MEG ENERGY

Sustainable. Innovative. Responsible.

eMVAPEX Commercial Demonstration

Non-Confidential Final Report

Project ID F0160215

Report Completed: February 2020

Prepared for:

Emissions Reduction Alberta

Prepared by:

MEG Energy Corp.

Disclaimer

Emissions Reduction Alberta (“ERA”) makes no warranty, express or implied, nor assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information contained in this publication, nor does that use thereof not infringe on privately owned rights. The views and opinions of the author expressed herein do not necessarily reflect those of ERA. The directors, officers, employees, agents and consultants of ERA are exempted, excluded and absolved from all liability for damage or injury, howsoever caused, to any person in connection with or arising out of the use by that person for any purpose of this publication or its contents."

MEG Energy Corp. (“MEG”) makes this report based pursuant to the terms of the contract between ERA and MEG (the “Agreement”). MEG reserves all rights in respect of intellectual property owned by MEG and nothing herein is intended to convey, assign or license any intellectual property thereto other than as set out in the Agreement.

Information set out herein, including estimates of future performance or benefits are made based on numerous assumptions and facts which MEG currently believes are reasonable, but which may now or in the future prove incorrect or subject to change. MEG makes no warranty, express or implied, nor assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information contained in this publication.

1. PROJECT INFORMATION:

Project Title:	eMVAPEX Commercial Demonstration
ERA Project ID:	F0160215
Submission Date:	February 28, 2020
Project Completion Date:	December 31, 2019
Total Project Cost:	$61,232,741
ERA Total Funding:	$10,000,000
ERA Funding Holdback:	$2,000,000
ERA Project Advisor:	Bruce Duong

2. APPLICANT INFORMATION:

Applicant (Organization):	**MEG Energy Corp.**
Address:	21st Floor, 600 – 3rd Ave SW Calgary, Alberta, T2P 0G5
Applicant Representative Name:	Kyle Thacker
Title:	Sr Reservoir Engineer
Phone Number:	1-587-233-8326
Email:	kyle.thacker@megenergy.com

3. PROJECT PARTNERS

The eMVAPEX project was supported with funding from Emissions Reduction Alberta, Alberta Innovates (AI), Natural Resources Canada (NRCan), and Sustainable Development Technology Canada (SDTC).

A. EXECUTIVE SUMMARY

MEG is an Alberta company focused on sustainable in situ development and production. As of the date hereof, MEG's bitumen production averages approximately 93,000 bbls/day. For long term success, MEG uses innovation to lower the cost and greenhouse gas (GHG) emission intensity of bitumen production. Steam generation is the main contributor to GHG emissions and the operating cost of bitumen production. The concept eMVAPEX (enhanced Modified VAPour EXtraction), an extension of MEG's patented eMSAGP (enhanced Modified Steam And Gas Push) technology, involves injection of light hydrocarbons (ex. propane) in lieu of steam after initial steam assisted gravity drainage (SAGD) operation when bitumen recovery reaches approximately between 20-30%. It is anticipated that an industry standard SAGD asset with an SOR of 2.75 could increase bitumen production by up to 75%, with the same steam assets, by employing eMVAPEX. The resulting overall GHG emission intensity could be reduced by up to ~43%. Also, the overall recovery from the reservoir is expected to improve. eMVAPEX, when deployed commercially, is anticipated to have significantly improved capital efficiencies relative to SAGD, reducing the cost barrier to bringing on additional in situ production.

The eMVAPEX pilot began operating at MEG's Christina Lake Regional Project (CLRP) in late 2016 and this project is the 3rd Phase of the pilot. Phase 3 consists of 7 well patterns operating using eMVAPEX, and a propane recycle facility. Results have demonstrated the majority of the objectives are achievable, including a significant reduction in SOR. However, piloting activities will continue in 2020 to continue to evaluate the performance, as well as eliminate propane injection on some wells to test post-propane injection performance. A commercialization decision is anticipated to be made by the end of 2020. If successful, future MEG pads, as well as other SAGD producers, could begin transitioning to eMVAPEX as early as 2023.

Table of Contents

List of Tables

List of Figures

B. INTRODUCTION

SAGD is an energy intensive process that requires significant investments in steam generation and water treating capacity. SAGD facilities are typically configured with steam generation situated at a central processing facility (CPF) with further steam deployment out to the pad. Steam is generated with a series of stationary combustion sources (commonly once through steam generators (OTSG's)) consuming fuel such as natural gas or mixed fuel gas. Typically, stationary combustion emissions will account for approximately 99% of the total in situ facility GHG emissions with steam generation accounting for more than 90% of this. Therefore, reducing the steam generation requirements per barrel of production is key to lowering a facility's GHG intensity. Through the use of targeted solvent injection, the eMVAPEX initiative aims to increase bitumen production and recovery, and reduce GHG and water use intensities by reducing the SOR. eMVAPEX is uniquely positioned to take advantage of existing SAGD steam facilities. By converting SAGD operating wells to eMVAPEX, SAGD operators can potentially realize significant value.

C. PROJECT DESCRIPTION

Technology Description

eMVAPEX is a modification of VAPEX (VAPour EXtraction) invented by Roger Butler. For VAPEX, the well arrangement is the same as that for SAGD (i.e. a well pair located near the base of the reservoir), with the steam replaced by (hot or cold) solvent vapour. In VAPEX, the solvent condenses and dissolves in the bitumen resulting in viscosity reduction of the oil phase.

eMVAPEX is a 2-step modification of VAPEX. In VAPEX, solvent vapor alone is injected right from the start. For MVAPEX, the 1st modification to VAPEX, there is an initial SAGD mode until the average temperature in the target reservoir region is in a range for bitumen to become mobile. For typical Athabasca bitumen, this range is 60-100^{o}C and is realized after 3 to 5 years of SAGD operation at about 20-30% of SAGD recovery. At this stage of the process, the average bitumen viscosity in the reservoir region outside the chamber is similar to the viscosity of heavy oil, and solvent injection in vapour form begins with or without steam/non-condensable gas (NCG), resulting in increased oil rates and lower cumulative SOR (CSOR), as compared to SAGD. In the 2nd modification, the process is further enhanced by drilling additional producers (infill wells) between adjacent SAGD well pairs creating the full eMVAPEX technology. These additional producers capture the mobile bitumen-solvent mixture outside the chambers increasing extraction performance. MEG is the owner of the patent for the eMVAPEX process (Canadian Patent No: 2912159, issued January 3rd, 2017 and United States Patent No: US10,145,226 issued to MEG on December 4th, 2018).

Solvent addition to the SAGD process is not a new concept and has been studied since the 1990's. Two main forms of solvent addition have been piloted so far using SAGD type of well arrangement: steam/solvent co-injection (light hydrocarbon solvents up to 20 vol% are injected with steam) and pure solvent injection. eMVAPEX captures the best of both steam and solvent injection through the use of condensable gas (CG) and infill wells. First, the project takes advantage of steam's higher heat capacity than light hydrocarbons to warm the bitumen reservoir. Once production is maintained, steam can be

removed and redirected to newly drilled wells. Second, solvent (ex. propane) is injected to reduce bitumen viscosity in place of steam to improve thermal efficiency and to maintain pressure in the well. The infill wells provide a more effective distribution of injection media increasing the rate and amount of production. The solvent can distribute more effectively throughout the reservoir to increase production by up to 20% when compared to steam based production. As a result, the overall recovery can be increased by up to 5-10%. The warmed reservoir reduces bitumen viscosity which accelerates the mixing and mass transfer between solvent and bitumen. This further reduces viscosity and improves the bitumen's ability to flow, increasing production rates. A potential side benefit of the improved mixing of solvent and bitumen is a more effective deasphalting can occur, resulting in a more valuable product.

Since eMVAPEX may be regarded as an extension of eMSAGP (Canadian Patent No: 2776704 issued to MEG on November 18th, 2014), the next logical step is to pilot eMVAPEX and compare its performance with that of eMSAGP and SAGD. eMSAGP has been piloted and subsequently commercialized at MEG's CLRP resulting in significant reduction of CSOR and increased bitumen recovery. The steam freed up by eMSAGP has been used to startup new SAGD well pairs without the need to increase steam generating capacity. If the eMVAPEX pilot establishes the superiority of eMVAPEX over eMSAGP, MEG anticipates applying eMVAPEX further at MEG's in situ projects and potentially licensing to other industry participants once proven at MEG.

Project Objectives and Performance Metrics

Technical Objectives

- Successfully and continuously inject propane in up to 10 operating SAGD well pair injectors;
- Maintain Bottom Hole Pressure (BHP) with propane (minimal steam/NCG injection);
- Reservoir Recovery of >75% of the injected propane (daily rate);
- Achieve a Net Propane Oil Ratio of <0.2;
- Increase Oil Quality (demonstrate change in API gravity); and
- Demonstrate propane recycle viability and operability, achieve recycle facility uptime of >90%.

Strategic Objectives

- Maintain or increase Bitumen Production and Recovery compared to eMSAGP;
- Reductions in the GHG intensity of bitumen production, by reducing the instantaneous SOR for bitumen to <0.7;
- Reductions in the water use intensity of bitumen production, by reducing the instantaneous SOR for bitumen to <0.7; and
- Communicating lessons learned, technical gaps and future opportunities.

The technical and strategic objectives for this project have not changed.

D. METHODOLOGY

MEG has taken a phased approach to prove up and commercialize eMVAPEX as outlined in Table 1. Phase 1 has been operating since late 2016 and early positive results proved up the concept and justified the expansion to Phase 2, which has been operating since August 2017. The objectives of the Phase 3 of the pilot are to confirm:

- Reservoir performance and propane recovery on a pad scale; and
- Propane recycle viability and operability.

Figure 1 illustrates the timeline for the Phased eMVAPEX Pilot.

Phase 1	Phase 2	Phase 3
Proof of concept	Pre-commercial Prototype	Commercial Prototype
Unconfined pilot (1pair+2infills)	Confined pilot (3pairs+4infills)	Expand C3 injection (up to 10pairs+infills) with C3 recycle
Objectives ✓ Reservoir performance, e.g. Oil rate, steam-oil-ratio (GHG reductions), solvent-oil-ratio, solvent recovery ✓ Operating parameters for facility design	Objectives ✓ Confirm reservoir performance and solvent recovery	Objectives • Confirm reservoir performance and solvent recovery • C3 recycle viability and operability

Table 1 – eMVAPEX Pilot Phased Approach

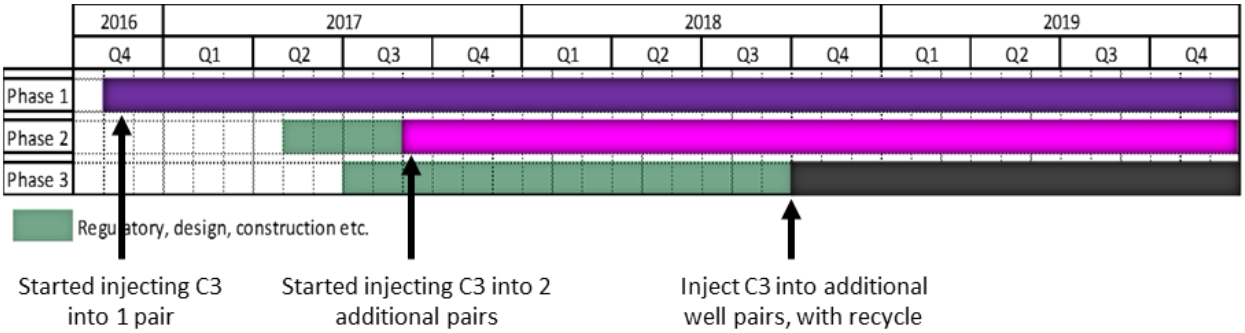

Figure 1 – eMVAPEX Pilot Phased Timeline

In addition to this project AI and NRCan also financially supported Phase 1 and Phase 1+2, repectively.

E. OUTCOMES AND IMPACTS

Important outcomes from Phase 3 of the eMVAPEX pilot include:

- Successfully injected propane into 7 operating SAGD injectors;
- Adequate BHP maintenance with propane;
- High propane recovery from the reservoir, >70%;
- A Net Propane to Bitumen ratio of 0.2-0.4;
- A marginal increase in bitumen API gravity;
- Propane recycle viability and operability with a facility availability of approximately 93%;
- Production rates and recoveries may be higher than SAGD, but lower than eMSAGP; and
- An instantaneous SOR of <0.1 may be achievable, resulting in reduced GHG and water use intensities.

F. ENVIRONMENTAL BENEFITS

The application of the eMVAPEX technology has the potential to substantially reduce GHG emissions from the in-situ extraction process by decreasing the overall steam requirement per unit of production (SOR) over the life of a well. SAGD facilities are typically configured with steam generation situated at a CPF with further steam deployment out to the pad. Steam is generated with a series of stationary combustion sources (commonly OTSG's) consuming fuel such as natural gas or mixed fuel gas. In addition, there may be some smaller supporting units such as heaters which consume fuel that contribute to the overall GHG profile. Typically, stationary combustion emissions will account for approximately 99% of the total in-situ facility greenhouse gas emissions with steam generation accounting for more than 90% of this. Therefore, reducing the steam generation requirements per barrel of production is key to lowering a facility's GHG intensity. Additionally, due to the large proportion of GHG emissions associated with steam generation there is a close correlation between SOR and GHG intensity and the SOR improvements associated with eMVAPEX application can serve as a reasonable basis for estimating overall GHG implications.

The industry SAGD average SOR was 2.75 for commercial SAGD facility performance in 2018 (Source: AER 2018 ST53). Industry average SOR has trended down in recent years, but there is some risk of an increasing trend in the future due to in situ producers typically developing the best assets first. Relative to SAGD eMVAPEX is expected to reduce emissions intensity for steam generation by as much as 43% by reducing the overall SOR to approximately 1.6.

A Well-to-Refinery gate emissions estimate was performed to better understand the environmental benefit of eMVAPEX. The Oil Production Greenhouse Gas Emissions Estimator (OPGEE) life cycle assessment (LCA) tool was used to estimate the emissions intensity of an industry average SAGD asset. The estimate includes the following production related emissions sources:

- Miscellaneous emissions from sources such as Land use, venting, flaring, etc.
- Processing, which consists primarily of natural gas combustion for steam and electricity generation;
- Electricity export credits;
- Dilbit transportation to refinery;
- Upstream Diluent supply;

- Upstream Natural gas supply;

For this analysis the industry average SAGD assets were assumed to have a similar steam generation configuration as MEG with cogeneration and electricity export. The following additional metrics were used outside of the LCA tool to estimate the emissions intensity for eMVAPEX:

- Incremental emissions from burning some recovered propane in the CPF, partially offset by a reduction in natural gas emissions; and
- Upstream propane supply and transportation.

Based on these inputs, in 2030 eMVAPEX could provide an estimated 2 Mt CO2e/yr reduction in GHG emission if 90% of MEG and 10% of non-MEG in-situ bitumen production (approximately 346,000 bbl/day) is using eMVAPEX. This assumes the in situ bitumen production grows to 2,245,000 bbls/day in 2030, as CAPP has it estimated in their 2019 forecast, and the reduction in emissions is relative to a base case without eMVAPEX and an industry SOR of 2.75.

The forgoing estimates are based on assumptions which MEG believes are reasonable, but which may prove incorrect over time.

G. CONCLUSIONS

The goals for this project are as follows:

- Complete the pre-project activities, including financing, regulatory approval, and detailed design;
- Complete the construction and commissioning of the propane recycle facility;
- Operate the expanded pilot and recycle facility for up to 18 months;
- Acquire data and work towards meeting the technical and strategic objectives of the project;
- Confirm reservoir performance on a pad scale, and propane recycle viability and operability; and
- Potentially make a commercialization decision.

The project has successfully achieved most of the stated goals. The majority of the reservoir performance metrics were successfully achieved, however, the pilot data indicated the net propane to bitumen ratio is higher than planned, and the production rate and recovery may be less than that of eMSAGP.

Piloting activities will continue in 2020 to continue to evaluate the performance, as well as eliminate propane injection on some wells to test post-propane injection performance. A commercialization decision is anticipated to be made by the end of 2020.