

**Technical Audit Report
Gas Over Bitumen Technical Solutions
December 2010**

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DISCLAIMER

This report and its contents, the project in respect of which it is submitted, and the conclusions and recommendations arising from it do not necessarily reflect the views of the Government of Alberta and industry.

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Gas Over Bitumen Technical Solutions

A) Executive summary

1) Purpose

The purpose of this report is to summarize the findings of an audit and review of the Gas Over Bitumen (GOB) Technical Solutions Committee activities, assess the status and progress towards a technical solution, and to determine technical committee needs going forward. This review includes information contained in the public domain and as presented in Innovative Energy Technology Project (IETP) reports up to and including 2006.

2) Low Pressure Steam Assisted Gravity Drainage (LP SAGD)

For the purposes of this report, LP SAGD is as described in the Technical Road Map. LP SAGD is required if the associated gas pool pressure is not greater than the SAGD operating pressure.

3) Progress

The question has been posed; has there been progress towards a technical solution(s)? The answer to this question is; YES. The evidence supports progress in the areas of artificial lift, re-pressuring and pressure maintenance of shut-in associated gas pools, and through the field operational learning obtained from the Surmont and Christina Lake steam assisted gravity drainage (SAGD) projects.

i) Artificial Lift

There has been great progress over the past decade with artificial lift. Applications have evolved from initially gas/steam lift, to electrical submersible pumps (ESP's), and more recently to metal/metal progressive cavity pumps (PCP's). These advances are a direct result of efforts from the bench scale testing joint industry project (JIP), through vendor testing and improvements, and operator field testing and application. The advances now provide high temperature ESP's and PCP's that were not available ten years ago, provide the opportunity to operate low pressure SAGD, the ability to operate SAGD in balance with reservoir and thief zone pressure, the ability to achieve stable wellbore operations, and the ability to achieve lower cumulative steam to oil ratios (CSOR's) and improved SAGD performance.

ii) Re-pressuring/pressure maintenance

Re-pressuring and pressure maintenance of associate gas caps has advanced significantly. The gas re-injection and production experiment (GRIFE), the EnCana air injection and displacement (EnCAID) and the Christina Lake Re-pressuring projects have demonstrated progress in gas to gas displacement and recovery of methane, the ability to maintain gas cap reservoir pressure, and the ability to re-pressure depleted associated gas caps in contact with bitumen.

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iii) Surmont Project

The Surmont pilot project has been operating since July 1997 and has advanced its findings regarding operating SAGD in a resource with bitumen in contact with top water and a depleted associated gas cap; so much so that ConocoPhillips is operating its commercial project and has filed a 125,000 bopd expansion application. As of March 2010, 26 well pairs (WP's) are operating at an average rate of 736 bopd, an instantaneous steam oil ratio (ISOR) of 2.7 and a CSOR of 3.0. The key conclusion to date demonstrates that successful SAGD performance requires operations to balance the steam chamber pressure with the thief zone pressure. This results in the need to design operations with 3 stages of steam chamber pressures. The initial stage operates at a steam chamber pressure of 3,000 to 4,500 kPa utilizing gas lift in order to build the steam chamber. The second plateau stage operates at a pressure of 1,500 to 3,000 kPa utilizing mechanical lift to promote lateral steam chamber growth. The third end of life stage operates at less than 1,500 kPa with mechanical lift in order to minimize CSOR.

iv) Christina Lake Project

Like the Surmont project, the Christina Lake project has concluded that SAGD operations must balance the steam chamber pressure with the gas zone. Additionally, due to the state of gas cap pressure depletion, the gas cap pressure must be increased to allow SAGD operations to be in balance with the bottom water and top gas pressure system. As a result of this learning, the operating design includes steam chamber pressure higher than the gas cap pressure with gas lift prior to the steam chamber interacting with the gas cap, followed with steam chamber pressures in balance with the gas cap utilizing ESP's once operations are interacting with the gas cap. As of March 2010, the project was operating 14 WP's at an average rate of 1,021 bopd, an ISOR of 2.0, a CSOR of 2.0, and the Christina Lake project has received commercial application approval.

v) Other Project Experiences

Two other SAGD projects, Firebag and Long Lake, which do not have specific gas over bitumen characteristics, offer some valuable supporting evidence to the conclusions realized at Surmont and Christina Lake. Firebag and Long Lake have low reservoir pressures and have some resource with lean bitumen zones which behave as thief zones when steam chambers are operated at pressures higher than reservoir pressure. Firebag and Long Lake clearly reinforce that in order to realize successful SAGD performance, operators need to understand the reservoir characteristics and the state of the reservoir pressure to effectively design the SAGD operating conditions and the associated artificial lift systems to balance SAGD operations with reservoir conditions.

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4) Other JIP's and initiatives

i) Well bore architecture

At the time of this JIP, high temperature ESP's and PCP's did not exist. The JIP assessed the ability to operate existing pumps at low pump intake sub cools and pressures by investigating new SAGD well pair architectures or configurations that allow existing pumps (at that time) to operate under low pressure SAGD operations and to investigate vertical well sump and boosting/cooling systems. The study conclusions were valuable at the time. However, industry pursued advancing the temperature application of ESP's and PCP's resulting in no further work in the wellbore architecture field.

ii) Facility capital and operating cost study

The technical solutions sub committee debated the economic merits of low pressure SAGD in its early years. This study compared the capital and operating costs of Low Pressure (LP) SAGD (500 kPaa) utilizing ESP's and E-Lift lift systems, to higher pressure SAGD operations (2,200 kPaa) utilizing gas lift systems. The study concluded that LP SAGD can provide better economics than High Pressure (HP) SAGD.

iii) Non Condensable Gas (NCG) literature survey

This JIP focused on a literature search to identify gaps in current knowledge and to compile industry field experience regarding the impacts of NCG on the SAGD process. The study focused on opportunities and strategies to maximize the benefits of naturally generated or injected NCG's during bitumen recovery by SAGD at lower pressures and in the presence of associated gas caps. The study is complete and the conclusions are confidential.

iv) Advance down hole instrumentation

The technical sub committee established workshops to advance reliable and cost effective pressure and temperature measurement devices capable of service at SAGD operating conditions. These devices can assist in optimizing SAGD performance through monitoring and control of sub cool and steam chamber conformance. The transfer of information and experiences amongst operators and to and from suppliers of equipment and service providers has allowed the devices and systems to advance to provide more reliable service in a SAGD environment. As a result, more data is available during LP SAGD operations to allow operators to evaluate the reservoir performance with GOB circumstances.

v) Impact of Non Condensable Gas

The results of this JIP will be helpful for simulation studies.

vi) Bitumen De-methanization study

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The study objectives were to determine bitumen viscosity at high temperature under dead oil conditions and fully saturated conditions to determine the impact on SAGD performance to support guidelines for optimal SAGD operating pressures. This study makes an important contribution to improving the accuracy of modeling predictions by refining the fundamental physical input parameters.

5) Impact of Innovative Energy Technology Project (IETP)

To date the Technical Steering Committee determined that 11 projects have the potential to contribute to a technical solution to the GOB issue which have received IETP funding. This funding has provided the impetus to advance GOB innovation applications in the field, to develop JIP's to facilitate risk sharing, and broadening the dissemination of information. Many of these projects may not have proceeded without the IETP program. Some of these projects may have proceeded without funding but likely in isolation of broader participation through JIP's.

6) Gaps

Further progress towards a technical solution(s) can be realized by having the technical committee focus efforts on the following areas:

- i) Potential contamination of gas cap from SAGD operations; especially in cases where P&NG interests are held by a party other than oil sands mineral rights
- ii) further evaluation of SAGD operations while in contact with thief zones to understand how different SAGD performance is in GOB circumstances compared to simple reservoirs
- iii) understanding and advancing the field application of SAGD operations while gas to gas displacement and pressure maintenance programs are proceeding in an effort to understand the potential to have co-production of associated gas and bitumen
- iv) furthering the design and operations with flue gas pressure maintenance to effectively deal with corrosion

7) Recommendations

- i) continue the activities through the GOB technical committee
- ii) continue to provide funding through IETP
- iii) consider IETP increasing or removing its \$30 MM max funding per project to facilitate impactful larger projects to proceed. IETP currently funds up to 30% of an approved project to a maximum of \$10 million per approved project. There is opportunity for larger scale projects (in excess of \$100 million); especially if they include the testing of co-production of shut-in associated gas and bitumen.
- iv) consider preparing an update to this report subsequent to July 2011 to include the release of 2008 IETP reports

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B) Background

The seed for the GOB regulatory review was planted when Gulf Canada Resources Ltd. (now ConocoPhillips Canada) filed an application on November 12, 1996 to the Alberta Energy Utilities Board ((AEUB) now Energy Resources Conservation Board (ERCB)) to shut in associated gas production on its Surrmont oil sands leases. Other oil sands holders submitted similar requests "outlining their concerns regarding the potential adverse effects on the eventual recovery of bitumen if associated gas was produced in advance of the bitumen. Some oil sands leaseholders requested that all current and future associated gas production from affected oil sands deposits be curtailed. Given the broad implications of such a decision, the Board held a general inquiry on the issue to solicit the views of all segments of the industry". This inquiry was held during the summer of 1997 (May 29 to June 20, 1997) and included participation by most players in the in situ oil sands industry and area P&NG gas producers represented by the Alberta Producers Group (APG). The final "EUB Inquiry Gas/Bitumen Production in Oil Sands Areas" report was issued March 25, 1998 which can be found at:

<http://www.ercb.ca/docs/documents/decisions/1998/GasBitumen1998.pdf>.

The following quotes the Board directly; "the Board concluded that in some instances the effect on bitumen recovery could be significant. In order to chart a prudent course for the future development of the gas and bitumen resources in the oil sands areas, the Board concluded that:

- although limited field data are available, sufficient evidence exists to suggest that associated gas production could have a detrimental effect on some bitumen resources, to the extent that significant volumes might never be recoverable;
- while it is possible that thermal bitumen processes could have a detrimental effect on associated gas recovery, such effects would likely be relatively minor;
- Alberta's current and prospective gas reserves and deliverability position would not be materially affected by discouraging some associated gas production in the oil sands areas in favour of conserving the bitumen resources; and
- an evaluation of the appropriate timing of producing gas associated with bitumen should be consistent with the Board's approach to evaluating the production of gas associated with conventional oil."

"To summarize, the Board will:

- allow associated gas production in the oil sands areas from wells drilled and completed by 1 July 1998, subject to the resolution of any concerns raised by oil sands leaseholders or the Board on its own initiative;
- require concurrent production approval for the production of all associated gas in the oil sands areas from wells drilled after 1 July 1998;

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- require, effective 1 July 1998, all new wells in the oil sands areas to be drilled to the base of the oil sands zone;
- develop a notification process, in consultation with the affected parties, to advise leaseholders of prospective developments;
- support modifications to the existing lease tenure system in the oil sands areas to reduce resource development conflicts; and
- investigate the means of conducting further research on the effects of concurrent gas and bitumen production.”

Subsequent to this General Inquiry, Gulf amended its request to include the shut-in of associated gas production within a three mile buffer area surrounding its Surmont leases; totalling 183 wells. This request was to take into consideration that gas pools overlapped the oil sands lease area and a Region of Influence (ROI) needed to be addressed. The APG was now represented by the specific gas producers under the Surmont Producers Group (SPG). A hearing to consider Gulf’s request was held from April 28 to September 24, 1999, with the Board decision report D2000-22 released March 30, 2000. The Board ordered the following:

- the shut-in of associated gas production from 146 wells, and
- Gulf to submit annual reports on the management of the resources on its Surmont leases, including the continued assessment of the effect that the pressure of the overlying gas zone has on the recovery of bitumen.

The Board also made the following conclusions which are germane to the requirements for a GOB technical solution:

- The bitumen resources on the Surmont leases warrant consideration for protection;
- The amount of bitumen potentially recoverable from the Surmont leases is significantly greater on an energy basis than that of either estimate of the remaining recoverable gas reserves;
- Thick bitumen sands can be in contact with the overlying gas and water zones;
- Some of the depleted gas pool pressure was transmitted a significant distance into the bitumen zone;
- There is significant risk of SAGD steam chambers communicating with overlying gas and water zones at Surmont;
- The extent, magnitude, rate, time frame, and paths for transmission of pressure decrease are critical elements in establishing the extent of the effects of gas production;
- Continued pressure depletion would increase the risk of bitumen sterilization;
- The Board is not prepared to rely on re-pressuring of depleted gas zones until it has been proven that its implementation is both feasible and practical;

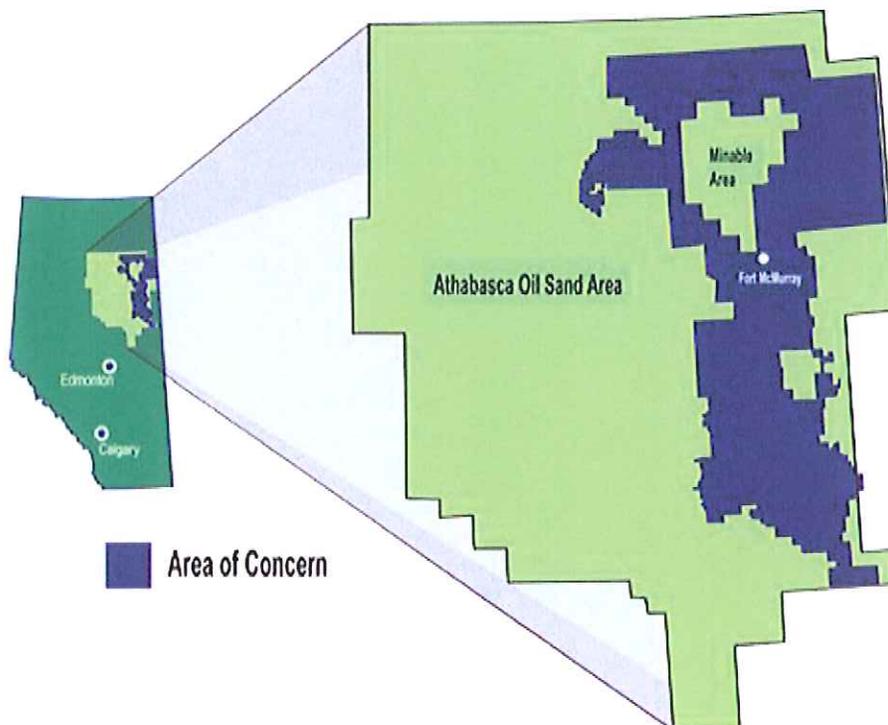
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- Artificial lift becomes increasingly difficult as the steam chamber pressure is decreased below 800 kPaa until at some point it is not likely to be technically feasible to lift the fluids at all; and
- The SAGD process could result in loss of associated gas into the bitumen zone and that there could be a loss of evolved solution gas from the bitumen zone into the overlying gas zone.

Additional applications, hearings and decisions have further reinforced the need for a technical solution. D2003-23, D2004-45, D2004-62, D2004-88, D2005-122, 2007- 56, D2007-108, D2009-24, and D2009-61 have all dealt with identifying gas to shut in and gas which will remain on production and have dealt with GOB issues in the Athabasca, Cold Lake and Peace River oil sands deposits.

The ERCB issued its Athabasca Wabiskaw-McMurray Regional Geological Study on December 31, 2003. The study was initiated through GB2003-28 to identify where gas pools are associated with bitumen within two geographical areas of the Athabasca Wabiskaw-McMurray deposit. The main study area lies south of Township 87, excluding the Surmont oil sands leases, and the north study area is west of the surface mining deposit. The total study area encompasses almost 5000 square miles. The following is a map of the area of concern.



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The study had four components; first to develop a geological framework (including the identification of significant mudstones and shales), second to evaluate and map gas pools, third to evaluate and map bitumen, and fourth to integrate the results to provide an understanding of where gas is associated with bitumen. To quote the ERCB in its January 2, 2004 announcement; "The EUB study identifies where natural gas is in contact with bitumen in the Wabiskaw-McMurray. The study does not specifically identify individual gas wells that may be subject to permanent shut-in. EUB staff will use the study to prepare recommendations respecting the production status of specified gas wells in the study area." "EUB staff will analyze all of the gas pools and make recommendations as to which gas wells negatively impact bitumen recovery."

C) Purpose of GOB Technical Solutions Steering Committee

Following D2000-22, the Crown, Gulf, and the SPG negotiated a "Settlement Agreement" in March 2002 which required the parties to develop GOB technical solutions. Herein lies the birth of the GOB Technical Solutions Steering Committee.

The principles met through this agreement include:

- The negotiated settlement resolves the Surmont GOB issue quickly, equitably, and encourages development of a technical solution
- there is incentive for all to find a technical solution allowing for the resumption of gas production in the near term

1) Facilitation Funding

The Crown engaged Triangle Engineering Ltd. to facilitate the Steering Committee and the Technical Sub Committees, and funded this facilitation until the Settlement Agreement allowed shared funding with industry. The Crown now funds one third of the facilitation costs and industry jointly funds two thirds.

2) Steering Committee

Members from the parties to the Settlement Agreement convened the first Steering Committee meeting on November 9, 2001, prior to signing the Settlement Agreement, to develop the goals and objectives for the committee and to establish technical sub committees to conduct the activities to pursue technical solutions.

3) Initial Steering Committee members

- i) Crown – ADOE
- ii) Oil sands interests – Gulf (now ConocoPhillips) and Petro-Canada (now Suncor)
- iii) P&NG interests – Paramount (now Perpetual Energy) and Northstar Energy (now Devon)
- iv) Broader industry interests – CAPP (no longer a member)
- v) Technical interests – AERI

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vi) Observer – EUB (now ERCB).

4) **Current Steering Committee members**

- i) ADOE – representing the Crown
- ii) ConocoPhillips – representing oil sands
- iii) Devon – representing oil sands and P&NG
- iv) Cenovus – representing oil sands and P&NG
- v) MEG Energy – representing oil sands and P&NG
- vi) Nexen – representing oil sands
- vii) Perpetual Energy – representing P&NG
- viii) Suncor – representing oil sands
- ix) ERCB – observer

5) **Project Scope**

The following presents the original “Project Scope”:

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Project Scope

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Industry & Government Collaboration

1) **OBJECTIVE:**

- Develop and demonstrate multiple flexible commercial technical solutions to the gas over bitumen conflict that will allow efficient and orderly exploitation of both resources
- Identify & prioritize technical areas requiring study and testing
- Promote joint R & D and field testing of appropriate applications

2) **IDEAL OUTCOME:**

- Associated natural gas and bitumen production may occur independently without regulatory or technical barriers.

3) **THIS PROJECT IS:**

- A technical solution
- Focused on the facts
- Open minded; it doesn't matter where the solution or ideas come from
- All discussions of the Steering Committee and the Technical Subcommittees will be without prejudice.

4) **THIS PROJECT IS NOT:**

- A business solution
- Policy or regulatory solutions or changes
- Monetary or other solution for shut in natural gas producers
- Lease tenure
- Corporate positions

5) **PARTICIPATION:**

- Is open to organizations that are committed to advancing this initiative. Commitment is demonstrated by dedicating human, intellectual, and financial resources, and in kind services and products, to the pursuits that evolve.

6) **STEERING COMMITTEE MEMBERS:**

Terry Abel	EUB	403 297 3382	terry.abel@gov.ab.ca
Eddy Isaacs	AERI	403 297 5219	eddy.isaacs@gov.ab.ca
John Legrow	Conoco	406 233 3287	john_legrow@gulf.ca
David Monroe	Paramount	403 290 3695	david.monroe@paramountres.com
Larry Morrison	CAPP	403 267 1114	morrison@capp.ca
John Pearce	Devon	403 213 8061	john.pearce@devoncanada.com
Tom Ross	ADOE	780 422 9482	tom.ross@gov.ab.ca
George Sinclair	Petro-Canada	403 296 6226	gsinclair@petro-canada.ca
Dave Theriault	ADOE	403 660 9956	dtheriault@petro-canada.ca
Linda White	ADOE	780 499 4953	linda.white@gov.ab.ca

6) Technical Sub Committees

The Steering Committee established 4 technical sub committees based upon the main conclusions from D2000-22 which would allow pursuit of GOB technical solutions:

1. Low Pressure SAGD
2. Artificial lift
3. Re-Pressuring
4. Lateral and Vertical Communication

Membership has grown from the original participants in the technical sub committees to 23 organizations. Additionally, the 4 sub committees now meet jointly.

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Evolution since 2001 has caused changes in industry ownership and interests broadening industry participation to currently 23 companies in the technical committees and with the Steering Committee. These participants have a mix of interests in oil sands and associated gas through out the entire oil sands deposit and the technical committee focus is no longer restricted to the Surmont area.

The project scope identified above has been expanded and now includes a responsibility to conduct a technical review of IETP applications and to recommend to IETP that the projects support the GOB technical solution.

7) Current Sub Committee Members

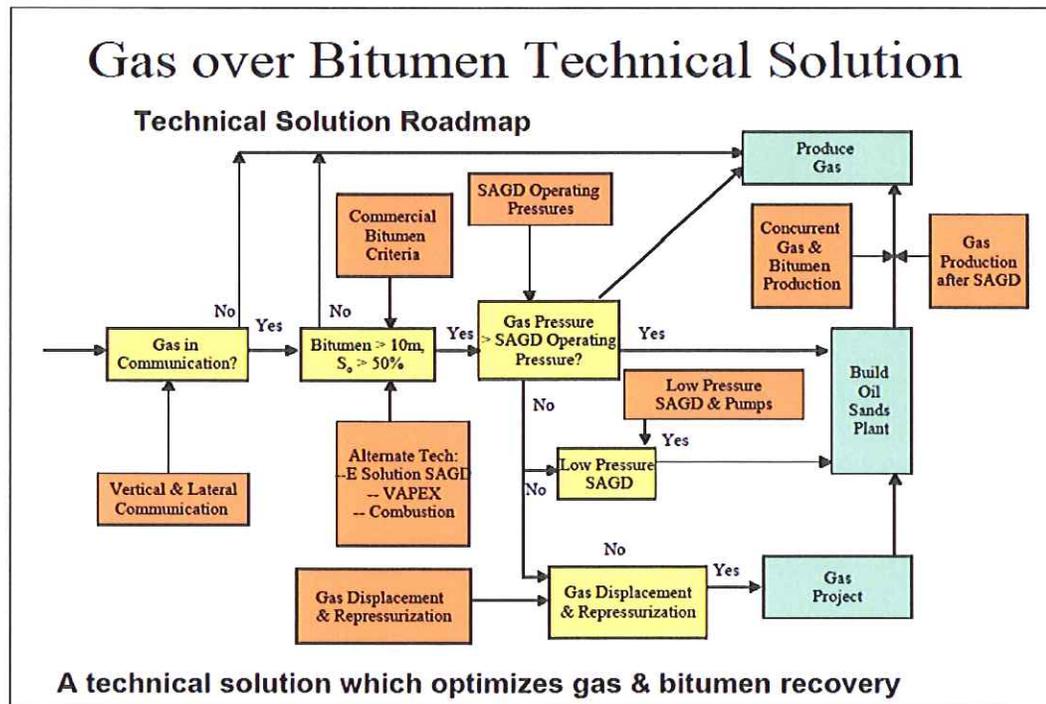
- i) ADOE
- ii) Alberta Oil Sands
- iii) Athabasca Oil Sands Corporation
- iv) Cenovus
- v) Chevron
- vi) ConocoPhillips
- vii) Devon
- viii) ERCB
- ix) Husky
- x) Imperial
- xi) Jacos
- xii) Laricina
- xiii) Marathon
- xiv) MEG Energy
- xv) Nexen
- xvi) Oil Sands Quest
- xvii) Perpetual Energy
- xviii) Petrobank
- xix) Southern Pacific
- xx) Statoil
- xxi) Suncor
- xxii) Sunshine
- xxiii) Total

8) Technical Road Map

In December 2003 the sub committees developed the following technical road map to help communicate and drive the initiatives towards a technical solution. The orange boxes represent technology development areas, the yellow boxes are choices, and the green boxes are outcomes.

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The road map identified 3 areas of focus; understand the geology, fix the reservoir, and improve the reservoir recovery process. All Joint Industry Projects (JIP) are directed to these three focus areas.

D) Joint Industry Projects (JIP)

1) Understand The Geology

i) Surmont Shut-in Data Analysis (IETP 01-005)

Paramount Resources (now Perpetual Energy) was the JIP sponsor for the Surmont Shut-in Data Analysis with the final report issued in July 2004. The study objectives were in pursuit of understanding pressure & fluid communication, vertical & lateral continuity and to develop criteria and guidelines for gas and oil sands production strategies. The JIP scope was to ensure all available pressure data (deadweight pressures, static gradient pressures and build up pressure data) from the wells affected under AEUB shut in order from D2000-22 is scrutinized for accuracy and validity. The goal was to have a comprehensive pressure data base.

The data base of pressures was vetted by the Lateral and Vertical Communication Sub Committee in 2002 rendering the data base ready for engineering analysis. Exploitation Technologies was commissioned to conduct a geological and reservoir engineering evaluation to understand the Regions of Influence (ROI) in the Surmont and Chard shut in areas.

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The results of the reservoir analysis concluded that the Surmont gas pools consist of many small pools not in lateral pressure communication. Individual pools are isolated and do not communicate laterally. However, vertical pressure communication within a given pool exists in almost all cases. This means that the gas, top water and bitumen zones are in vertical pressure communication. If these conclusions are correct, they imply the potential for successful gas pool re-pressuring opportunities.

There was discussion amongst the JIP members regarding the fact that each participant has different conclusions and opinions than what the report finds, that the study was not designed to answer all of the outstanding questions or issues, and that an application must be made to the AEUB in order to allow the affected/interested parties to have its views and evidence considered prior to a Board decision.

2) Fix The Reservoir:

Four projects have been underway for some time.

i) Surmont Gas Re-Injection & Production Experiment (GRIPE) (IETP 01-001/012)

The MEG Energy Corp. (originally Paramount Resources /ConocoPhillips) Surmont GRIPE pilot is investigating the merits of gas to gas displacement of methane while maintaining gas pool pressure. In addition, the use of compressor engine exhaust (flue gas) as the injection fluid allows for carbon sequestration. The project received regulatory approval October 2004 and initiated injection in April 2005. The project is to test incremental gas recovery on two gas pools each with one flue gas injector and two production wells. The project also includes 12 observation wells to monitor the pressures in the gas, water, and bitumen zones during the methane displacement process, and facilities to capture flue gas from the Kettle River gas plant. Ten observation wells are located outside of the two gas pools, and there is one independent pressure observation well in each of the two gas pools. Data is also captured from annual static gradients on injection and production wells.

The project has suffered numerous corrosion problems with surface equipment due to the presence of water and oxygen in the flue gas. Cumulative operating time overall is only 38%; more recent performance is 44%. This poor run time translates into deferring overall learning.

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MEG acquired the GRIPE in 2007 and restarted the project after replacing corroded pipeline couplings. Flue gas break through has been detected in the Northern X pool. Pool AAA has not yet seen any nitrogen breakthrough to date. The project has achieved 12% incremental gas recovery so far, and has maintained reservoir pressures. Failures and downtime are directly attributed to corrosion, and pilot operating and repair costs have exceeded gas production revenues. The project was restarted May 2010 and MEG has extended the ERCB scheme approval for two more years in an effort to complete the pilot.

MEG's update of October 14, 2010 indicated they have advanced corrosion learning resulting in a 94% run time since the May 2010 restart. MEG believes that GRIPE is working and that site specific commercial solutions are available to potentially recover 30 BCF of remaining shut-in gas in the Surmont area.

ii) **EnCAID K3 Pool Methane Displacement (IETP 01-003)**

Cenovus (previously EnCana) EnCAID K3 Pool Methane displacement project is conducting a field pilot test of methane displacement technology utilizing air combustion gases with down hole low temperature combustion to remove oxygen content by utilizing the 20% bitumen content in the gas zone, leaving a nitrogen flood. This approach of oxygen removal in situ is expected to eliminate the corrosion issues experienced in the GRIPE project. Cenovus believes that the "advantages of high injectivity, high displacement and thermal efficiencies, air is the cheapest, most readily available and abundant fluid for injection". The project has a gas cap directly above the bitumen with ~4 Bcf of shut in gas and consists of one vertical injection well and four vertical production wells and 2 horizontal production wells. The project received EUB approval in January 2006 and a letter of support from Petro-Canada the bitumen lease holder.

Cenovus provided an update in March 2008 and indicated that since ignition in June 2006, 1.7 Bcf of air was injected and 1.6 Bcf of gas was produced causing the pool pressure to be increased by 100 kPag, combustion is present at the top of the gas zone, CO₂ seems to be retained in the reservoir, and first N₂ was detected after 7.5 months at the closest horizontal production well. The EnCAID project experiences higher run time (only 2 days down during more than 580 days of operations) than the MEG project suggesting that the down hole combustion process of oxygen removal is superior to surface removal conducted at GRIPE.

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Cenovus presented paper 2008-497 at the March 2008 World Heavy Oil Congress and presented a number of conclusions for the EnCAID project. "The project has survived the technical concerns and mechanical design, navigated the important ignition process and safely operated for almost two years". Cenovus also states "Successful ignition of EnCAID process, safe operation, efficient delivery of pressure support, steady and continuous air injection" as other accomplishments.

Cenovus provided a further update in March 2009 after 950 days of operation. History matching of the process is difficult but is being pursued to understand nitrogen and combustion travel within the reservoir. The test is providing better geological reservoir understanding. 2.8 Bcf of air was injected and 2.3 Bcf of gas was produced contributing to a pressure increase of approximately 40 kPag, calculated by simple voidage balance. However, the overall reservoir pressure has increased by approximately 180 kPag indicating additional pressure support throughout the complex geology and/or that a lateral baffle exists between gas pools.

The EnCAID project is adding significant learning's regarding ROI's in the geological circumstances, the opportunity for gas pool pressure maintenance, a line of sight for gas pool re-pressuring, and an understanding of the commercial merits of gas to gas displacement and recovery of remaining methane in the pool.

iii) Christina Lake Re-pressuring (IETP 02-034)

Cenovus (previously EnCana) is also conducting a field pilot test of re-pressuring with air. The reservoir has gas over bitumen over water making the system more complicated and requires the pressures in all three zones to be in balance for successful SAGD operations. The gas cap was originally at 2000 kPa and was reduced to 500 kPa from gas production and the bottom water zone is at 3000 kPa. Cenovus holds mineral rights to both the oil sands and P&NG providing greater opportunity for coproduction of both resources. As of August 2010 the SAGD project is producing 14,660 bopd.

The project has three phases:

- Phase 1 re-pressured the Brackish Bay gas pool overlying the bitumen in section 16-76-6W4M. Phase 1 was completed in October, 2005 and is not part of the IETP.
- Phase 2 is re-pressuring the SAGD gas pool overlying the bitumen in section 15-76-6W4M, and consists of two air injection wells and two piezometer observation wells. Gas injection for Phase 2 began in October 2005.

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- Phase 3 plans to re-pressure the SAGD gas pool overlying the bitumen in sections 11 to 14 -76-6W4M, and consists of five air injection wells and six piezometer observation wells. There are 12 observation wells monitoring the gas cap, bitumen zone, and bottom water pressures throughout the 3 phases.

Cenovus provided an update in March 2010. Prior to re-pressuring operations, pressure rebound, attributed to solution gas effects, was observed after shut in of production. Phase 2 has resulted in the small gas cap being re-pressured to 2,200 kPag, just above the original gas pool pressure in an effort to obtain a pressure balance between the SAGD operating pressures at Christina Lake Phase 1B currently at 2,200-2,500 kPag. As of May 2008, gas cap pressure increases are being observed from SAGD operations, indicating the steam chambers are operating in contact with the gas cap. Pressure declines are being observed in an observation well in the gas pool away from current SAGD operations indicating that the east and west lobes of the Phase 2 gas cap are not in full pressure communication. The project has also been able to increase the gas pool pressure more quickly than the pressure decrease from gas production. This is thought to be attributed to the fact that air does not go into solution with the bitumen.

Phase 3 plans to re-pressure the larger gas pool to 2,000-2,500 kPag by Q3 2010, again to achieve pressure balance between the desired SAGD operating pressures at Christina Lake Phase 1C operations planned to operate at 2,000-2,500 kPag. Cenovus has received ERCB approval to re-pressure the Phase 3 gas cap with air. Cenovus predicts it will need to inject 7.3 BCF of NCG to get the SAGD gas interval to a pressure of 2,500 kPa.

Phase 1C SAGD operations will commence concurrent to re-pressuring since it takes time for the steam chamber to grow vertically and reach the gas cap.

Cenovus has the following conclusions:

- Combustion to remove oxygen in the injected air at Christina Lake is not practical due to the low reservoir temperatures. SAGD operations are not seeing oxygen in the produced gas as it is consumed at the higher SAGD temperatures
- Air can safely and economically re-pressure gas overlying bitumen in the geological features at Christina Lake
- SAGD can operate while in contact with a gas cap, as long as the system is in pressure balance

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- Cenovus anticipates no difficulties operating SAGD well pairs under a gas cap, as long as re-pressuring targets are met on a timely basis
- Re-pressuring with air is preferable to natural gas, as the only costs associated with air injection is compression, and it avoids using clean fuel gas to aid bitumen production

iv) Experimental GOB Scheme Re-pressuring and Gas Storage over Bitumen

Paramount Energy Trust (now Perpetual Energy) applied for a project at the Corner 'C' Pool to conduct gas re-pressuring to identify gas cap/pool confinement, re-pressuring ability, and understand lateral and vertical communication.

Paramount Energy presented its IETP application May 17, 2007 for technical committee recommendation to the steering committee for endorsement as a project which contributes to a technical solution to the gas over bitumen issue. The technical committee did not endorse the original application. Paramount Energy revised its IETP application reflecting the technical committee suggestions and was subsequently endorsed by the technical sub committee, the steering committee, and the executive steering committee. Unfortunately, this project has not proceeded.

3) Improve The Process:

i) Surmont Pilot (IETP 01-013)

Since July 1997 ConocoPhillips has conducted a field pilot test of LP SAGD in contact with top water and top gas. This project could develop guidelines for optimal SAGD operating pressures, allow the calibration of reservoir models at low pressure, and demonstrate the application of artificial lift at low pressures and low sub cools. The pilot consists of three SAGD well pairs and 14 observation wells.

Early in the operating life of this pilot, ConocoPhillips conducted SAGD operations near 3,100 kPa and planned to do so until pressure and fluid communication was observed between the steam chamber and the low pressure top water and gas zones. The first two short (350 m) 'A' and 'B' well pairs have seen the steam chamber pressure operated as low as 1,050 kPa. Steam generator capacity has limited the ability to service all three well pairs; hence, the 'C' well pair has seen limited steam injection relative to the other two well pairs. Under these facility constraints, the full length (700 m) 'C' well pair attempted low pressure start up which was not as effective as the high pressure startup on the 'A' and 'B' well pairs and resulted in poorer steam chamber development along the length of its well pair. This has

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resulted in lower CDOR's and higher CSOR's than demonstrated on the 'A' and 'B' well pairs.

The pilot has demonstrated successful low pressure SAGD operations to date, but needs further operations to conclude that effective SAGD operations can occur once the steam chamber is in contact with the low pressure water and gas zones. As of the 2006 annual report, the 'A' and 'C' well pairs are operating at 2,000 kPag, and the 'B' well pair is operating at 1,600 kPag and is interacting with the Thief Zone. Steam chamber operating pressures will need to balance with the pressure of the Thief Zone. To date, the pilot cumulative steam oil ratio (CSOR) is approximately 3.1.

SAGD operations have demonstrated that reservoir heterogeneities act as baffles to steam chamber development, versus barriers. Reservoir quality between the producer and injector wells impacts the initial stage of the SAGD steam chamber development. The impacts of these baffles are dependent on the thickness and the chamber operating pressures. Thinner baffles and higher operating pressures shorten the time to have the steam chamber pass around and/or through the baffle. These baffles are generally located higher in the reservoir making steam chamber management easier as the chamber rises to interact with the Thief Zone. To date, steam chamber operations have continued as interaction with the Thief Zone continues, with ultimate recovery and performance to be fully assessed with ongoing operations. This ability is reinforced by the fact that ConocoPhillips has commercial operations proceeding and as of August 2010 is producing 22,467 bopd.

The main challenge with consistent operations has been related to artificial lift performance. As a result, the Surmont pilot has tested numerous artificial lift systems during its 12 year operations; gas lift, E-Lift, mechanical rod pumps, ESP's, the Can-K twin screw multi phase pump, and the Hydraulic Gas Pump. The first few years of operations utilized gas lift and E-Lift since the steam chamber pressures were high enough to allow gas lift to be effective. E-Lift is essentially a down hole system that separates the gas and liquid phases and allows the production fluids to be collected and produced with a wide range of mechanical artificial lift systems. There were some problems with initial installation which did not allow a full test of the system. The system was pulled from service and to date has not been through a full test.

During its July 2009 update, ConocoPhillips made the following statements regarding artificial lift:

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- E-Lift is a complex installation which was not able to achieve low subcools at any operating pressure and has erratic production operations;
- Gas lift is effective in lifting high rates of fluids and achieves low subcools, however, severe slugging occurs at pressures lower than 2,300 kPa;
- ESP technology has improved over the years. Early applications failed due to high temperatures. Recent applications are more satisfactory with run times improving from 109 days to as high as 659 days;
- Rod pumps have experienced frequent failures, are susceptible to wear, and are not able to achieve high rates and low sub cools;
- Can-K; failed during a short field test;
- HGP; had no mechanical failures, but control is tricky and demanding. The HGP pump has the potential for low opex, even though it requires a gas handling system, and is still under trial;
- ConocoPhillips concludes that gas lift is effective for higher SAGD pressures and temperatures, and ESP's are effective for lower pressures and temperatures.



4- CONCLUSION

Sumont Pilot AL Learnings

	Gas Lift	E- Lift™	ESP	Can-K	Rod Pump	HGP
High Temp.	✓	✓	Up to 220C	✗	Up to 230C	✓
Low Flow Rate	✗	✗	✓		✓	✓
High Flow Rate	✓	✗	✓	✓	✗	✓
Low Subcools	✓		✗			✓
CAPEX	✓	✗	✗	✗	✓	✓
OPEX	✗	✗	✓		✓	✓
Run Life	✓		Has improved	✗	✗	✓
Operability	✓	✗	✓		✗	On Trial
OVERALL	✓	✗	✓	✗	✗	✓

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ii) Joslyn LP SAGD Test (IETP 01-025)

In 2005, Total (formerly Deer Creek) entered into a data sale agreement with numerous industry parties for its field pilot testing of LP SAGD. At this time, Joslyn was the shallowest and lowest

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pressure SAGD operations. Like the Surmont pilot, Joslyn could advance guidelines for optimal SAGD operating pressures and allow the JIP to calibrate reservoir models at low pressure. The Joslyn reservoir does not have a Gas Over Bitumen situation, however, industry valued the learnings that could be realized from operating SAGD near 1,000 kPa which could be translated to SAGD operations in contact with low pressure gas caps.

The project operated in 2004 and 2005 utilizing two types of artificial lift, a Sucker Rod Pump and an ESP (Electrical Submersible Pump). These systems were unable to handle the variations in reservoir flow due to reduced reservoir temperatures caused by facility downtime. The ESP experienced general wear on the pump components after a 231 day run time.

Total found that ESP's are not ideal pumps for this type of shallow SAGD production, and installed an elastomer Progressing Cavity Pump (PCP) in September 2006. As expected, the pump failed after one month of operations, but demonstrated more stable production than an ESP and rod pump. Total then installed the first high temperature metal to metal PCP in October 2006 and found that these pumps provide longer runtime and fewer workovers, allowing an assessment of the PCP's at 185 C and the performance of LP SAGD.

Total provided an update in August 2009 and provided the following observations:

- Reservoir quality impacts SAGD performance, the SAGD process may be more robust at higher pressures and temperatures due to the associated lower viscosity achieved
- Low pressure (1200 kPa) impacts chamber development and productivity. This is similar to what was experienced at Surmont with its low pressure start up
- ESP's, while they have an application at low pressure and low temperature, were unable to handle production variations, especially the varying bitumen water ratios
- Metal to metal PCPs were successful in starting and operating at low pressure with up to a 2 year run life with fewer workovers than ESP's. Total has tested PCP's on 10 wells

iii) Firebag AL and LP SAGD test (IETP 01-018)

During 2005 and 2006, Suncor tested 3 Can-K twin-screw pumps at its Firebag project. These high volume multiphase positive displacement subsurface pumps were installed in 2 classical SAGD wells to compare to the natural or steam lift system originally deployed in the project. This multiphase pump is designed to handle from 100%

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liquid to 95 to 98% gas, and to handle slugs of 100% gas for short periods. This should allow operations to continue pumping if steam or gas is present in the fluid. In contrast, an Electrical Submersible Pumps (ESP's) will cavitate and get damaged if steam or gas gets into the pump stages. Therefore, a centrifugal pump must always have a column of fluid above the intake. This means operating with a subcool above 15 °C.

The test objectives were to evaluate the capability of the pump to operate efficiently at low pressures and very low sub-cool conditions; that is with high vapor to liquid ratios. Suncor also entered into a data sale agreement with a number of industry parties. The field test was also hoping to evaluate SAGD reservoir performance at steam chamber pressures of 2000, 1500, and 1000 kPa. At the time of this pilot, natural steam lift or gas lift was deployed at the largest SAGD projects at Foster Creek and MacKay, where steam chambers were able to be operated at pressures above reservoir pressures as these reservoirs did not have low pressure thief zones or gas caps. Initial work was occurring with testing the application of centrifugal Electrical Submersible Pumps (ESP's). Firebag does have some areas of the project where the reservoir has lean bitumen zones which require balancing the steam chamber operating pressure to the reservoir pressure. It was expected that this test could benefit the gas over bitumen resource.

During the field test, the Can-K pump had 3 mechanical failures causing Suncor to alter its plans and start to test centrifugal ESP's in June 2005 to implement low pressure SAGD and in December 2006 made a request to Alberta Energy to terminate the pilot. However, the Can-K tests did achieve the following:

- allowed flexible and continuous SAGD operation
- successful operation of producing well below 1500 kPa
- low SOR for a well pair early in its SAGD life
- operate successfully at zero sub-cool

Additionally, Suncor also concluded the following:

- The Can-K Pump longevity did not meet Suncor's requirements. One pump operated for 54 days, another for 36 days, and the third for 29 days
- This technology is not mature enough for commercial deployment
- artificial lift systems allow wells to be produced in a flexible, safe and economic way
- electric centrifugal pumps provide a more satisfactory option for artificial lift at Firebag, given the current state of technology

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- the presence of a flexible and wide-range artificial lift system can decrease the SOR (Steam-Oil Ratio) which is the key performance indicators of SAGD projects
- Although it is not particularly an issue for Firebag, lower operating pressure helps to balance pressure between a bitumen-producing zone and any associated gas zone, allowing for higher recovery factors for bitumen in this situation

iv) **Bench scale artificial lift test (IETP 01-006)**

Cenovus (previously EnCana) is the JIP sponsor formed in 2004. The purpose of the JIP was to advance artificial lift systems and to bench test numerous down hole pumps to determine if these systems can operate efficiently and reliably at low pump intake pressures, low sub cools, and high gas to liquid ratio which result from operating SAGD at lower pressures. Additional objectives included; better sub cool and steam trap control, extend run life and improve operating costs. In order to conduct the bench scale tests, a 9 5/8" flow loop was constructed at C-FER with the capability to operate up to 200 C and to test different liquid and gas volumes. This laboratory controlled testing could potentially lead to field trials.

Phases I and II encompassed testing of Can-K Twin Screw Pump, Netzech Elastomer PCP, Woodgroup ESP, Kudu Metal Stator PCP, and an SPT Gear Pump. Due to mechanical failures the Can-K and SPT systems could not be fully tested and there is no interest amongst the JIP to conduct further testing. The metal stator PCP, elastomer PCP and ESP's were fully evaluated.

The testing results showed that artificial lift systems tested can operate at low intake pressures without losing significant performance. As expected, positive displacement systems (PCP's Elastomer and Metal) provided the best operation at low intake pressures, as low as 7 kPa, while there was some impact on the performance of the dynamic system (ESP's) at the lower intake pressures. It was also observed that ESP's could still operate at intake pressure as low as 140 kPa, however under this condition operational stability lessened.

This is a significant result in addressing the issue of what the lower operating limit achievable for SAGD operations is. Based on the results, Cenovus feels that these artificial lift systems can allow SAGD operation at pressures as low as 350 kPa, assuming a drawdown of 200 kPa between the chamber and the pump intake.

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Phase III is currently progressing in an upgraded test loop to test two new artificial lift systems; Baker Hughes High Temperature ESP system and R&M (Moyno) PCP System at temperatures up to 260 C.

v) Bitumen de-methanization project (IETP 01-004)

Paramount Resources was the JIP sponsor for the Bitumen de-methanization project. The study objectives were to determine bitumen viscosity at high temperature under dead oil conditions and fully saturated conditions to determine impact on SAGD performance to support guidelines for optimal SAGD operating pressures. Analysis was conducted on MacKay, Christina Lake, and Surmont samples at pressures of 500, 1500, and 4000 kPa, and temperatures of 10, 30, 70, 100, 125, 150, 200, and 220 C.

The de-methanization JIP presented its findings in February 2010. This study makes an important contribution to improving the accuracy of modeling predictions by refining the fundamental physical input parameters. The study concludes:

- The de-methanization JIP presented its findings. This study has made an important contribution to improving the accuracy of modeling predictions by refining the fundamental physical input parameters.
- Temperature variation has a larger effect on oil viscosity than the methane saturation at a given temperature.
- Pressure has a larger effect on methane solubility than temperature.
- The Mehrotra and Svrcek correlations under predicted methane solubility (by about 30%) and live oil viscosity (20% to 60% over low to high viscosity MacKay River oil, 40% to 80% over low to high viscosity Christina Lake oil).
- Both the Butler and STARS equations predicted the methane solubility and live oil viscosity within 10% - 20% over a low to high (>50,000 cp) range once constants were tuned to the measured data of this study.
- The fully saturated methane solubility were very similar for all samples.

vi) Wellbore architecture

ConocoPhillips is the JIP Sponsor. The JIP was set up in two phases to advance the ability to operate existing pumps at low pump intake sub cools and pressures. Phase 1 investigated new SAGD well pair architectures that allow existing pumps to operate under low pressure SAGD operations. Phase 2 investigated vertical well sump and boosting/cooling systems.

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- The study focus was driven by the technical circumstances at the time. At LP SAGD, current artificial lift solutions do not exist or are not reliable. There is a need to identify new completion designs and well configurations to allow for the implementation of existing pumps/systems.
- Phase 1 of the study concluded that cooling and cooling-boosting systems rank highest since they use existing wellbore architectures, that sump off the toe and sump off the build concepts rank next as it involves moderate changes and carry moderate risks relative to the other concepts, and that vertical well sump concepts have the highest D&C costs, greatest D&C risks, and may require significant work to develop a cost-effective intersection and junction system suitable for SAGD applications.
- Phase 2 then focused on evaluating vertical well sumps, cooling-boosting, and closed loop cooling by developing economic models on 4 scenarios; base case 2000kPa SAGD (constant inj./prod. profile), cooling concept 750kPa with ESP, cooling-boosting case 500kPa with ESP and jet pump, and vertical well sump 500kPa with rod pump.
- Phase 2 concludes that LP-SAGD scenarios are as good as or better than HP base case.

vii) Facility capital and operating cost study

The Artificial Lift and Low Pressure SAGD Gas Over Bitumen technical solutions sub committee debated the economic merits of low pressure SAGD in its early years. A collaborative study to investigate these merits was undertaken by Petro-Canada (now Suncor), Suncor, and IMV Projects. This study compared the capital and operating costs of Low Pressure SAGD utilizing ESP's and E-Lift lift systems, to higher pressure SAGD operations utilizing gas lift systems. This included the down hole wellbore configurations, operating assumptions, facility process flow diagrams, capital and operating cost structure, and before tax and royalty net present values. The JIP presented its findings to industry in May 2004.

The following presents the downhole conditions.

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DESIGN BASIS AND ASSUMPTIONS

Downhole Conditions – Steady State Operation

	Case 1 Gas Lift	Case 2 ELift™	Case 3 Downhole ESP
Bottom Hole Pressure (kPaa)	>2200	500	500
Oil Rate m3/d (Theoretical)	187	85	85
(bbls)	(1187)	(535)	(535)
GOR (sm3/m3 of bitumen)	3	3	3
Wellhead CSOR (dry)	2.2	1.6	1.6
Operating Wells	22	47	47
Operating Pads (15-17 Wells/Pad)	2	3	3

Conditions estimated from 850 meter long Hz section
 TVD assumed at 250 mKB
 Wellhead Tubing Producing Pressure at least 500 kPa

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The following presents the plant operating assumptions:

DESIGN BASIS AND ASSUMPTIONS

Plant Design – Steady State Operation

	Case 1 Gas Lift	Case 2 ELift™	Case 3 Downhole ESP
Bitumen Rate (bbl / sd)	25,000	25,000	25,000
(m3 / sd)	3,975	3,975	3,975
Number of Operating Wells	22	47	47
Steam Plant SOR (wet)	3.1	2.3	2.3
Steam Generated (m3 / sd CWE)	12,500	9,100	9,100
Minimum Number of Steam Gens	4	3	3
Steam Exiting Plant (m3 / sd CWE)	9,400	6,800	6,800
Total Well Liquids (m3 / sd)	12,700	10,300	10,300
Diluent Rate (m3 / sd)	2,200	2,200	2,200

sd - Stream Day
 Plant designed for 25,000 bbls/day after ramp-up
 Plant will compared on a 25 year life

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The study concluded that LP SAGD can provide better economics than HP SAGD. The following presents the summary conclusions showing before tax NPV discounted at 10%:

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Summary

	Case 1 Gas Lift	Case 2 ELift™	Case 3 ESP
INITIAL CAPEX	\$325	\$378	\$369
OPEX	\$68.0	\$59.7	\$61.2
NPV	\$567	\$607	\$606

THINGS TO CONSIDER

- Sensitivity of CSOR
- Sensitivity of CDOR
- Combination of High Pressure then Low Pressure
- Optimize Surface MPP

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viii) NCG (Non Condensable Gas) literature survey

Nexen was the JIP sponsor. The JIP scope focused on a literature search to identify gaps in current knowledge and to compile industry field experience regarding the impacts of NCG on the SAGD process. The study focused on opportunities and strategies to maximize the benefits of naturally generated or injected NCG's during bitumen recovery by SAGD at lower pressures and in the presence of associated gas caps. The study is complete and the conclusions are confidential.

ix) Advance down hole instrumentation

Workshops were established to advance reliable and cost effective pressure and temperature measurement devices capable of service at SAGD operating conditions. Additionally, these devices would optimize SAGD performance through monitoring and control of sub cool and steam chamber conformance. Alternating workshops with vendors and operators were held:

- Operator workshop; March 15, 2007.
- Vendor workshop; Oct 18, 2007.
- Operator workshop; Sept 25, 2008.
- Vendor workshop; December 10, 2008.
- Vendor workshop; September 17, 2009.
- Operator workshop; Sept 16, 2010.

The transfer of information and experiences amongst operators and to and from suppliers of equipment and service providers has allowed

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the devices and systems to advance to provide more reliable service in a SAGD environment. As a result, more data is available during LP SAGD operations to allow operators to evaluate the reservoir performance with GOB circumstances.

x) Impact of Non Condensable Gas

Nexen was the JIP sponsor. The final report was issued December 2009. The JIP members are pleased with the outcome and believe that the results will be helpful for simulation studies.

E) Impact of IETP

GOB projects making application under the Innovative Energy Technology Program (IETP) requires GOB Technical Solution Executive Steering Committee endorsement prior to IETP approval by the Minister.

A total of 11 GOB projects through 12 applications have applied for IETP funding. The MEG Energy GRIPE project has 2 separate applications; one for MEG's injection operations, and one for ConocoPhillips' pressure monitoring wells. The Technical Steering Committee has determined that these 11 projects have the potential to contribute to a technical solution to the GOB issue.

This funding has provided the impetus to advance GOB innovation applications in the field, to develop JIP's to facilitate risk sharing, and broadening the dissemination of information. Many of these projects may not have proceeded without the IETP program. Some of these projects may have proceeded without funding but in isolation of broader participation through JIP's.

The following table presents the IETP Approved GOB Projects as of September 22, 2009.

IETP Project #	Operator	Description	Public Reports
01-001/012	Paramount/MEG	Gas Re-injection and Production Experiment (GRIPE)	2005 2006
01-003	Cenovus	Air injection and Gas Displacement Solution	2005 2006
01-004	Paramount	Bitumen De-methanization	2005
01-005	Paramount	Gas Pool Production and Shut in Pressure Data Analysis	2005
01-006	Cenovus	Low Pressure (LP) Artificial Lift Bench Scale Testing	2005
01-013	ConocoPhillips	Surmont SAGD Pilot	2005 2006
01-018	Suncor	Low Pressure (LP) SAGD Artificial Lift Pilot	2005 2006
01-025	Total	Joslyn Low Pressure (LP) SAGD Pilot Phase #1	2005 2006
02-034	Cenovus	Air Re-pressuring at Christina Lake for Production of SAGD Bitumen	2006

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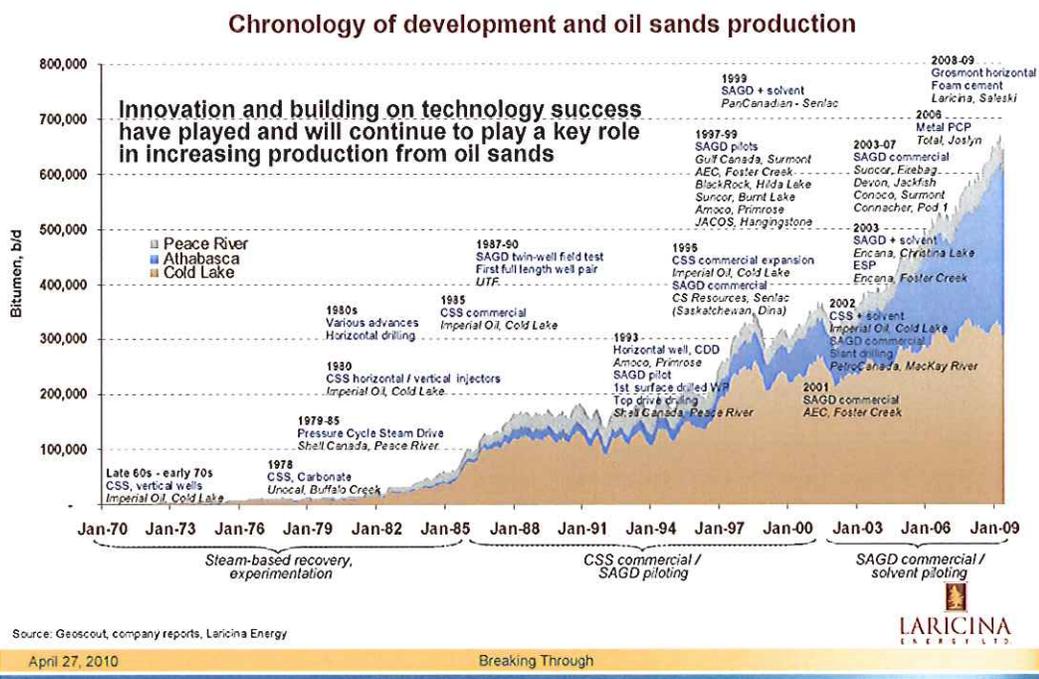
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F) Progress

The question has been posed; has there been progress towards a technical solution(s)? The answer to this question is; YES. The evidence supports progress in the areas of artificial lift, re-pressuring and pressure maintenance of shut-in associated gas pools, and through the field operational learnings obtained from the Surmont and Christina Lake steam assisted gravity drainage (SAGD) projects. The following chart obtained from Laricina Energy Ltd.'s web site show the oil sands production growth and the associated technical successes which have contributed to this growth.

Innovation and building on success

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1) Artificial Lift

There has been great progress over the past decade with artificial lift. Applications have evolved from initially gas/steam lift, to electrical submersible pumps (ESP's), and more recently to metal/metal progressive cavity pumps (PCP's). These advances are a direct result of efforts from the bench scale testing joint industry project (JIP), through vendor testing and improvements, and operator field testing and application. The advances now provide high temperature ESP's and PCP's that were not available ten years ago, provide the opportunity to operate low pressure SAGD, operate SAGD in balance with reservoir and thief zone pressure,

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achieve stable wellbore operations, and achieve lower cumulative steam to oil ratios (CSOR's).

The first SAGD projects were developed in simple reservoirs without any thief zones present and operators were able to design and operate SAGD at steam chamber pressures above reservoir pressure. At this time there were no high temperature ESP's or PCP's available. Foster Creek started operations in 1997 and MacKay in 2002 and both operated with gas lift. Hangingstone started in 1999 and operated at a high enough pressure to utilize steam lift.

However, complex reservoirs with top water, top gas, bottom water, or inter reservoir lean zones require an artificial lift solution different from gas or steam lift once the steam chamber communicate with a thief zone. Surmont started with gas lift in 1997, Christina Lake started with gas/steam lift in 2002, and Firebag & Long Lake started with gas lift in 2003. All of these projects required an artificial lift solution to operate steam chambers in communication with thief zones.

With the development and advancement of high temperature ESP's and PCP's industry has stepped to application with both simple and complex reservoirs. At Foster Creek, ESP's are now the design basis and rod pumps are initially installed on cool wedge wells then converted to ESP's when the wells get hot. Foster Creek is also testing metal/metal PCP's. As of March 2009 there are approximately 76 ESP's operating at Foster Creek. MacKay continues to utilize gas lift and is currently testing ESP and metal/metal PCP applications. Hangingstone continues with steam lift.

Big gains have been realized on complex reservoirs. At Surmont, the operating plan now includes gas lift initially to allow for higher pressure operations then switch to ESP's once the steam chamber is communicating with thief zone and operations need to balance to the thief zone pressure. Christina Lake has 14 of 16 wells on ESP, Firebag has 24 of 30 wells on ESP, and Long Lake has 25 wells on ESP.

The benefits from these artificial lift developments in simple reservoirs include; stable operations, lower SAGD chamber pressures, and lower CSOR. Complex reservoirs realize these same benefits and also benefit from the ability to operate in balance with reservoir pressure which has resulted in the Surmont commercial project and the Christina Lake expansion to proceed.

2) Re-pressuring/pressure maintenance

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Re-pressuring and pressure maintenance of associate gas caps has advanced significantly. The gas re-injection and production experiment (GRIPE), the EnCana air injection and displacement (EnCAID) and the Christina Lake Re-pressuring projects have demonstrated progress in gas to gas displacement and recovery of methane, the ability to maintain gas cap reservoir pressure, and the ability to re-pressure depleted associated gas caps in contact with bitumen.

Specifically, GRIPE has achieved successful flue gas displacement and 12% incremental gas recovery and reservoir pressure maintenance. However, its low operating performance of 44% due to corrosion on surface equipment has limited its ability to optimize the reservoir performance. As of October 2010 GRIPE is running at a 94% on time.

Christina Lake Re-pressuring has achieved re-pressuring with air and balances the complex system with top gas, bitumen, and bottom water resulting in successful SAGD operations. Commercial Scheme Approval was received on March 30, 2010 to expand production to 100,000 bopd and to inject methane or air for gas cap re-pressuring. This approval implies that Cenovus believes that gas cap re-pressuring is technically and commercially feasible, and that the ERCB is prepared to accept this operation in the specific reservoir characteristics. It is important to understand that Cenovus has mineral rights to both the oil sands and P&NG.

EnCAID has achieved ignition and ongoing combustion of the low bitumen saturation in the gas zone, has observed substantial heat conduction into the bitumen zone, recovered net formation methane of 2.6 Bcf, and has not had the corrosion issues seen at GRIPE.

These field experiences appear to support the findings of the Exploitation Technologies report discussed earlier in its report regarding Surmont Shut-in Data Analysis which purported the "potential for successful gas pool re-pressuring opportunities".

3) Surmont Project

The Surmont pilot project has been operating since July 1997 and has advanced its findings regarding operating SAGD in a resource with bitumen in contact with top water and a depleted associated gas cap; so much so that ConocoPhillips is operating its commercial project and has filed a 125,000 bopd expansion application. As of March 2010, 26 WP's are operating at an average rate of 736 bopd, an ISOR of 2.7 and a CSOR of 3.0. The key conclusion to date demonstrates that successful SAGD performance requires operations to balance the steam chamber pressure with the thief zone pressure. This results in the need to design operations with 3 stages of steam chamber pressures. The initial stage operates at a

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steam chamber pressure of 3,000 to 4,500 kPa utilizing gas lift in order to build the steam chamber. The second plateau stage operates at a pressure of 1,500 to 3,000 kPa utilizing mechanical lift to promote lateral steam chamber growth. The third end of life stage operates at less than 1,500 kPa with mechanical lift in order to minimize CSOR.

Surmont has also observed that thief zone interaction may occur early in steam chamber development as pressure interaction precedes fluid interaction which requires operations to be nimble in order to adapt operating practices to reservoir performance. Outstanding learning includes how much lower recovery factors will be for SAGD operations with gas cap and top water compared to simple reservoirs, and the project requires a fulsome understanding of operating effects once steam chambers connect or commingle with each other.

4) **Christina Lake Project:**

Like the Surmont project, the Christina Lake project has concluded that SAGD operations must balance the steam chamber pressure with the gas zone. Additionally, due to the state of gas cap pressure depletion, the gas cap pressure must be increased to allow SAGD operations to be in balance with the bottom water and top gas pressure system. As a result of this knowledge, the operating design includes steam chamber pressure higher than the gas cap pressure with gas lift prior to the steam chamber interacting with the gas cap, followed with steam chamber pressures in balance with the gas cap utilizing ESP's once operations are interacting with the gas cap. As of March 2010, the project was operating 14 WP's at an average rate of 1,021 bopd, an ISOR of 2.0, a CSOR of 2.0, and the Christina Lake has received commercial application approval.

5) **Other Project Experiences:**

Two other SAGD projects, Firebag and Long Lake, which do not have specific gas over bitumen characteristics, offer some valuable supporting evidence to the conclusions realized at Surmont and Christina Lake. Firebag and Long Lake have low reservoir pressures with some lean bitumen zones which behave as thief zones when steam chambers are operated at pressures higher than reservoir pressure. Firebag and Long Lake clearly reinforce, that in order to realize successful SAGD operations, operators need to understand the reservoir characteristics and the state of the reservoir pressure to effectively design the SAGD operating conditions and the associated artificial lift systems to balance SAGD operations with reservoir conditions.

The following table provides some interesting insights regarding industry experience with balancing steam chamber pressure with reservoir pressure and the impact to SAGD performance. The table provides the instantaneous water to steam ratio (IWSR), cumulative water to steam ratio (CWSR), instantaneous steam oil ratio (ISOR), and the CSOR after

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approximately 9 months of stable operations and at March 2010. In the cases of MacKay, Firebag, and Long Lake which had CWSR's below 0.8 at the 9 month period, another data point is provided when operations achieved an IWSR at 0.9 or better.

Project	Date	Time	IWSR	CWSR	ISOR	CSOR
Foster Creek	July 98	9 mo's	0.9	1.05	5.3	4.0
	Mar 10		0.9	0.97	2.3	2.5
MacKay	July 03	9 mo's	0.8	0.72	3.2	3.4
	July 05		0.9	0.90	2.1	2.5
	Mar 10		0.9	0.98	2.3	2.5
Christina Lake	May 03	9 mo's	1.0	1.08	2.6	2.8
	Mar 10		1.1	1.14	2.0	2.0
Firebag	May 04	9 mo's	0.7	0.54	3.4	7.3
	Aug 06		1.0	0.80	3.3	3.9
	Mar 10		1.0	0.92	3.0	3.3
Long Lake	Dec 03	9 mo's	0.5	0.34	5.9	11.4
	Aug 06		1.2	0.77	4.6	5.7
	Mar 10		0.9	0.76	5.9	6.9
Surmont Pilot	Aug 98	9 mo's	0.9	0.95	2.8	5.2
	Nov 99		1.3	1.01	3.2	3.5
Commercial	Mar 08		0.9	1.06	3.7	3.4
	Mar 10		0.9	0.86	2.7	3.0

The IWSR and CWSR provide an indication of the usefulness or effectiveness of the steam that is injected. The basic premise is that the injected steam in vapour phase condenses to water or liquid phase in the reservoir steam chamber and is produced with the bitumen realizing a CWSR of approximately 1.0. If the CWSR is less than 1.0, the steam chamber pressure is higher than the reservoir thief zone pressure and steam is lost to an area outside the steam chamber and is not available to transfer heat to the bitumen to cause bitumen to flow into the production well. If the CWSR is greater than 1.0, the steam chamber pressure is lower than the reservoir thief zone pressure and the mobile water flows into the production well.

There is a direct correlation between IWSR and CWSR to the ISOR and CSOR. Projects which achieve operations in balance with reservoir pressure achieve a CWSR near 1.0 and achieve better CSOR's than those projects which do not achieve operations in balanced with reservoir pressure.

Recall that Firebag and Long Lake were designed with gas lift and steam chamber operating pressures above reservoir pressure. As a result, at 9 months of operations, Firebag had a low IWSR (0.7) and a low CWSR (0.54) which resulted in a high ISOR (3.4) and a high CSOR (7.3). Similarly, Long Lake at 9 months of operations had a low IWSR (0.5) and a low CWSR (0.34) which resulted in a high ISOR (5.9) and a high CSOR

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(11.4). Once Firebag converted its operations to mechanical lift using ESP's allowing operating the steam chamber pressure in balance with reservoir pressure, the water steam balance and steam oil ratios improved (IWSR of 1.0, CWSR of 0.92, ISOR of 3.0, and CSOR of 3.3). Long Lake also converted to ESP's, but at a much later time than Firebag. As a result, Long Lake has achieved an improved instantaneous water steam balance (IWSR of 0.9). However, since Long Lake had longer operations not in balance, the cumulative water steam balance and steam to oil ratios have not improved as much as Firebag (CWSR of 0.76, ISOR of 5.9, and CSOR of 6.9).

G) Gaps

Further progress towards a technical solution(s) can be realized by having the technical committee focus efforts on the following areas:

- 1) Potential contamination of gas cap from SAGD operations; especially in cases where P&NG interests are held by a party other than oil sands mineral rights
- 2) further evaluation of SAGD operations while in contact with thief zones to understand how different SAGD performance is in GOB circumstances compared to simple reservoirs
- 3) understanding and advancing the field testing and application of SAGD operations while gas to gas displacement and pressure maintenance programs are proceeding in an effort to understand the potential to have co-production of associated gas and bitumen
- 4) furthering the design and operations with flue gas pressure maintenance to effectively deal with corrosion

H) Recommendations

- 1) continue the activities through the GOB technical committee
- 2) continue to provide funding through IETP
- 3) consider IETP increasing or removing its \$30 MM max funding per project to facilitate impactful larger projects to proceed. IETP currently funds up to 30% of an approved project to a maximum of \$10 million per approved project. There is opportunity for larger scale projects (in excess of \$100 million); especially if they include the testing of co-production of shut-in associated gas and bitumen.
- 4) consider preparing an update to this report subsequent to July 2011 to include the release of 2008 IETP reports