2 and 527 tonnes of NOx.

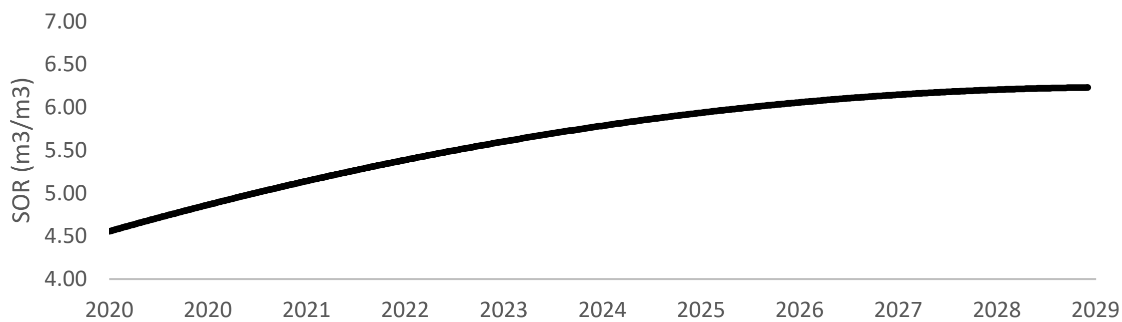

Figure 7 Mature Pad SOR Forecast without NCG

GHG emissions would be further reduced if NCG was increased on these pads to the point where steam is completely taken away. Athabasca is also considering when NCG can be executed on other pads in Leismer.

4.3 Discussion about the immediate and potential future non-GHG benefits resulting from the completed project.

With NCG co-injection at Leismer able to reduce SOR and steam demand at mature pads, Athabasca can allocate that steam to future projects without the need of adding additional infrastructure which saves indirect emissions through construction, material and transportation.

Successful demonstration of NCG implementation for energy reduction at Leismer Pads 1 to 4 will be shared in Athabasca's annual D54 reporting. This information can be reviewed amongst industry peers and applied to other SAGD projects.

5 Overall Conclusions

NCG co-injection successfully lowered the energy intensity of mature SAGD recovery ahead of schedule and under budget. With NCG, SOR was reduced by 25% within 10 months of startup, more than double the initial project target of 10% over 3 years. Well and pad modifications were completed under budget. The total NCG injected volume of 4,804 e3m3 from June 2019 to March 2020 was at a cost also under budget. The 245,700 m3 steam saved resulted in 32,500 tonnes of CO2 emissions saved. Over the next 10 years, there is an estimated additional 722,500 tonnes of CO2 emissions savings.

6 Scientific Achievements

With results from this project being so recent there has not been any publications or presentations based on this project to date.

7 Next Steps

Based on the NCG results at Leismer Pads 1 to 4, Athabasca will be able to continue to optimize SOR reductions and subsequently reduce GHG emissions at these pads. Leismer currently has approval for NCG co-injection for all of its current and future SAGD wells.

8 Communication Plans

The results from the project will be communicated through channels that Athabasca regularly uses to provide updates to the industry. These include, but may not be limited to, annual D54 regulatory reporting, industry meetings, monthly data reporting to the AER, and conferences and presentations to the industry when presented with the opportunity.