eMVAPEX Pilot, Phase 1
Final Report

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Executive Summary

MEG Energy Corp. ("MEG") is an Alberta company focused on sustainable in situ development and production. As of the date hereof, MEG's bitumen production averages approximately 80,000 BPD. 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 hydrocarbon solvents (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 3.0 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 expected to have significantly improved capital efficiencies relative to SAGD, reducing the cost barrier to bring on additional in situ production. In addition, eMVAPEX is expected to reduce operating costs, improving bitumen production competitiveness relative other sources of crude oil.

Phase 1 of the eMVAPEX pilot began at MEG's Christina Lake Regional Project (CLRP) in late 2016 and positive results include:

- No major operating problems and propane injection onstream factor >90%
- SOR reduction of >90% to ~0.2
- Bitumen production increase of >20% relative to SAGD
- High propane recovery from the reservoir, up to 70%

Encouraging results justified expanding the pilot to Phase 2 ahead of schedule, which commenced operation in August 2017.

The next step for the eMVAPEX technology development is the continued operation of the Phase 2 pilot, and expansion to Phase 3. Expanding to and operating Phase 3 will confirm reservoir performance as well as provide the opportunity to operate the Phase 1 and 2 wells for an extended duration to get a better understanding of longer term effects. The other key item to commercialization is designing and operating a propane recycle facility. Phase 3 is currently being designed and tentatively scheduled to come online mid-2018. By early 2019, if the pilot continues to perform well, MEG expects to have enough information to potentially make a decision on commercialization. If successful, future MEG pads, as well as other SAGD producers, could begin transitioning to eMVAPEX as early as 2020.

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1.0 Project Description

1.1 Introduction and Technology Description

SAGD is an energy intensive process that requires significant investments in steam generation capacity. Reductions in steam requirements can have significant impacts on a project's emissions intensity, facility capital costs and operating costs. eMVAPEX is a technology with the potential to address these concerns, and improve the economics and environmental impact of bitumen extraction. 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°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).

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), which has been successfully field tested by MEG, the next logical step is to pilot eMVAPEX and compare its performance with that of eMSAGP and SAGD. eMSAGP has been piloted successfully at MEG's CLRP and has been applied in 6 commercial pads 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.

1.2 Project Objectives

The Overall Goals and Objectives of eMVAPEX are to:

i. Reduce GHG emissions & water usage by 43% from industry average SAGD production by reducing the SOR for bitumen produced from an average of 3.0 to 1.7
ii. Increase the average bitumen production rate (on a pattern basis) by 20% compared to SAGD (before decline)
iii. Increase bitumen recovery by 5-10% of original oil in place as compared to SAGD

The Goals and Objectives for Phase 1 are to:

i. Successfully and continuously inject propane into a producing SAGD well pair
ii. Obtain sufficient data to analyze the impact of replacing steam with propane

The goals and objectives for Phase 1 did not change during the project.

1.3 Work Scope Overview

The scope of work for Phase 1 of the eMVAPEX Pilot includes the following:

- Design and construction of a propane injection facility
- Propane injection into well pair AP2 for ~1 year
- Decision on whether or not to expand the pilot to a larger pilot, Phase 2

AP2I propane injection began November 29th, 2016 and is ongoing.

2.0 Approach and Results

2.1 Technology Development

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 proposed Phase 3 of the pilot are to confirm:

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

Phase 3 is expected to confirm the remaining key pieces of information to make a commercialization decision. Early results from Phase 1 & 2 are promising, but they are a small scale prototype with relatively short operating history. Expanding to and operating Phase 3 will confirm reservoir performance as well as provide the opportunity to operate the Phase 1 and 2 wells for an extended duration to get a better understanding of longer term effects. The other key item to commercialization is designing and operating a propane recycle facility. Market propane prices are depressed due to lack of industrial uses, but recycling still improves project economics by reducing the amount of make-up

propane that has to be purchased. Phase 3 will provide valuable information for designing and operating local pad recycle facilities. Pad recycle was selected for this project due to the improved capital efficiency relative to constructing at the Central Processing Facility (CPF). Figure 1 illustrates the timeline for the Phased eMVAPEX Pilot. Phase 3 is currently being designed and tentatively scheduled to come online mid-2018. By early 2019, if the pilot continues to perform well, MEG expects to have enough information to potentially make a decision on commercialization. If successful, future MEG pads, as well as other SAGD producers, could begin transitioning to eMVAPEX as early as 2020.

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 (10pairs+11infills) 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

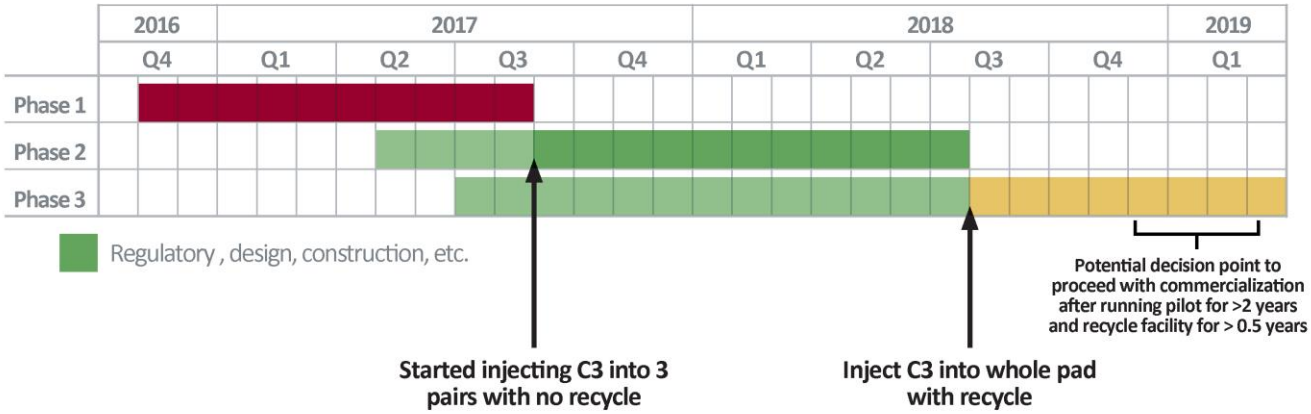

Figure 1 – eMVAPEX Pilot Phased Timeline

2.2 Technical Results and Analysis (redacted)

2.3 Project Outcomes (redacted)

2.4 Important Lessons Learned

Lessons Learned

- Pumping arrangement – The propane injection facility was originally designed having a single pump. Due to the differential pressure required and properties of propane a booster pump was

required in addition to the injection pump to meet Net Positive Suction Head (NPSH) requirements.

- Gas detection and isolation – During the HAZOP additional requirements for gas detection and isolation in the system were identified.
- Electric Heat Trace (EHT) at the pad location – During times when propane injection is offline there is potential for steam to creep back into the propane piping and freeze. Electric heat trace from the propane injection point back to the propane XV on the pad was added to the design to mitigate this risk. This is a lessons learned from the eMSAGP process that is being incorporated into the eMVAPEX design.
- Bullet offloading – The original plan was to jack and roll the propane bullet at site. Upon further review, it was determined that due to the height of the vessel the safer option would be to use cranes to offload the bullet.
- Pump Seal System – The skid fabricator communicated late in the design that the injection pump seal system is not closed. It constantly requires addition of oil, and produces a stream of waste oil. As a result modifications to the pump skid were made to include a supply tank with secondary containment, and tubing to an off skid spent oil bucket.
- Propane runback line – One of the projects implemented after start-up was a runback line on the propane pipeline. This line relieves pressure back to the bullet in the event of a trip, preventing PSV release to atmosphere.
- BHP Maintenance – propane has been adequately maintaining pressure with minimal steam and NCG injection.
- Steam Requirement – steam has not been required except to vaporize the propane being injected. If the propane can be vaporized by other means steam injection could potentially be eliminated completely.
- Propane Vapourization – MEG intends to only inject propane as a vapour. In Phase 1 of the eMVAPEX pilot propane was delivered as a liquid and, therefore, has to be vaporized. This was done by mixing with steam. It has been observed that the majority of the propane injection downtime has been due to steam outages. By vapourizing the propane using other means the propane injection uptime could be improved.

3.0 Relevance and Estimated Impact

eMVAPEX is expected to reduce GHG emissions and water usage by up to 43% from industry average SAGD production by reducing the SOR for bitumen produced from an average of 3 to approximately 1.7. Current MEG bitumen production and SOR are approximately 80,000 bpcd and 2.3, respectively. Implementing eMVAPEX could reduce the SOR to 1.7, corresponding to an approximately 446 kt/yr reduction in CO2e emissions associated with steam generation. Early results from Phase 1 of the eMVAPEX pilot indicate further SOR reductions can be achieved, directly aligning with Alberta's strategic goal of reducing GHG emissions and water usage. Building on the success MEG has already achieved, there is high confidence that eMVAPEX will produce energy more cleanly and be part of the long-term solution to reduce air pollutants from energy production and use.

With the solvent added in place of steam, the freed up steam can be repurposed to newly drilled wells. In essence, with an SOR reduction of 43%, the overall plant bitumen production may be increased up to 75% (likely with some capital additions to increase oil and water processing). Under the appropriate reservoir conditions and with the improved solvent and bitumen mixing, the Athabasca bitumen produced from eMVAPEX could be in the 12-14 API range above the typical 8 API. At 12-14 API the

partially deasphalted bitumen would have a reduced viscosity and require less diluent for transport. This would potentially increase Alberta's pipeline takeaway capacity.

eMVAPEX, when deployed commercially, is expected to have significantly improved capital efficiencies relative to SAGD, reducing the cost barrier to bring on additional in situ production. Increased production enables further drilling activity, which may lead to more skilled jobs for Canadians. Current Canadian in situ production is ~1.5 MMbpd and is expected to increase by 43% by 2030 (2017 CAPP Forecast) – a major economic growth area for Alberta/Canada. In addition, eMVAPEX is expected to reduce operating costs, improving bitumen production competitiveness relative other sources of crude oil. Based on preliminary economics the expected IRR for the commercial roll-out of eMVAPEX remains >30%. A 20,000 bopcd facility using the eMVAPEX process is also expected to generate up to 180 person-years of employment for highly skilled personnel over a 4 year period.

To our knowledge, eMVAPEX is the first field pilot that uses propane as a solvent for in situ thermal processes. Market price for propane is forecasted to remain depressed in the foreseeable future because of the lack of industrial usage. If the eMVAPEX process is proven, it may open a new market for propane which could in turn generate economic benefits for Alberta.

The project involves collaboration and knowledge sharing amongst the public sector (Alberta Innovates (AI), Natural Resources Canada (NRCan)) with reports containing results from the testing. Collaboration and knowledge sharing will occur throughout the entire project to inform the advancement of cleaner energy production. MEG plans to continue to invest in progressing cleaner energy production innovations, like eMVAPEX. The learnings from the eMVAPEX pilot may inform and guide research by academia to further the fundamental principles for cleaner bitumen production. The public sector will obtain valuable learnings to guide further investment in in situ production research and industry will have a successful first-of-a-kind commercial demonstration to justify investment in eMVAPEX. MEG's objectives are aligned with Alberta's, i.e., MEG is looking for demonstration technologies that can make meaningful reductions in GHG emissions as quickly as practical so that these new technologies can be part of the solution to meet the goal of capping emissions to 100 Mt/yr by 2030 while ensuring the continued development of our bitumen resources. MEG believes that this can be achieved by disseminating information to the public in a timely manner and making the technologies available to other operators. Dissemination of information to the general public is normally done via the publication of data by the Alberta Energy Regulator (AER). The performance data for this pilot are expected to be available to the public in September 2019.

4.0 Overall Conclusions and Next Steps (redacted)

5.0 Communications Plan

The project involves collaboration and knowledge sharing amongst the public sector (AI, NRCan) with reports containing results from the testing. The public sector will obtain valuable learnings to guide further investment in in situ production research and industry will have a successful first-of-a-kind commercial demonstration to justify investment in eMVAPEX. MEG is looking for demonstration technologies that can make meaningful reductions in GHG emissions as quickly as practical. MEG believes that this can be achieved by disseminating information to the public in a timely manner and making the technologies available to other operators. Dissemination of information to the general public

is normally done via the publication of data by the AER. The performance data for this pilot are expected to be available to the public in September 2019.

6.0 Scientific Achievements

MEG was granted Canadian Patent No. 2912159 in respect of the eMVAPEX process on January 3, 2017. MEG continues to own this patent and all other intellectual property associated with the eMVAPEX process.