Non-Confidential Final Report

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1. Executive Summary

Nsolv is a water-free, in-situ bitumen extraction technology that reduces GHG emissions by 70-80% compared to the SAGD process. The BEST Pilot Project demonstrated the Nsolv technology. Suncor's Dover lease (near Ft. McMurray, AB) is the host site for the 250-300 barrels-per-day facility, comprising a 300m horizontal well pair and a surface plant for processing produced hydrocarbons. The Nsolv process uses proven horizontal well technology and injects a warm solvent vapor, such as propane or butane. The solvent vapor condenses underground and dissolves the valuable oil fractions out of the bitumen, leaving heavy metals and asphaltenes behind.

The process produces a lighter, partially upgraded, and hence, more valuable, oil product and may recover more resource from each well at lower capital and operating costs than existing in-situ processes. In addition, the Nsolv process's low injection pressure and energy efficiency may unlock additional reserves that are not accessible through present technology including reservoirs that exhibit characteristics such as shallow depth, thin pay, carbonates, gas-over-bitumen, and water-over-bitumen.

Nsolv's technology has the potential to reduce greenhouse gas (GHG) emissions associated with in situ extraction by 10.1 MtCO_2e by 2025, and 47.2 MtCO_2e by 2030, given present rates of technology adoption.

The GHG benefits associated with the technology are derived from two sources: extraction emissions associated with liberating oil from the ground, and from a reduction in downstream upgrading requirements. The process uses no water, lessening the oil sands industry's demand on this scarce resource, eliminating the need for water treatment chemicals and delivering greater flexibility when it comes to siting a plant.

The primary purpose of the BEST Pilot Project was to prove out the Nsolv process under field conditions to confirm the information already developed in laboratory tests and advance the technology to commercial readiness.

Key aspects to evaluate included:

- Bitumen production rates
- Solvent-to-oil ratio
- Solvent hold-up and solvent losses
- Oil quality
- Facility operability, both downhole and on surface

The BEST Pilot Project is a temporary facility that is intended to be operated for no more than 3 years to demonstrate the extraction technology. At the end of the BEST Pilot Project life, all Pilot Project facilities will be removed and the Pilot Project site reclaimed.

2. Project Description

2.1 Introduction and Background

Three phases in the development of the technology were envisioned:

- Laboratory testing
- Pilot Project – field testing
- Commercial Plant

The proof-of-process laboratory testing was performed during 2005-2007 at the Alberta Research Council. Results were successful, and the further evaluation of these results to a commercial scenario has indicated that Nsolv has the potential to be a viable in-situ process.

The BEST Pilot Plant is defined as a test facility whose primary purpose was to prove out the Nsolv technology in an actual reservoir setting and extend the information developed in the laboratory. This primary purpose affected the design of the project in many ways, notably that it focused on the fundamental process efficacy and was not an attempt to build a scaled-down commercial plant:

- Proving out and developing the Nsolv process was the primary goal.
- The Pilot Project size was based on the minimum feasible to prove out the technology in a field setting.
- Data collection and lessons learned from actual operations was emphasized.
- The facility was designed for operating flexibility.
- Capital costs were kept to a minimum by focusing on “must-have” process steps. As an example, solvent purity is a key requirement for the Nsolv process, therefore the plant design ensured this, but due to the small scale of the plant, the design did not focus on minimizing the energy usage to achieve this outcome. Achieving the required solvent purity and minimizing energy usage of the associated process steps is relegated to the eventual commercial plant design.

Suncor is providing the host site for the BEST Pilot Project and is involved with all regulatory required reporting related to the Pilot Project. The Dover Facility is located in the Athabasca Oil Sands Area, approximately 45 km northwest of Fort McMurray and 25 km southwest of Fort McKay in Sections 7, 18 and 19 of Township 93 Range 12, west of the Fourth Meridian. Figure 1 shows the project location in reference to the province of Alberta and the Athabasca Oil Sands, and Figure 2 is a satellite image of the site in relation to Fort McMurray and surrounding operating facilities.

Figure 1: Project Location

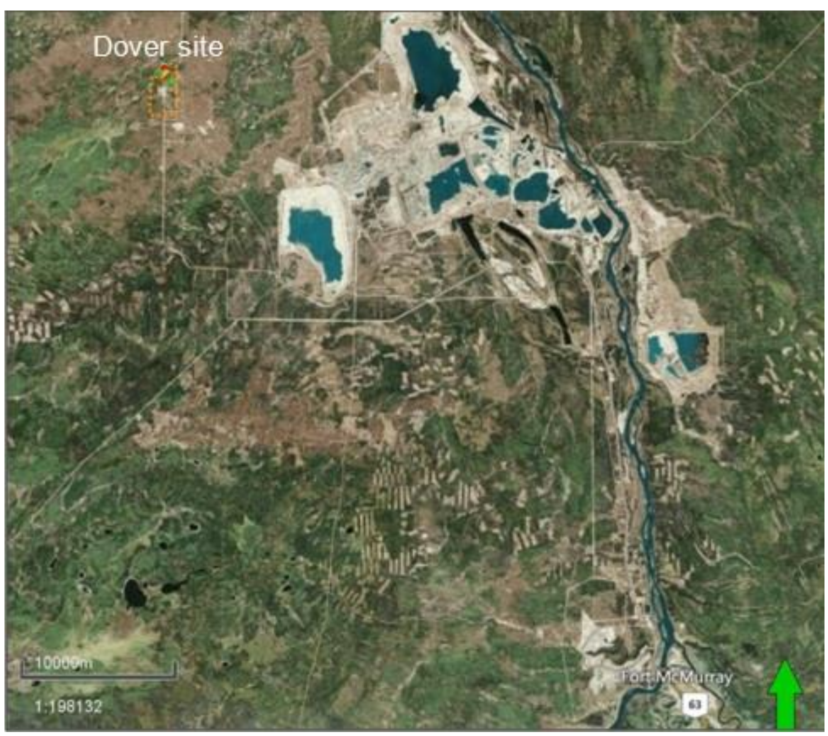


Figure 2: Project Location Satellite View

The Nsolv process, developed by Nsolv Corporation (Nsolv) is based on the injection of warm solvent vapour into the oil sands. The Nsolv extraction conditions are very gentle and preferentially extract the most mobile and valuable components of the bitumen. The Nsolv process works as follows, refer to Figure 3 for a diagrammatic representation of the process:

1. The solvent, injected at bubble point conditions[1] (40-60°C), condenses at the cold interface between the warm vapour chamber and the cold surrounding bitumen-saturated sand. This provides a modest temperature rise, allowing for rapid dissolution of bitumen by the solvent, and then simple gravity drainage for collection at the production well.
2. A downhole production pump then transfers the fluid (oil and solvent mixture) from the production well to the surface facility.
3. The fluid moves through a separation process to separate the oil from the solvent.
4. The oil is pumped to large storage tanks and trucked off site.
5. The solvent is recovered and transferred to a solvent purification process. This process consists of a distillation column that purifies the solvent to the desired specification. Once the solvent specification is met, the solvent is heated and re-injected back into the reservoir for oil extraction.

The reservoir contains formation water that gets pumped to the surface with the oil and solvent fluid. The water is removed from the fluid in the separation process, pumped to storage tanks and then trucked off site for disposal.

[1] The bubble point is the temperature, at a specific pressure, of a liquid where the first vapour bubble is formed. Solvent is injected as a slightly superheated vapour so that contact with the colder bitumen forces it to condense.

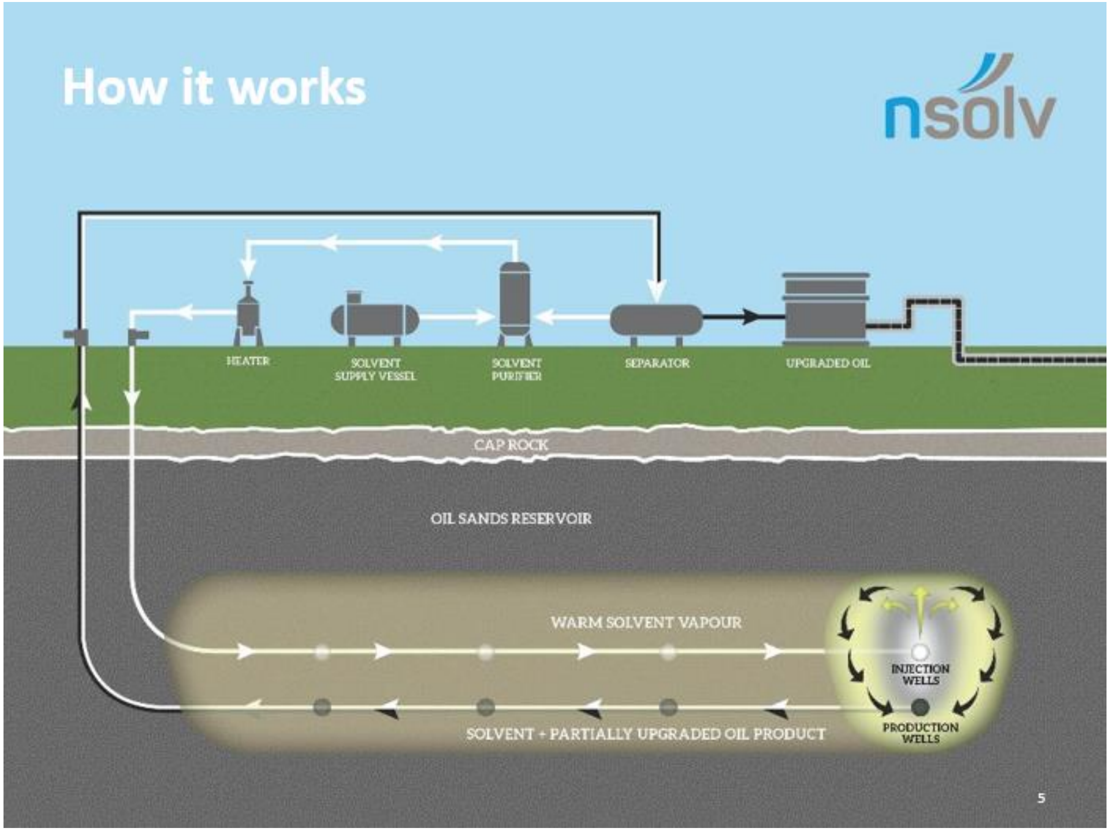


Figure 3: How the Nsolv Process Works

The objective, from an Engineering, Procurement and Construction Management (EPCM) perspective was to engineer, procure, construct and commission a facility of simplistic design, based on the Nsolv process. It was important to specify and procure equipment that was familiar to the in-situ industry. The plant is comprised of conventional oil and gas equipment that are known to fabricators and operators. It is the Nsolv operating process that varies from existing in-situ techniques and not the equipment.

The BEST Pilot Project has been conceived as a skid-mounted, modular design. The benefits of this type of design was not only ease of shop fabrication and transportation to site, but also facilitated simple erection, commissioning and maintenance relative to on-site field fabricated facilities.

2.2 Technology Description

2.2.1 Process Overview

Figure 4 below shows a simplified diagram of the Nsolv process. It is continuous, whereby the flow from the injection loops back around to the production well.

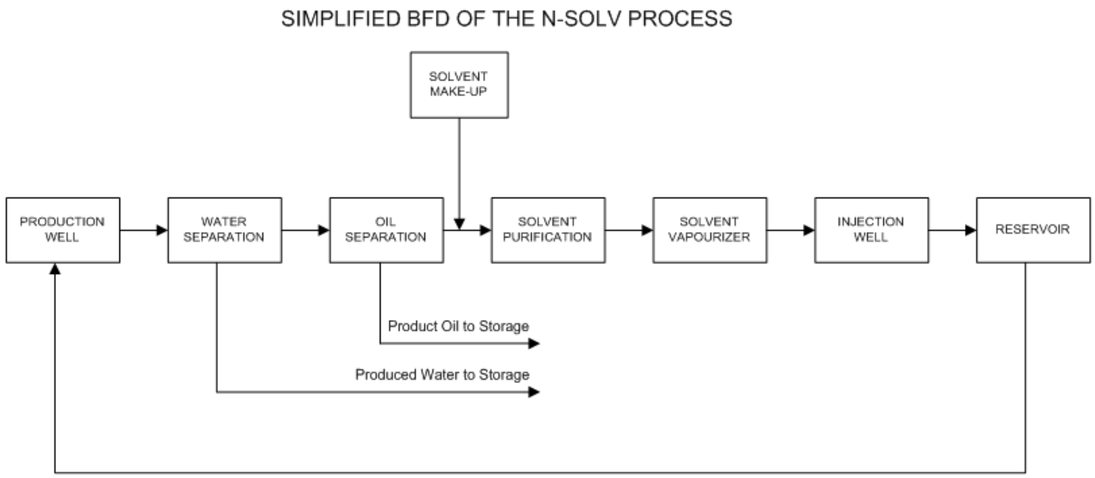


Figure 4: Process Block Flow Diagram

Inputs:

- Primary feedstock – bitumen, typically located within the Alberta oil sands region
- Solvent – propane or butane; choice is reservoir dependent
- Natural gas – to heat the solvent to 40-60 °C
- Electricity – for pumps, compressors, and controls

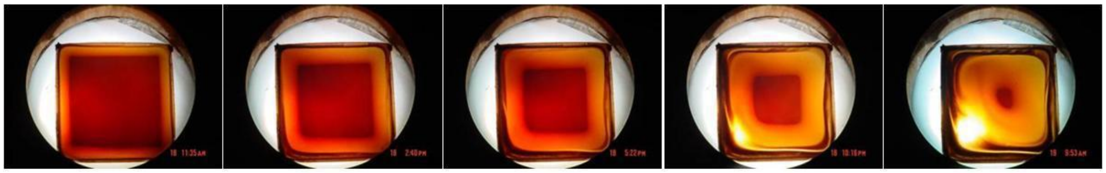
Outputs:

- Sales oil – Partially upgraded oil, having been upgraded from 8 API to 14 API via the in-situ rejection of asphaltenes and heavy metals from the produced product.
- Formation water – it is unavoidable that some pre-existing water from the reservoir is produced; this water is treated and discharged or sent to a designated disposal facility.
- Solvent impurities – methane, ethane and other gases in the produced solvent stream will be recycled back to the natural gas burner to reduce the external fuel gas requirement.

2.2.2 Scientific Basis

Nsolv builds upon a 35+ year legacy of research on solvent-based gravity drainage. Hatch (Canadian Patent 1,059,432) studied solvent vapour gravity drainage during the 1970s and 1980s at DB Robinson, ORF and ARC. Experiments conducted at ARC showed that the solvent extraction process worked but was too slow to be commercially viable.

Bench scale tests at Nenniger's laboratory showed that solvent dissolution of bitumen produces shock fronts, as illustrated by Figure 5. The solvent dilution process is apparently confined to a 200 micron wide shock front, so the bitumen dissolution resembles that of a melting ice cube or a dissolving salt block, the significance of this being that solvent does not 'get lost' in the bitumen, absent a pressure drive to push solvent into the un-extracted reservoir. Nsolv was patented in 2000, based on the insight that modest amounts of heating, delivered via condensing solvent, could provide oil rates comparable to SAGD.



Increasing Time (24 hour interval) →

Figure 5: Shock Front Development

In 2001, Nenniger discovered that blended injection fluids, such as the propane and methane mixes needed to achieve VAPEX's dew point criteria produce an inherently unstable material balance. The methane cannot exit from the chamber and rapidly suffocates the gravity drainage process. Nsolv avoids this fatal flaw by using highly purified solvent and operating at bubble point conditions, like SAGD.

From 2003 to 2007, Nsolv was tested in a sophisticated set of experiments conducted at ARC, funded by Hatch and IERD; these tests confirmed the key features of the process, including rapid chamber growth rates, the harmful impact of non-condensable gases, and the enhanced oil quality and uniform disposition of asphaltenes throughout the extracted sand.

Nsolv has demonstrated chamber growth of 3-cm/ day at a modest extraction temperature of 40˚C in a 5 Darcy sand using Athabasca bitumen. By comparison, SAGD chamber growth rates averaged 1-cm/day at the UTF- Dover Pilot at 230˚C. The ARC experiments also confirmed that a 1% methane contamination level, i.e., 99% pure solvent, reduced the Nsolv oil extraction rate by a factor of 4.

While the 3-cm/day Nsolv chamber growth rate was initially met with skepticism, the experimental results are consistent with over 90 solvent-based gravity drainage experiments performed by independent researchers. Nsolv developed and published a correlation that successfully predicts oil rates from nearly 100 solvent-based gravity drainage experiments, using a huge variety of crude oils, a variety of experiments (Hele-Shaw, glass beads and sand packs), a variety of solvents (CO_2, Ethane, Propane, Butane), a range of temperatures (7-90˚C) and pressures (0.1 to 9 MPa). The correlation, represented in Figure 6, predicts Nsolv can achieve SAGD production rates at a temperature almost 200˚C lower than SAGD.

Figure 7 provides evidence that the entire shock front is compressed into a length of a single pore (i.e., about 100 microns for 5 Darcy sand). This shock front mechanism also predicts that the overall penetration rate is set by the slow speed at the front of the dilution wave, i.e., by solvent penetration into the raw bitumen. The correlation is consistent with the proposed rate limiting step. In Nsolv, the application of a 30°C temperature rise drops the bitumen viscosity from 106cP to 104cP and this 100 fold drop in viscosity provides the great acceleration

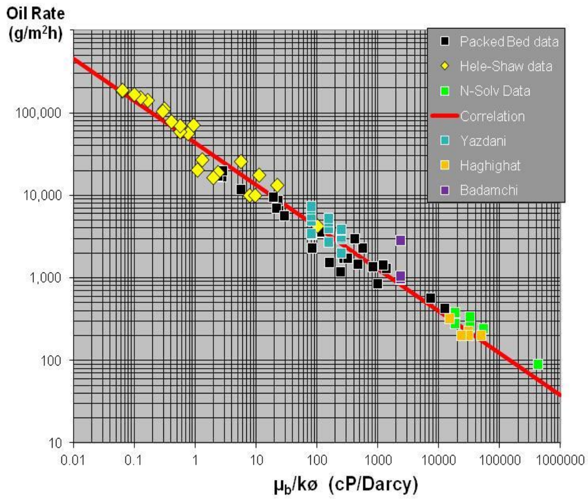


Figure 6: Solvent Gravity Drainage Correlation

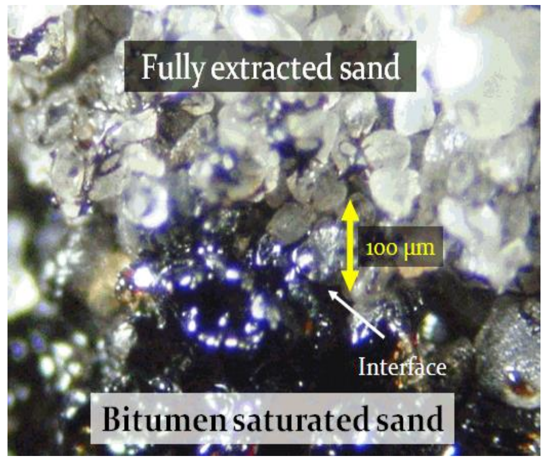


Figure 7: Detail of Extraction Interface

observed in the Nsolv extraction (penetration) rate.

The shock mechanism provides other benefits. It implies that the gravity drainage chamber will be tank-like with a sharp, well-defined and distinct edge. The Nsolv scientific results were summarized and presented in CIM-SPE papers[2] in 2008 and 2009. Research results at the University of Alberta, University of Calgary, University of Regina, and University of Waterloo have been very encouraging and consistent with Nsolv results.

2.3 Project goals

The following performance targets were sought for the Pilot Project:

1. **Extraction Rate:** Achieve SAGD oil extraction rates or better in the Athabasca McMurray formation at 40°C instead of 230°C.
2. **Oil Quality:** Upgrade, in-situ, bitumen from ~8 °API to ~13 °API or better (a level that is more than sufficient to bypass downstream refinery cokers), nickel and vanadium less than 150 ppm.
3. **Recovery Factor:** Recovery factor within chamber of 65% or higher.

[2] Available upon request.

4. **Solvent / Oil Ratio:** A solvent-to-oil ratio of 5 or less.
5. **Solvent Hold-up:** Hold-up in extraction chamber similar to steam (water) experienced in SAGD (Expecting below 0.4 bbl solvent/bbl oil, likely 0.2 bbl solvent/bbl oil).
6. **GHG Emissions:** Reduction of 80% or better in GHG emissions relative to SAGD, based on heat delivered to the reservoir.

2.4 Work scope overview

The following represents the overall scope of the project:

- Designed, engineered, procured, fabricated modules, constructed and installed equipment and commissioned a facility for the processing of the produced fluids and injection of conditioned solvent.
- Designed, engineered, procured, drilled, completed and instrumented a single horizontal Nsolv well pair with 300 meter horizontal length and applicable artificial lift system.
- Designed, engineered, procured, drilled, completed and instrumented 7 vertical observation (OB) wells.
- Assisted Suncor with the application process, including the public consultation part, for obtaining the necessary permits to build and operate the Nsolv plant at the Dover site.
- Delivered a safe and fit for purpose facility that enables Nsolv Corporation to conduct operational tests of the Nsolv process.
- Developed a testing program to evaluate the operating performance of the technology over a range of operating conditions.
- Delivered an operable facility to the operators of the plant, including reference materials and training that will ensure they were/are able to operate and maintain the facility in a safe and sound manner, meeting or exceeding all applicable codes and regulations, including all Health, Safety and Environmental practices as defined by Suncor's TLM standards.
- Operate the Nsolv BEST Pilot Project for a period sufficient to prove the commercial viability of the Nsolv technology at a bitumen production rate of up to 250-300[3] bpd and a solvent injection rate of up to 1,500 bpd. It is assumed that the facility will be operational for a minimum of 12 months, and that operations will not exceed 3 years.

3. Outcomes and Learnings

3.1 Experimental Procedures/Methodology

The choice of solvent is contingent upon the reservoir selected for the project. While the Pilot Project was designed to run on either propane or butane, the shallow Dover reservoir could only support lower pressure, butane operation. Propane is more suitable for deep reservoirs

[3] The Nsolv Pilot Project has 1500 bbl/day solvent processing capacity, which translates into 500-bbl/day oil production at 3:1 solvent-oil ratio. However, the reservoir that became available to Nsolv is very shallow and thin, hence the actual required solvent-oil ratio ranges between 5:1 and 6:1, yielding a maximum oil production capacity for the plant of 250-300 bbl/day.

as it has a bubble point temperature of around 40°C at 1270kPag. Since it is desired to operate within the 40°C – 60°C range, butane (60°C bubble point temperature at 600 kPag and field grade) is preferred over propane for shallow reservoirs like the Nsolv pilot reservoir. This temperature range was found to provide preferable economic results in that extraction rates are sufficiently high above 40°C and SvOR is sufficiently low below 60°C. If a future project has a low pressure reservoir, then there is no risk, because the pilot solvent, butane, would be deployed. Simulation, including history matching of lab scale sand pack test work with propane as solvent, will be used to estimate in-situ performance and fluid behavior for the design of a larger scale facility if (and only if) propane is required as a solvent. Note that Nsolv's ARC sand pack test work in 2005-2007 was based on propane solvent rather than butane; hence, Nsolv does already have experience with this solvent. Furthermore, Nenniger & Dunn (2008) developed a correlation to predict bitumen/heavy oil production rates for solvent based gravity drainage, drawing from over 60 individual lab tests on different crude oils and solvents. Their presented research indicates that oil production rate is insensitive to solvent choice.

3.2 Project Outcomes and Analysis of Results

3.2.1 Pilot Project Performance

Presently, Nsolv has advanced its technology readiness level to a fully-functional, near full-scale prototype, operating in the field acceptably (based on defined criteria set forth by CCEMC) over an extended period of time. Nsolv BEST Pilot Project has been operating for over 16 months and has produced over 50,000 barrels of upgraded oil from its single, 300 meter well pair and associated surface plant.

3.2.2 Oil quality

Figure 8 shows the calculated in-situ asphaltene precipitation volume. The calculation uses the simulated distillation results of each of the core bitumen, solvent, asphaltene + fraction and diesel and then recombines them to create the product oil simulated distillation curve based on mass balance. The results give a good estimate of the asphaltene + fraction absent from the product oil and based on the curve in Figure 8 the approximate average in-situ asphaltene precipitation volume is 25% over the life of the Pilot Project up to May 31st, 2015.

As illustrated in Figure 8, the in-situ asphaltene precipitation increased during the initial stages of solvent injection, but started to level off with time. This trend is captured in the calculated de-asphalted bitumen API, which also increased with time and then started to level off. But, the product oil API decreased during the reporting period even though the degree of de-asphalting increased during this time. This is because oil quality is also a function of diesel cut and solvent content.

During the warm-up and displacement phases, a significant amount of diesel was injected into the reservoir. As this diesel was recovered from the reservoir, diesel cut of the produced oil decreased and so did the API.

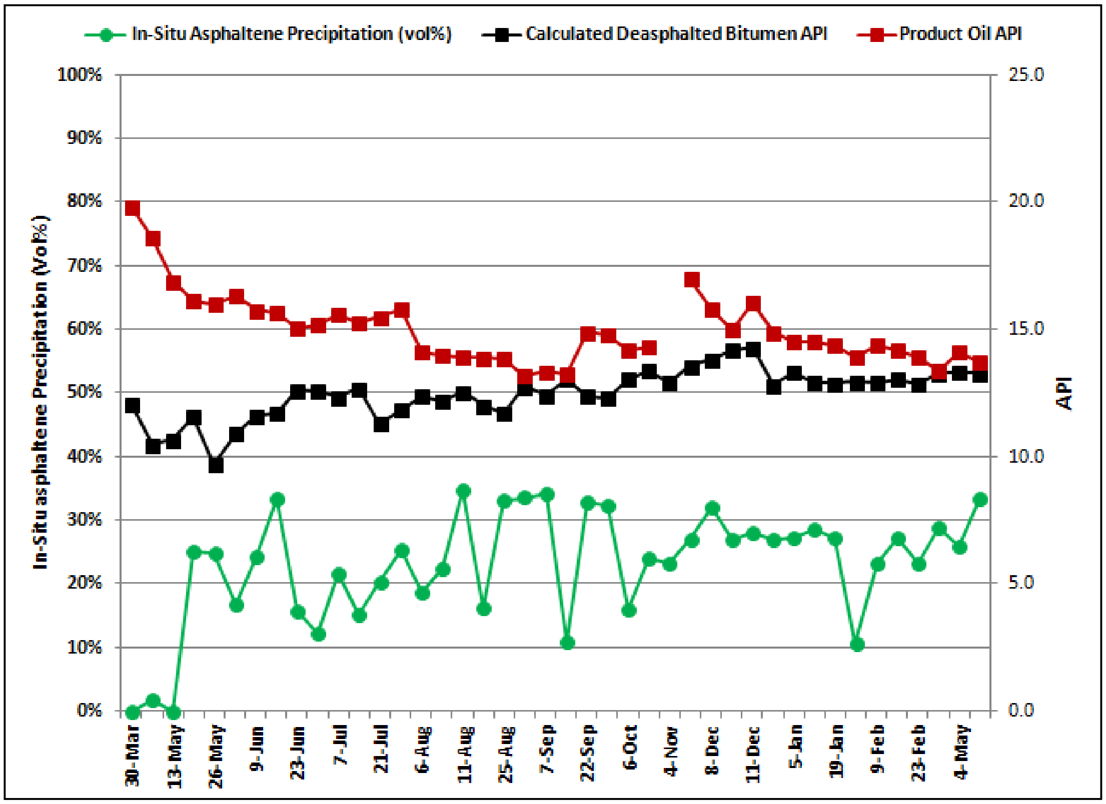


Figure 8: In-situ Asphaltene Precipitation

Vanadium content in the product oil decreased from around 455 ppm (AGAT core samples) to 76 ppm and nickel is at 30.4 ppm for trucked oil samples taken on June 1st, 2015. Both these values are less than the target of 150 ppm. Carbon residue in the product oil decreased from 13.9 wt% (AGAT core samples) to 6.1 wt% on June 1st, 2015.

3.2.3 Recovery factor

Lab results suggest as low as 5° drainage angle compared to 10-12° for SAGD but further information needs to be collected in the field including multiple OB well pair chamber intersections, supplemented with seismic and coring results. Nsolv produces an upgraded product out of the ground and leaves behind approximately 24% of initial bitumen saturation, which contains the heaviest ends of the bitumen. SAGD bitumen looses comparable amounts through in-situ film residue and downstream upgrading and refining so the ultimate recovery is expected to be similar between the two technologies.

Within the accuracy limits of the mass balance methodology employed, nearly 100% of the diesel injected into the reservoir has been recovered.

3.2.4 Solvent / Oil Ratio

Figure 9 shows monthly and cumulative solvent to oil ratios (solvent injected/oil produced) for the Nsolv Pilot Project. The original design assumed an injected Solvent-to-oil ratio of 3. The original SOR estimates were based on a 2 m taller pay zone as the wells had to be moved up to avoid a potential mud streak. The Pilot Project has been operating above the original design assumption. This is largely due to heat losses to the reservoir. In addition, as the payzone thickness is reduced, proportion of heat loss to the overburden increases relative to the heat required for extraction.

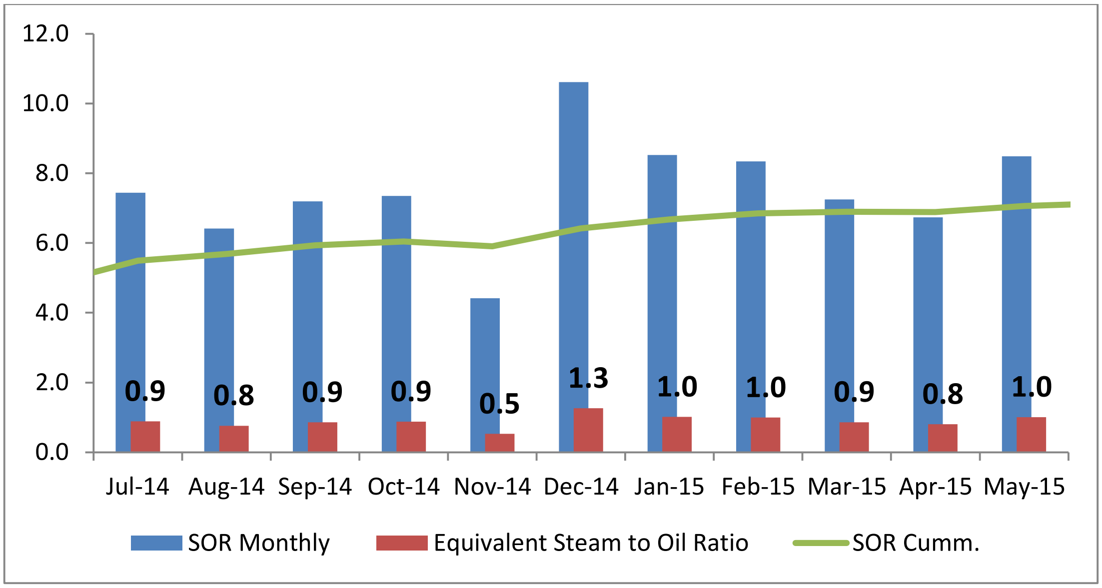


Figure 9. Solvent-to-Oil Ratio

3.2.5 *Solvent Purity*

Solvent purity is defined in terms of non-condensable content (C1, C2). It is important to minimize the non-condensable content of the solvent since it hinders heat transfer at the bitumen interface. The non-condensable injection is being maintained below 1% (mole basis).

3.2.6 *GHG Emissions*

Refer to section 4, Greenhouse Gas and Non-GHG Impacts, for a full analysis of the GHG impacts.

3.2.7 *Solvent Chamber Growth*

Overall chamber growth is measured by observing temperature signals at observation (OB) wells. Figure 10 shows the temperature at various dates across the observation well for OB11. The temperatures has increased from June 30, 2014 to June 8, 2015. The temperature series for June 8, 2015 shows that a wider band of higher temperatures around 56 °C are building around the injection well, this suggests that a solvent chamber is building around OB11 and the injector.

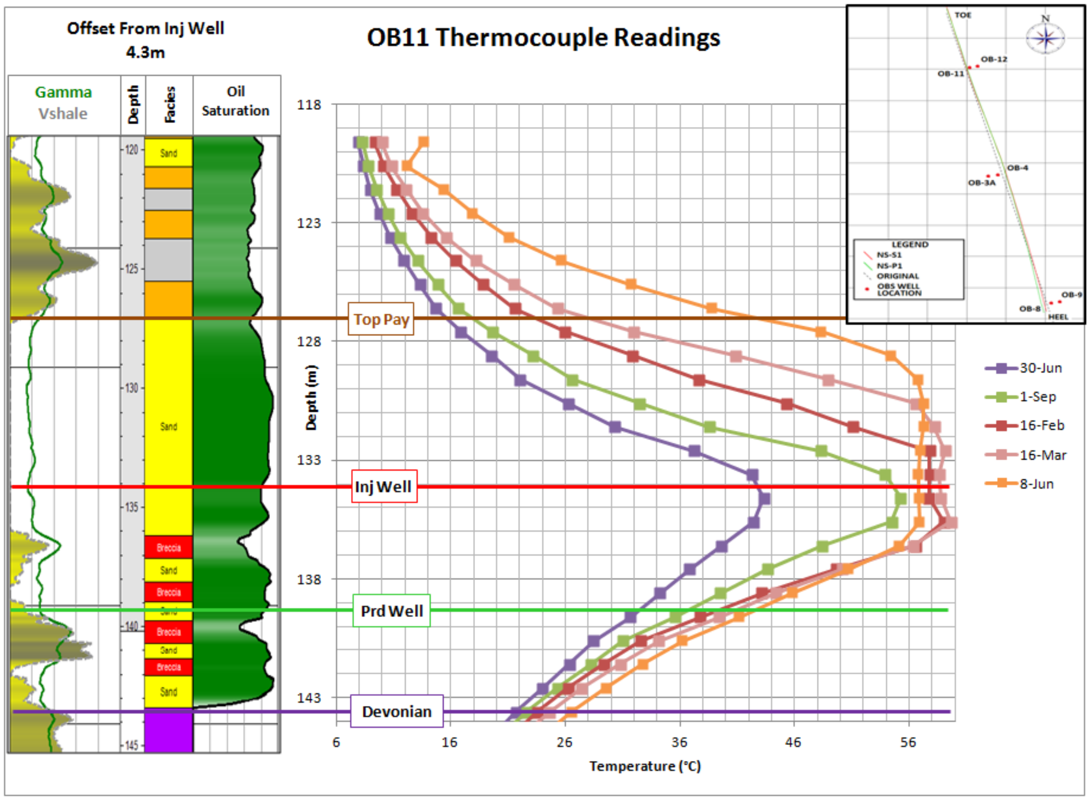


Figure 10: OB11 Thermocouple Readings

On March 15th, 2015 Nsolv acquired a 0.5 km2, multi-component 3D seismic survey that consisted of 32 receiver lines spaced 28m apart and 21 source lines spaced 32m apart. 2084 shots and 2316 receivers were spaced 8m apart along the lines, as can be seen in Figure 11, to produce good resolution and high quality of data throughout the reservoir interval. The small program was centered over the 300m long horizontal well pair and its main objective was to image the size, shape and position of the solvent chamber and its relation to the horizontal well pair. Early analysis showed that the acquisition was successful and returned very high quality seismic data for further analysis.

Two workflows, PP (compression data) pre-stack inversion as well as PP-PS (compression and shear data) joint pre-stack inversion, were carried out to give the best confidence in the interpretation. The results from the multi-component PP-PS processing workflow showed better ability to image the solvent chamber as can be seen in Figure 12. The results from the 3D seismic correlated very well with the existing observation well thermocouple data, reservoir saturation logs, and horizontal distributed temperature sensing (DTS) data giving an overall high level of confidence to the interpretation.

In general, the seismic results confirmed the early analysis and interpretation but also showed a chamber developing between the heel and mid observation wells that was not present on the observation well data at the time of the shoot. The seismic interpretation showed a variable chamber ranging from 5 up to 30m wide, refer to Figure 13, developed along approximately

80% of the 300m well length, but because of the heel to mid portion being elevated above the injector well a seismic conformance estimate is difficult to give and the falloff test conformance interpretation (~56% on Mar 30th, 2015) is a more reliable number. The producer conformance (~71%) is also difficult to interpret for similar reasons but agrees much better with the falloff interpretation of 60% for producer conformance. The shape and variability of the chamber indicated a very immature chamber that still needs to coalesce and expand to improve injector and producer conformance. The seismic also showed at the time of the shoot that the top of pay had not been reached yet and the chamber could still grow vertically a few meters in most areas. Horizontal growth also appeared to be much more extensive than vertical growth.

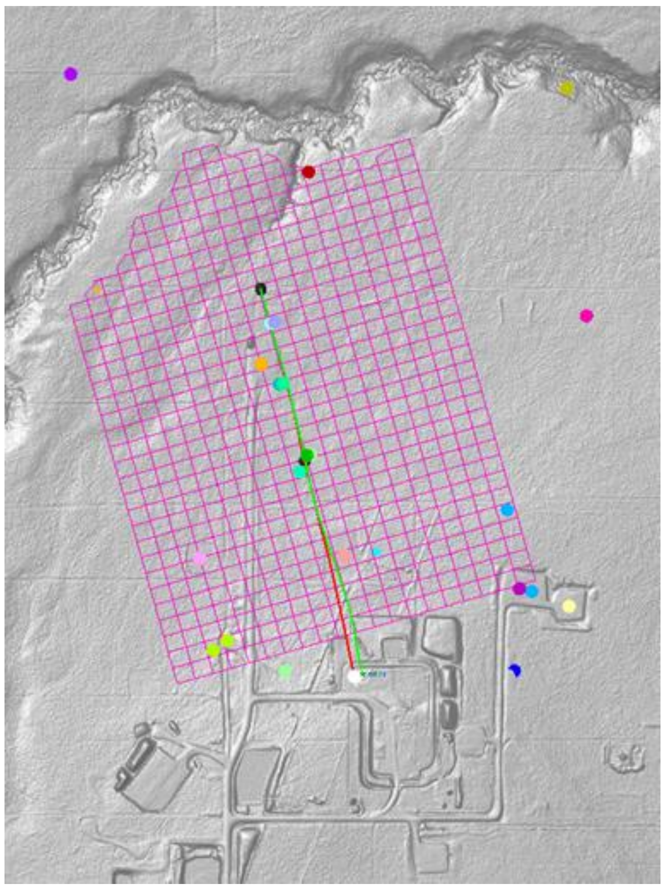


Figure 11: Seismic Grid Layout

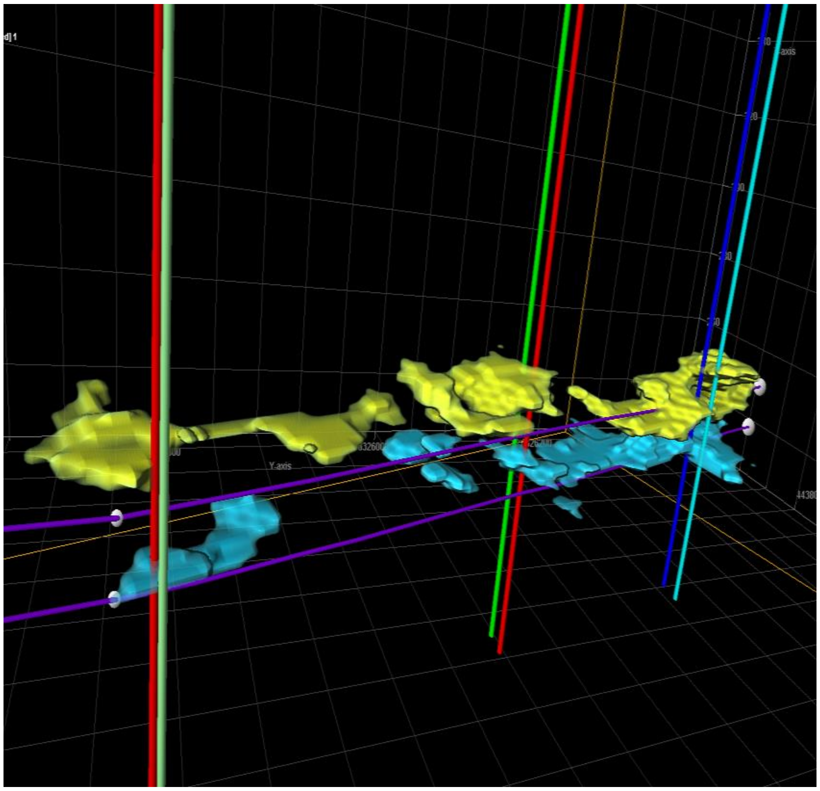


Figure 12: Chamber Growth

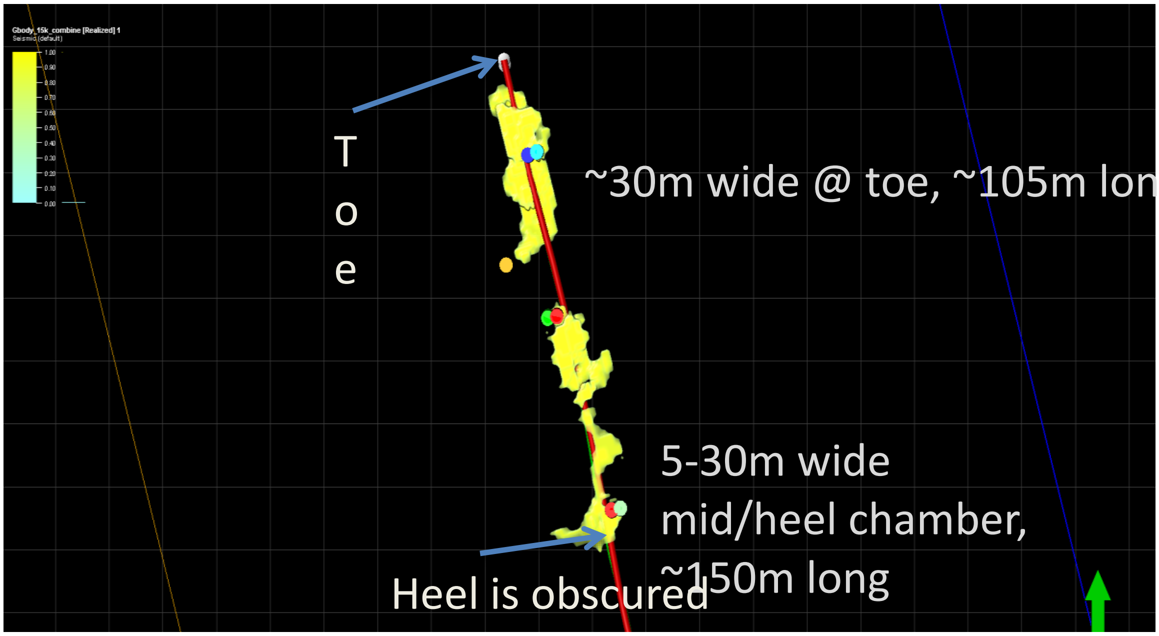


Figure 13: Plan View of Vapour Chamber

3.3 Technology Development, Installation and Commissioning

By constructing, commissioning and operating a Pilot Project, a lot of knowledge was gained about the Nsolv technology. Technical challenges came up throughout the pilot life that was addressed in order to continue to operate successfully. Section **Error! Reference source not found.** is a discussion about the lessons learned throughout the project with a number of items relating to the improvement of the technology and installation.

One aspect of the Nsolv technology that has not been investigated is Solvent Recovery. Economic application of the technology requires a certain level of recovery of solvent that is held-up in the reservoir over the course of a well pair to be recovered at the end of the pilot life. Testing this now would have a major cooling effect on the solvent chamber and cannot be directly tested until the Pilot Project has collected sufficient performance data from the solvent injection phase of operation. A solvent blowdown phase is planned at the end of the Pilot Project, which will provide direct measurements of this parameter. Until this information is available, reservoir simulation, including history matching of the Pilot Project start-up diesel solvent recovery (i.e., 100% to date), will be used to estimate solvent recovery at a field scale. Moreover, Nsolv's economics make only a 50% recovery assumption of injected solvent, noting the current diesel (a mild solvent) recovery from the pilot startup is 100%, i.e. none has been lost.

3.4 Safety

There has not been any major safety incident during the BEST Pilot Project life.

3.5 Discussion

The metrics that were set out before starting the BEST Pilot Project have been achieved except for the recovery of the solvent that will be observed at the end of the Pilot Project life.

The data that was gather thus far has proven the technology and the next step in maturing the technology is to engineer, construct, commission and operate a demonstration commercial facility in order to prove the economies of scale as well as the GHG emissions savings.

4. Greenhouse Gas and Non-GHG Impacts

Nsolv is an in-situ extraction process similar to SAGD but uses solvents such as propane or butane at temperatures around 40°C instead of steam at around 230°C. The solvent is warmed and injected into the reservoir, where it liberates the bitumen which is pumped to the surface. Solvent is returned to the surface with the bitumen, where it is separated and recycled into the reservoir. A portion of solvent is held up in the reservoir as a result of the process, a portion of which can be recovered at the end of the life of the reservoir. The use of solvents at reduced temperatures relative to the SAGD baseline condition leads to the following environmental benefits:

- Avoided direct and indirect stationary combustion emissions by replacing high temperature steam with lower temperature solvent. Heating the solvent to moderate temperatures is more efficient than steam at reducing bitumen viscosity enough to enable gravity drainage;

- Improved yield of transportation fuel due to in-situ rejection of asphaltenes in the reservoir. A barrel of Nsolv oil yields more transportation fuel than SAGD-derived bitumen; and
- Zero process water use, thereby conserving all process water consumption associated with the steam-based SAGD process.

Nsolv also leads to a number of co-benefits not quantified in this assessment, including:

- Less hazardous waste generated downstream (during upgrading), by lowering the asphaltene content in the as-extracted Nsolv oil;
- Avoided water contamination and treatment requirements; and
- The potential for more efficient upgrading and refining due to the higher quality of Nsolv oil, which is lighter than SAGD bitumen.

4.1 GHG benefits resulting from the completed project

GHG emissions have been recorded for the BEST Pilot Project to evaluate GHG savings from the project, and to extrapolate pilot data to larger scales of production in order to evaluate the Nsolv technology in a commercial facility setting. The assessment, summarized below, finds that process-related GHG emissions from the Pilot Project significantly reduce GHG emissions relative to SAGD, while auxiliary-related emissions generated during early phases of the project (drainage and ramp-up) have a disproportionately large impact on emissions at very small production scales.

GHG Emissions at Extraction

Greenhouse gas emissions spanning drainage and ramp-up at the Nsolv BEST Pilot Project have been calculated in a bottom-up approach using measured site activity data (mass and energy flows) and accepted Canadian and U.S. GHG emission factors. The scope of the calculation covers emissions of the full lifecycle up to extracted bitumen, incorporating upstream production and transportation of solvent and fuel gas. Emissions from the project are compared to in-situ SAGD bitumen extraction based on data from Jacobs Lifecycle Assessment of GHG Emissions commissioned by the Alberta Energy Research Institute (AERI) (Jacobs, 2009). Emissions anticipated from downstream processing including upgrading and refining have also been considered further below. In the calculation, extraction-related emissions have been grouped by source/activity at the BEST Pilot Project, including:

- **Fuel gas consumption for solvent heating –** consisting of on-site combustion and upstream production and transportation;
- **Solvent injection –** consisting of the upstream production and transportation of make-up solvent purchased by site to replace solvent permanently lost to the reservoir, product oil or flaring;
- **Auxiliary power –** consisting of upstream generation and distribution of power from the Alberta electricity grid required to operate pumps, fans, compressors and other on-site equipment;

- **Fuel gas consumption for auxiliary uses –** consisting of production, transportation and eventual combustion of fuel gas associated with auxiliary site applications such as blanket gas, flare pilots, pipe purges, space heating, etc;
- **Solvent flaring –** consisting of emissions generated during flaring of solvent during on-site processing;
- **Solution gas flaring –** consisting of emissions from flaring the non-recoverable volatile fraction of reservoir output.

Figure 15 shows the average distribution of emissions by source per barrel basis during stable operating periods. The average emissions profile excludes the following periods:

- October 15 to December 31, 2014, which consisted of two PCP pump workovers with excess solvent produced from the reservoir and flared as result of abnormal operation after re-start;
- March 29 to April 23, 2015, which consisted of a shutdown and workover to replace the PCP pump with an electric submersible pump with excess solvent flared after restart.

Figure 16 illustrates the contribution of emissions by activity/source during ramp up, showing 21% of emissions generated by fixed-process applications (dark shading) and 79% of emissions due to auxiliary applications and solvent flaring (light shading) during the stable ramp-up period. Auxiliary applications and solvent flaring do not scale with production capacity and are not expected to make a significant contribution to emissions in a commercial-scale facility.

Emissions from auxiliary applications and solvent flaring amount to 124 kgCO_2e/bbl-e of total Pilot Project emissions observed during the stable ramp-up period. At commercial scales exceeding 5000 bbl-e/d, emissions from auxiliary applications and solvent flaring are expected to be reduced to 6.0 kgCO_2e/bbl-e, or 37% of total extraction-related emissions.

(right).

Figure 14: Weekly GHG Emissions Profile – Nsolv BEST Pilot Project

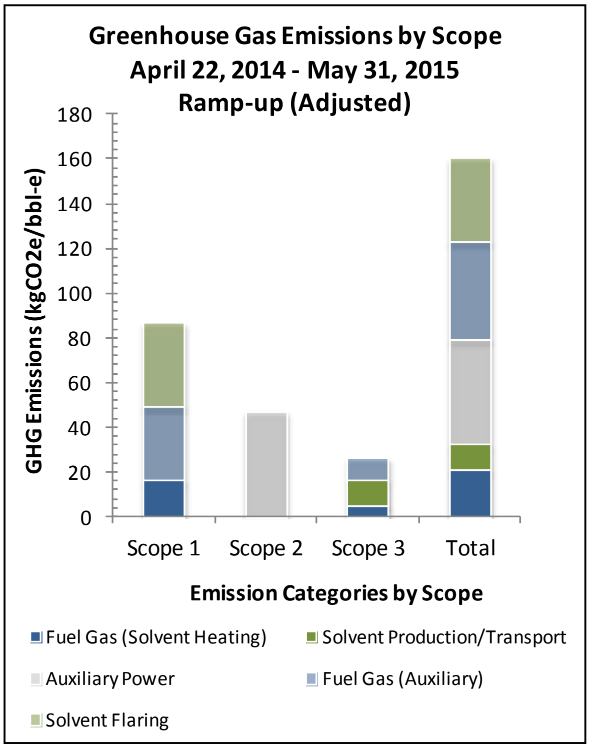


Figure 15: Average GHG Emissions Intensity - Nsolv BEST Pilot Project

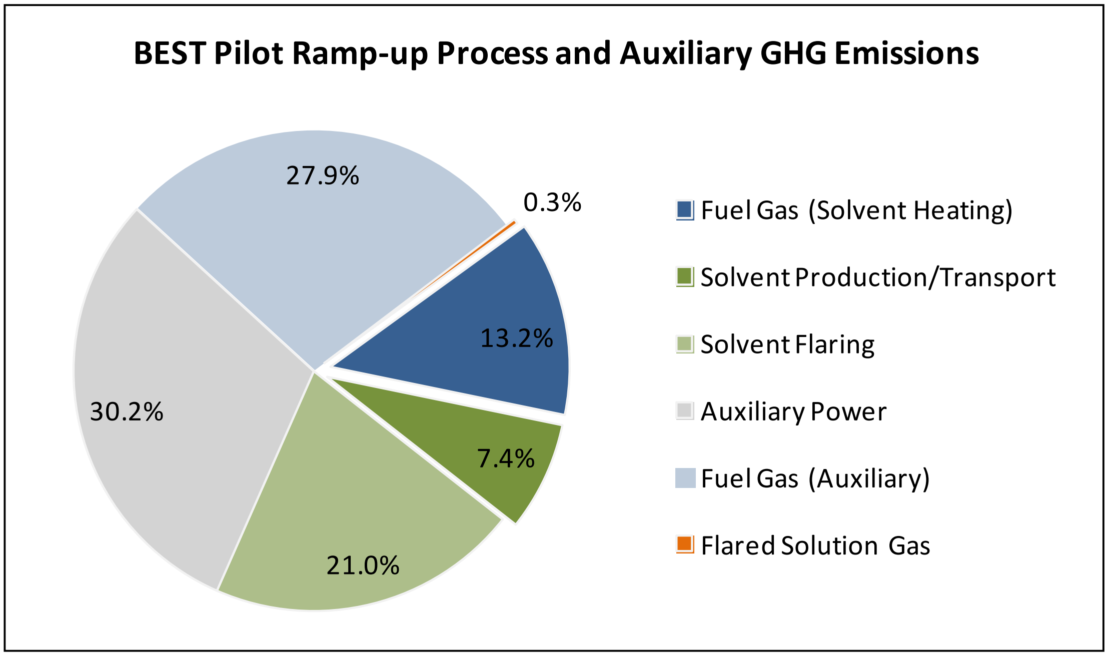
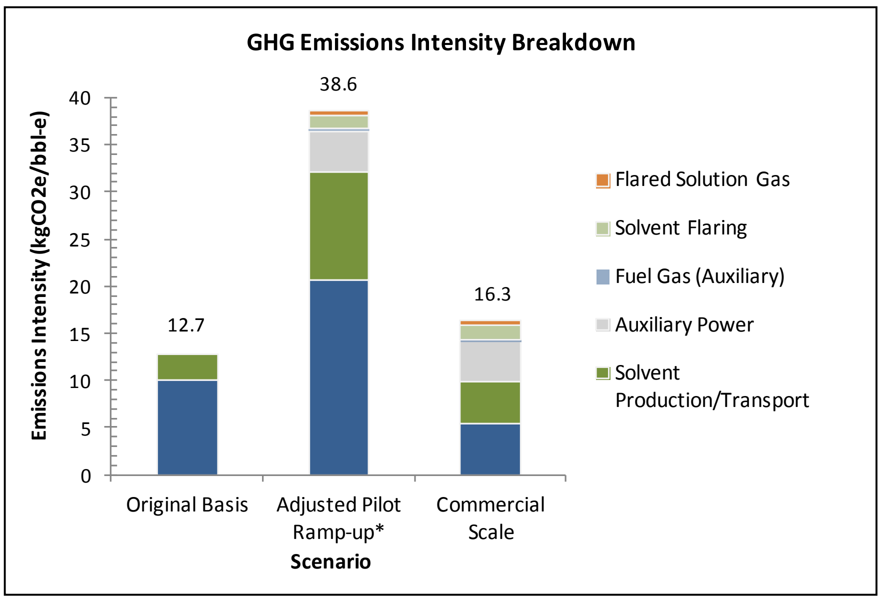


Figure 16: BEST Pilot Ramp-up Process and Auxiliary GHG Emissions

Figure 17 shows the GHG emissions intensity for various project scenarios including the original pre-pilot emissions estimate, emissions based on data from the ramp-up of the pilot facility, and emissions calculated from the commercial-scale model of the Nsolv process. For comparison, auxiliary applications and solvent flaring (light shading) during ramp-up have been adjusted to reflect the conditions present in a full-sized facility. Solvent heating and injection-related emissions during Pilot Project ramp-up have an average emission intensity of 20.7 kgCO_2e/bbl-e and 11.5 kgCO_2e/bbl-e, respectively. The emissions intensity for each source is elevated compared to the original GHG calculation at the start of the project on account of increased solvent hold-up and operating in a reservoir with higher SOR than anticipated. In a commercial scenario, lower SOR reservoirs and application of heat recovery to reduce fuel gas requirements are expected to reduce emissions from each source down to 5.4 kgCO_2e/bbl-e and 4.5 kgCO_2e/bbl-e, respectively. The commercial scenario also considers more conservative estimates of solvent hold-up as well as a provision for solvent losses to product oil and to flaring under unexpected equipment shutdowns. Combined, the total emissions in each scenario equal 12.7 kgCO_2e/bbl-e, 38.6 kgCO_2e/bbl-e and 16.3 kgCO_2e/bbl-e for the original, adjusted pilot and commercial scenarios, respectively.



* Adjusted Pilot Ramp-up scenario considers current pilot data for solvent heating and injection and commercial-scale emissions intensity for auxiliary fuel gas, power and solvent flaring.

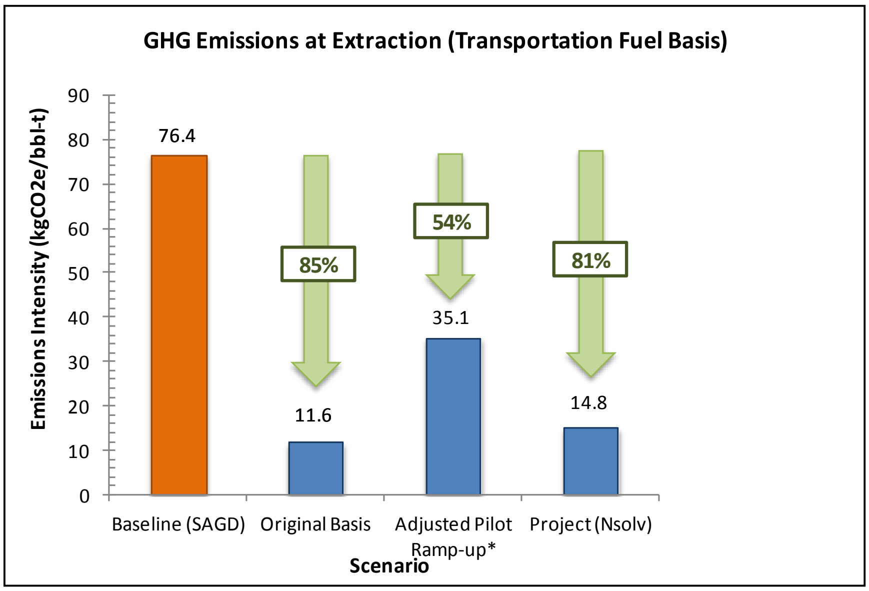
Figure 17: GHG Emissions Intensity Breakdown

GHG Emissions – Downstream Upgrading & Refining

On a lifecycle basis, the downstream processing of Nsolv oil is expected to have a number of benefits over SAGD on account of its reduced heavy metal and asphaltene content and lower bitumen density. The most significant effect is the improved yield of transportation fuel over SAGD bitumen. The yield of SAGD is lower due to 23% (by volume) of the SAGD bitumen rejected as coke. Nsolv derived product does not require coke rejection. In the Nsolv process, these materials are left in the reservoir, effectively increasing the yield of useful oil per barrel extracted.

After upgrading and refining, the yield from a barrel of Nsolv bitumen is 1.100 bbl transportation fuel, relative to 0.917 bbl for SAGD, an increase of 20%. Preliminary data from the BEST Pilot Project is confirming this yield gain – as quality testing is showing that bitumen extracted during ramp-up contains less asphaltenes and is lighter than typical SAGD (14.5 vs. 8.8 °API).

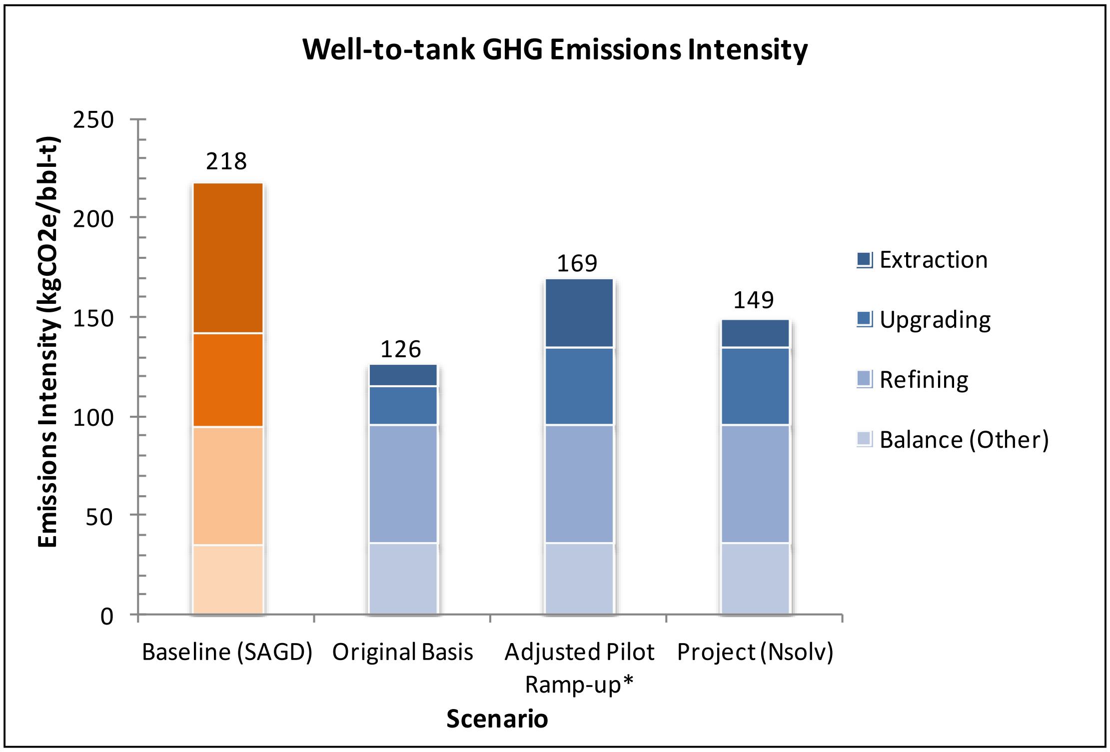
Figure 18 shows the total GHG emissions for in-situ bitumen extraction for each Nsolv scenario relative to the SAGD baseline. For an equivalent comparison, emissions from Nsolv and SAGD extraction are presented in units of transportation fuel, after incorporating yield gain and loss, respectively. Relative to the SAGD baseline, the BEST Pilot Project reduces emissions by 54%, while the emissions reduction extrapolated to commercial scale predicts a total reduction of 81%.



* Adjusted Pilot Ramp-up scenario considers current pilot data for solvent heating and injection and commercial-scale emissions intensity for auxiliary fuel gas, power and solvent flaring.

Figure 18: GHG Emissions at Extraction (Transportation Fuel Basis)

The total well-to-tank GHG emissions considering downstream transportation, upgrading and refining is presented in Figure 19 for Nsolv and SAGD. Note that other downstream benefits of Nsolv beyond improved yield, including reduced diluent required for shipping, and optimization of fuel gas and hydrogen use during the upgrading Nsolv oil have not been factored into the updated GHG estimate. As a conservative approach, the transportation, upgrading and refining processes for Nsolv oil and SAGD bitumen have been considered equal. However, sustained market penetration in Alberta may lead to Nsolv-specific upgrading and refining in the future to utilize additional cost and GHG savings.



* Adjusted Pilot Ramp-up scenario considers current pilot data for solvent heating and injection and commercial-scale emissions intensity for auxiliary fuel gas, power and solvent flaring.

Figure 19: Well-to-Tank GHG Emissions Intensity

4.2 Annual GHG Benefits Projected over a Ten-Year Period

4.2.1 Environmental Benefits Quantification

4.2.1.1 Summary of Environmental Benefits

The Nsolv process provides significant environmental benefits over the incumbent SAGD process for in-situ bitumen extraction in Alberta. A 10,000 bbl/d commercial facility and subsequent commercial roll-out of the Nsolv technology will reduce greenhouse gas (GHG) and other criteria air contaminant (CAC) emissions on a well-to-wheels basis by reducing reservoir heating requirements and improving yield of synthetic crude (SCO) for each barrel of bitumen extracted (bbl-e). By requiring zero process water, Nsolv also avoids the make-up water requirements and wastewater discharge of the SAGD process.

Table 1 summarizes the quantification of air and water benefits of the Nsolv process on a lifecycle well-to-tank basis. Other environmental benefits are expected to be achieved by the Nsolv process although these benefits have not been estimated below. Other benefits include reductions in other CAC emissions, soil contamination, and water contamination associated with reduced fossil fuel combustion, less upgrading waste products (e.g. coke), and avoided wastewater generation, respectively.

Table 1: Summary of Well-to-Tank Air and Water Benefits

	Intensity-based Reduction (per bbl-SCO)	Market Rollout Benefits		
		Annual Benefit 2025*	10-Year Benefit from Start of Project (2016-2025)†	10-Year Benefit from First Additional Site (2021-2030)‡
GHG Emissions	73.3kgCO_2e/bbl	3.8 MtCO_2e/yr	10.1 MtCO_2e	47.2 MtCO_2e
NO_X Emissions	24 g/bbl	1 251 t/yr	3 298 t	15 467 t
SO_X Emissions	33 g/bbl	1 706 t/yr	4 496 t	21 085 t
PM Emissions	0.5 g/bbl	26 t/yr	70 t	327 t
Water Conservation	147 L/bbl	7 631 km^3/yr	20 117 km^3	94 345 km^3

* The benefit achieved within the year (not cumulative), 10 years from present day.
† The benefit achieved cumulatively in the next 10 years from present day (from 2016-2025).
‡ The benefit achieved cumulatively in the first 10 years of commercial rollout (from 2021-2030).

4.2.1.2 *Basis of Environmental Performance*

A 10,000 bbl/d Nsolv facility is intended to prove the commercial viability of the technology, following the successful field demonstration at the BEST Pilot Project (located at Suncor's Dover lease). The objective of a commercial project is to demonstrate a sustainable future for the Alberta oil sands by delivering on the key economic and environmental benefits of the process. As a result of the favourable economics relative to the incumbent SAGD technology, the project is expected to lead to additional commercial applications of the technology and widespread environmental benefits for Alberta.

4.2.1.3 *Quantification Methodology*

The assessment of environmental benefits for GHG emissions and air emissions follows a life-cycle analysis approach consistent with ISO 14064 and ISO 14040, respectively. The assessment uses an appropriate baseline definition to quantify all material emission sources directly and indirectly associated with the project on a well-to-tank (WTT) basis. Emission factors used are sourced from federal, provincial and U.S. sources, including the Canadian National Inventory Reports, the National Pollutant Release Inventory, GHG-Genius and U.S. EPA AP-42. Alberta-specific grid electricity factors were used for increased accuracy and to maintain consistency with the data for the SAGD baseline.

To compare the project and baseline technology on a similar basis, the system boundaries of the emissions assessment covered the entire transportation fuel supply chain (WTT) including extraction, upgrading, refining and distribution. For each process stage, direct and indirect emission sources were considered (i.e. Scope 1, Scope 2, and Scope 3 sources). To quantify water conservation, only direct water consumption during extraction was considered.

Due to the different yields of Nsolv oil and SAGD bitumen, a barrel of synthetic crude oil (SCO) and a barrel of transportation fuel were selected as functionally equivalent units. The relationship between each unit is expressed as:

1 bbl Nsolv Oil : 1.041 bbl SCO : 1.100 Transportation Fuel

Baseline Condition

The baseline condition for the environmental benefits calculation is a green field SAGD facility. SAGD is the incumbent technology for in-situ oil extraction from the same category of oil sands reservoirs as Nsolv. In the absence of the commercialization of the Nsolv process, all new sub-surface oil sands extraction would use some variation of the SAGD process. Once successfully proven, Nsolv's strongly favourable economics and product quality will lead to the increasing selection of Nsolv over SAGD in new in-situ extraction projects.

SAGD involves steam injection into the reservoir to provide heat to reduce the oil viscosity, enabling it to be pumped to the surface. SAGD is an energy, water and emissions-intensive process, as a result of:

- Stationary combustion emissions to form 230°C steam during extraction;
- Coker shrinkage equivalent to 23 wt% of the bitumen due to rejection of heavy metals an asphaltenes (steam emissions are applied to a smaller barrel of refinery feedstock); and
- High process water consumption related to steam injected into the reservoir.

The SAGD baseline is represented using data provided in the Jacobs Lifecycle Assessment of GHG Emissions commissioned by the Alberta Energy Research Institute (AERI) (Jacobs, 2009). CAC emissions for SAGD extraction were determined from National Pollutant Release Inventory (NPRI) data by the 2013 Pembina study "Forecasting the Impacts of Oilsands Expansion". Water consumption data was based on 2012 data from the Canadian Association of Petroleum Producers (CAPP), in which in-situ bitumen extraction requires 0.8 bbl of make-up water per barrel of bitumen extracted, consisting of 51% brackish water and 49% fresh water.

Using these sources, GHG emissions from SAGD-bitumen extraction equals 70.1 kgCO_2e/bbl-bitumen. Similarly, SAGD results in 218.4 kgCO_2e/bbl-transportation fuel on a WTT basis.

Project Condition

The project condition considered for this application is a 10,000 bbl/d commercial Nsolv facility. Nsolv is an in-situ extraction process similar to SAGD but uses solvents such as propane or butane at temperatures around 40°C instead of steam at around 230°C. A commercial facility will build off of experience gained from Nsolv's 250-300 bbl/d BEST pilot plant.

Emissions from the Nsolv product life-cycle have been calculated in a bottom-up approach using a combination of measured site activity data (mass and energy flows), commercial feasibility study parameters, and accepted Canadian and U.S. emission factors. Key process parameters considered in the assessment include:

- Solvent-to-oil ratio (SOR): 3.0;
- Solvent hold-up in reservoir: 0.3 bbl/bbl-extracted; and
- Solvent hold-up recovery: 50%.

The emissions assessment for Nsolv considered the following direct and indirect emission sources specified in Table 2.

Table 2: Extraction Emissions for Nsolv Oil Production

Enission Source	Description	Scope	Activity Level		Emission Factor		GHG Emissions	
			Qty.	Unit	Qty.	Unit	Intensity (kgCO_2e/bbl-e[*])	Annual (tCO_2e/yr)
Fuel Gas - Combustion	Solvent heating, auxiliary applications.	1-Direct	0.105	GJ/bbl-e	41.5	kgCO_2e/GJ[a]	4.35	7 940
Fuel Gas - Production/Transport	Solvent heating, auxiliary applications.	3-Indirect (Other)	0.105	GJ/bbl-e	12.5	kgCO_2e/GJ[b]	1.31	2 390
Upstream Solvent Production/Transport	Make-up solvent for injection into reservoir.	3-Indirect (Other)	0.027	m^3/bbl-e	166.0	kgCO_2e/m^3[c]	4.51	8 230
Solvent Losses Flared	Flaring under unexpected equipment malfunction.	1-Direct	0.95	L/bbl-e	1.52	kgCO_2e/L[d]	1.45	2 640
Electricity	Misc. site applications (pumps, compressors, etc.).	2-Indirect (Power)	4.64	kWh/bbl-e	0.91	kgCO_2e/kWh[e]	4.22	7 710
Solution Gas Flared	Off-gas flaring from extracted bitumen.	1-Direct	0.25	Sm^3/bbl-e	1.90	kgCO_2/Sm^3[f]	0.48	880
Total Extraction Emissions	Scope 1 - Direct (on-site)						6.29	11 470
	Scope 2 - Indirect (power)						4.22	7 710
	Scope 3 - Indirect (other)						5.82	10 620
	Total						**16.33**	**29 800**

[*] bbl-e = barrels of bitumen extracted.
[a] BEST Pilot fuel gas assay data.
[b] GHG Genius, as natural gas.
[c] GHG Genius, as LPG.
[d] US EPA, as LPG.
[e] 2014 Canada National Inventory Report - Alberta Grid Emission Factor.
[f] Approximated as 100% methane.

The only material downstream environmental aspect considered in the quantification is the effect of increased yield of SCO and transportation fuel for Nsolv oil relative to SAGD. The yield of SAGD is lower due to 23% (by volume) of the SAGD bitumen rejected as coke during upgrading. Nsolv derived product does not require coke rejection. In the Nsolv process, these materials are left in the reservoir, effectively increasing the yield of useful oil per barrel extracted. After upgrading and refining, the yield from a barrel of Nsolv oil is 1.100 bbl transportation fuel, relative to 0.917 barrels for SAGD, an increase of 20%.

Based on this assessment, GHG emissions from Nsolv oil extraction equal 16.3 kgCO_2e/bbl-extracted. Adding downstream upgrading and refining using Jacobs data, the total WTT emissions from Nsolv equal 149.0 kgCO_2e/bbl-transportation fuel.

4.2.1.4 *Lifecycle Well-to-Tank Reductions*

The total direct and indirect emissions reductions and water conservation achieved by the Nsolv technology is presented in Table 3. In terms of GHG emissions, a commercial Nsolv facility is estimated to reduce in-situ extraction emissions by 81% and the entire fuel supply chain by 32% (WTT-basis) relative to SAGD (Figure 20). Similar to Nsolv's GHG benefit, reduced energy requirements relative to the SAGD process lead to comparable reductions in an assortment of fossil fuel-related CAC emissions. By avoiding water use, Nsolv conserves all water consumed by the SAGD process.

Table 3: Well-to-tank (WTT) life-cycle benefits of Nsolv oil

	Intensity-based Reduction (per bbl-SCO)	**Intensity-based Reduction (per bbl-transportation fuel)**
GHG Emissions	73.3kgCO_2e/bbl	69.4 kgCO_2e/bbl
NO_X Emissions	24 g/bbl	23 g/bbl
SO_X Emissions	33 g/bbl	31 g/bbl
PM Emissions	0.5 g/bbl	0.5 g/bbl
Water Conservation	147 L/bbl	139 L/bbl

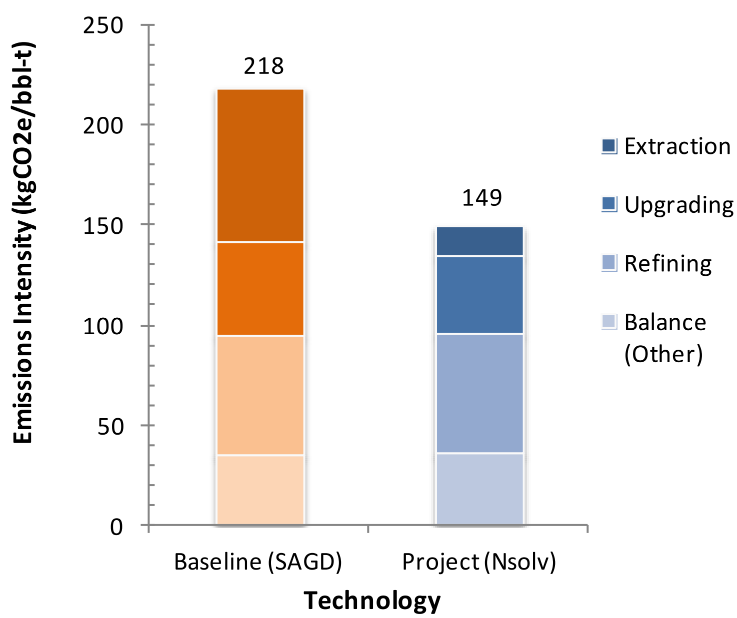


Figure 20: Well-to-Tank (WTT) Life-Cycle GHG Emissions of Nsolv and SAGD

4.2.1.5 Projected Reductions from Commercial Roll-out

Nsolv has significant potential for widespread displacement of SAGD as the preferred technology for developing in-situ extraction projects. During commercialization, Nsolv will gain increasing market share of new in-situ extraction projects in Alberta, leading to sustained environmental benefits equal to the intensity-based reductions in Table 2 for each barrel of oil produced.

While Nsolv is applicable to almost all new in-situ bitumen projects, a conservative market projection was adopted to reflect technology implementation barriers including the time required to grow industry acceptance and the engineering and construction experience and capacity to roll-out the technology.

Nsolv's projection is based on the Canadian Association of Petroleum Producers (CAPP) 2015 projections, and anticipates that the first additional commercial facility will be commissioned in 2021 based on a 20% adoption rate of greenfield in-situ projects. Then, between 2022 and 2030, Nsolv bases its projection on a 30% adoption rate of Greenfield in-situ projects. In addition, between 2021 and 2030, CAPP projects a large turnover of reservoirs accessed by existing SAGD facilities. Of this turnover, the projection considers that Nsolv will achieve a 5% adoption rate.

The results of the commercial roll-out model are shown in Figure 21, showing an increase in Nsolv's share of total in-situ production in Alberta from 1.1% in 2021 to 6.8% in 2025 and 16% in 2030.

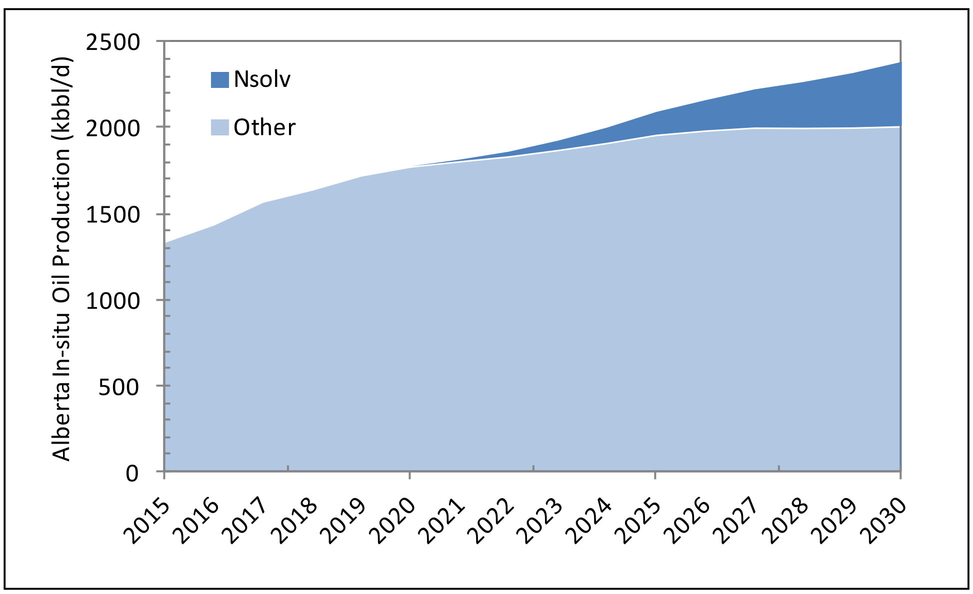


Figure 21: Projected Nsolv Market Rollout Schedule Relative to Total In-Situ Production

In the first ten years of commercial adoption, from 2021 to 2030, Nsolv is anticipated to achieve the following environmental benefits within Alberta:

- GHG emissions reductions equal to 47.2 million tCO2e;
- PM emissions reductions equal to 327 tPM;
- Nitrogen oxides emissions reductions equal to 15 467 tNOX;
- Sulphur oxides emissions reductions equal to 21 085 tSOX; and
- Conservation of 93.3 million cubic metres of water.

4.3 Immediate and Potential Future Non-GHG

The BEST Pilot Project, its successful demonstration, and the commercialization of the Nsolv technology has many non-GHG benefits, including significantly reduced air, soil and water environmental burdens as highlighted below. A large, but less quantifiable impact arises from stakeholder and community acceptance of continued oilsands development in a more sustainable manner.

4.3.1 Clean Air Benefits

Similar to Nsolv's GHG benefit, reduced energy requirements relative to the SAGD process lead to reductions in an assortment of fossil fuel-related CAC emissions. NO_X, SO_X, and PM emissions calculated from the Nsolv BEST Pilot Project and commercial feasibility model have been compared to industry emissions data from SAGD facilities (see quantification estimate above). The calculation followed the same methods, parameters and system boundaries as the GHG emissions calculation outlined above. Baseline in-situ extraction emissions were determined from National Pollutant Release Inventory (NPRI) data by the 2013 Pembina study "Forecasting the Impacts of Oilsands Expansion" (62 gNO_X/bbl, 41 gSO_X/bbl and 1.5 gPM/bbl).

On an equivalent SCO-basis, the commercial Nsolv process is expected to lead to reductions of 24 gNO_X/bbl, 33 gSO_X/bbl and 0.5 gPM/bbl. The annual emissions benefit from a 10,000bbl/d project is 91 tNO_X/yr, 125 tSO_X/yr and 1.9 tPM/yr, with expected market roll-out set to achieve a total annual benefit of 1251 tNO_X/yr, 1706 tSO_X/yr and 26 tPM/yr by 2025, increasing to 3365 tNO_X/yr, 4588 tSO_X/yr and 71 tPM/yr by 2030.

4.3.2 Water Benefits

The Nsolv process avoids all of the make-up water requirements of the SAGD process. According to 2012 data from the Canadian Association of Petroleum Producers (CAPP), in-situ bitumen extraction requires 0.8 bbl of make-up water per barrel of bitumen extracted, consisting of 51% brackish water and 49% fresh water.

On an equivalent SCO basis, incorporating Nsolv's improved yield, the total water conserved by the Nsolv process is 147 L/bbl-SCO (0.92 bbl/bbl-SCO). Water savings assume that all downstream water requirements during upgrading and refining are equal for Nsolv and SAGD-derived crude. The annual water conserved from a 10,000 bbl/d project is 557 million L/yr, with expected market roll-out set to achieve a total annual benefit of 7631 million L/yr by 2025, increasing to 20 527 million L/yr by 2030.

In addition to water conservation Nsolv also avoids all wastewater discharge associated with the SAGD process.

4.3.3 *Social*

For First Nations and all communities located within the oil sands areas, a reduction in the environmental cost associated with current in-situ production (GHGs and water consumption) will bring about much greater acceptance of oil sands development and also bring in-situ production much closer to its ideal state, in which it accesses valuable resources with minimal surface impacts.

The global interest in unconventional oil processing is growing tremendously around the globe: heavy crude (conventional and non-conventional) is expected to grow to 22% of total crude supplies by 2022, up from 16% in 2010. This will give Albertans and Canadians, with their beachhead in the Athabasca, an opportunity to expand into a premier global energy leadership position; this project will aid such capacity building.

Nsolv has also benefited from collaborative research and development with Canadian institutions, including the Alberta Research Council, University of Waterloo, Memorial University, and Hatch. Hatch also employs former and current engineering students in full-time and co-operative positions to develop their skills and, eventually, deploy the Nsolv technology.

4.3.4 *Other*

Due to the low operating pressures and temperatures associated with the Nsolv process, the Nsolv process can be used more safely than SAGD. The lower operating pressure of the process (balanced to reservoir pressure) avoids concerns of caprock fracture that exists for SAGD projects, while the lower operating temperature (40-60 ^{o} C vs. 230 ^{o} C for SAGD) also significantly reduces the ground heave associated with thermal expansion of the reservoir and overburden common to SAGD projects, which can result in surface elevation changes of several meters, influencing river and aquifer flow patterns.

5. Conclusions

The overall performance of the BEST Pilot Project has been very good and the viability of the Nsolv technology has been successfully demonstrated.

Nsolv collects over 3500 measurement points around the plant every few seconds. This data is collected and stored via a software package called PI where it is distributed to Nsolv engineers and outside parties for analysis, currently Shell, Suncor, PTTEP, and Hatch. Nsolv meets regularly and extensively with each of these entities to discuss the results of the pilot performance and ways to enhance it. In addition to Alberta-mandated oil production reporting, the oil quality is validated through Nsolv's internal lab capability as well as 3rd-party oil sands laboratories and through an additional collaboration with a confidential major oil company. Emissions and energy data has been collected and analyzed by lifecycle assessment specialists within Hatch's Environmental Services Group.

The potential benefits of the Nsolv technology are listed below with the plan of developing a commercial scale facility to prove the economics:

Table 4: Benefits of Nsolv technology

Economically viable at $40-50 WTI	1/7th the extraction energy of SAGD	40-50% lower capital cost than SAGD
Full cycle GHG similar to other crudes entering US	Zero water usage	In-situ upgrading, producing 14-16 API oil.
Robust, low risk economics due to strong correlation between operating costs and WTI price	Frees up 15-20% pipeline capacity due to lower diluent blending requirements	Higher netbacks for producers AND higher royalties to the Province of Alberta and its citizens.

While the Pilot Project faced and overcame numerous challenges, valuable experience was gained through the engineering, construction, commission and operating phases that will allow Nsolv to build a better, more efficient and stable operating plant for all future projects.

6. Scientific Achievements

Nsolv has been involved in the following public disclosures of the project and the project findings:

Presentations:

A. Stickler, Canadian Heavy Oil Association (CHOA) conference, October 16, 2013

P. Krawchuk, Petroleum Technology Alliance Canada (PTAC) Oil Sands forum, November 6, 2013

P. Krawchuk, CHOA Facilities Beer & Chat, May 22, 2014

A. Stickler, CHOA conference, fall 2014

J. Kuhach, Canadian Oil Sands Summit, February 2015

J. Kuhach, CERI 2015 Conference, April 2015

J. Kuhach, Rocky Mountain Energy Summit, August 2015

Publications:

Jaremko, D. (2015). N-Solv pilot, a conversation with Joe Kuhach, chief executive officer, N-Solv Corporation. *Journal of the Canadian Heavy Oil Association*, January 2015 edition, 16-17.

Boone, C & Stickler, A. (4-5 June 2014). Industry-driven innovation - a key for sustainability in the oil and gas sector. *G7 Climate Change, the new economy*, 4-5 June 2014, 58-59.

McWhinney, R (2015). Process Efficiencies of Unconventional Oil and Gas, Oil Sands In Situ: Solvent-based Extraction. *Canadian Energy Research Institute (CERI)*, Study No. 147 - June 2015, 46-49.

Student theses:

Cao, K.(2014). A Numerical Simulation Study of the N-Solv Process. *A Thesis submitted to the faculty of Graduate Studies in partial fulfilment of the requirements for the degree of Master of Science*, April 2014.

Patents:

Nsolv Corporation is the whole owner of the intellectual property rights associated with its in-situ extraction process, including 11 granted patents, and several applied for, comprising a total of over 400 patent claims, see Table 5 for the list.

Table 5: Intellectual Property List

IP Type	Country	Number	Filing Date	Status	Description
Patent	Canada	2,235,085	4/17/1998	Granted	Method and apparatus for stimulating heavy oil production
Patent	Canada	2,567,399	4/17/1998	Granted	Method and apparatus for stimulating heavy oil production
Patent	Canada	2,299,790	2/23/2000	Granted	Method and apparatus for stimulating heavy oil production
Patent	Canada	2,633,061	2/23/2000	Granted	Method and apparatus for stimulating heavy oil production
Patent	Canada	2,785,871	2/23/2000	Granted	Method and apparatus for stimulating heavy oil production
Patent	Canada	2,351,148	6/21/2001	Granted	Method and apparatus for stimulating heavy oil production
Patent	Canada	2,374,115	3/1/2002	Granted	Energy efficient method and apparatus for stimulating heavy oil production
Patent	Canada	2,436,158	7/29/2003	Granted	Heavy oil extraction test chamber with configurable temperature profile and feedback control
Patent	Canada	2,549,614	6/7/2006	Granted	Methods and apparatuses for SAGD hydrocarbon production
Patent	Canada	2,552,482	7/19/2006	Granted	Methods and apparatuses for enhanced in situ hydrocarbon production
Patent	Canada	2,591,354	6/1/2007	Granted	An in situ extraction process for the recovery of hydrocarbons
Patent	Canada	2,639,851	9/26/2008	Pending	A method of controlling growth and heat loss of an in situ gravity drainage chamber formed with a condensing solvent process
Patent	Canada	2,688,937	12/21/2009	Pending	A multi-step solvent extraction process for heavy oil reservoirs
Patent	Canada	2,777,966	5/23/2012	Pending	Solvent injection plant for enhanced oil recovery and method of operating same

IP Type	Country	Number	Filing Date	Status	Description
Patent	Canada	2,784,582	8/1/2012	Pending	Method and apparatus for establishing fluid communication between horizontal wells

Nsolv has filed 8 patents in the United States of America.

7. Technology Transfer Plan

7.1 Commercialization-Related Actions to be Undertaken Within Two Years of Project Completion.

Nsolv Corporation (Nsolv) wishes to develop an oil sands production facility capable of producing 5000 barrels of oil per day using Nsolv's solvent-based, in-situ bitumen extraction process, known as Bitumen Extraction Solvent Technology (BEST). The objective of the project is to demonstrate a sustainable future for the Alberta oil sands by delivering on the proven benefits of the process.

The project is scheduled to be operational by 2018 with a January 2016 start. Nsolv is working on funding towards a total initial capital expenditure of $240MM[4] to prove out a viable alternative to an effective, but inefficient incumbent in steam-assisted gravity drainage ("SAGD"), a technology that has been developed and refined with several billion dollars of investment over its history.

7.2 Potential Partnerships Under Development

Nsolv has an excellent group of alliances, beginning with its key shareholders, Hatch and Enbridge.

Through Hatch (www.hatch.ca), Nsolv has access to full EPCM services and sufficient bench depth to manage multiple project deployments simultaneously. Hatch offers complete engineering, procurement, construction management, and operational services that span the lifecycle of an Nsolv project. Additionally, Hatch has provided and continues to provide technology development services to Nsolv, including computational simulation services and analysis of the performance of the existing Pilot Project.

Enbridge's involvement in Nsolv provides excellent access to market for Nsolv's products. Presently, Enbridge's subsidiary, Tidal Energy, advises Nsolv on product marketing and transportation options.

Suncor is a publicly traded Canadian energy company engaged in exploration, production, refining and marketing of oil and gas and other energy products in Canada and other locations around the world. Suncor has been active in Canada for more than 85 years and has extensive oil sands mining and in-situ operations in Alberta. Suncor has extensive experience and

[4] As presented to CCEMC in its most recent grant funding request, the commercial demonstration plant is anticipated to have a CAPEX of $200MM for plant and equipment, as well as a working capital and start-up expense component totalling an additional $40MM.

qualified personnel in in-situ projects, Cyclic Steam Simulation (CSS) and Steam Assisted Gravity Drainage (SAGD). Additionally, their resources on new technology evaluation and deployment support are extensive, having been pioneers on many processes and reservoirs. Suncor is providing the host site for the Pilot Project and is intimately involved in facility risk and safety reviews and supplies Suncor personnel and materials as determined.

8. Communications Plan

Currently communications to third parties occurs under the guidance of data access agreements. All information is kept confidential until a data access agreement is signed with a third party.

Nsolv communicates general updates and news through the following mediums:

- News releases in local papers
- Presentations at conferences and industry events
- Publications
- Updates on the www.nsolv.ca website