Value through simple solutions

Understanding the Value Proposition of the JetShear™ Technology Platform

Fractal Systems, Inc.
Industry Background

Overview

Global primary energy demand grew 0.4% in 2014\(^1\), and fossil fuels currently meet over 85% of this demand. Crude oil meets approximately 33% of global demand\(^1\). Although alternatives to hydrocarbons will capture a greater market share in the future (e.g. currently only 2%), there is no doubt that hydrocarbon demand will continue to grow over the next several decades\(^2\).

*Figure 1 – Global Energy Demand\(^1\)*

![Graph showing global energy consumption from 2004 to 2014](image1)

*Figure 2 – World Consumption by Fuel Type\(^1\)*

![Graph showing world consumption by fuel type](image2)

However, the oil industry is having difficulty in meeting this growth with conventional hydrocarbons. There is an active debate across the industry about “peak oil” and its implications. Global oil reserves, estimated at 1.6 trillion barrels, continue to grow, and some use this fact to suggest that supply is plentiful. However, growth includes large amounts of unconventional oil. Of the unconventional hydrocarbons available, heavy oil, including extra-heavy and bitumen, is arguably the most important.

Heavy oils occur in most oil basins of the world. These oils are denser than conventional oils. The industry often uses a measure for density that is referred to as degrees API (e.g. developed by the American Petroleum Institute). This measure is inversely proportional to density and is non-linear (Figure 3).

*Figure 3 – Density of Hydrocarbons*

![Graph showing density of hydrocarbons](image3)

Although there are no uniform definitions for the terms heavy oil, extra-heavy oil and bitumen, the following are commonly used:

- **Heavy oil** – Petroleum with a gas free viscosity of between 100 and 10,000 centipoise (e.g. centipoise (cP) is a unit of measure of viscosity). In the absence of viscosity information, heavy oils have an API gravity between 10° and 22.5°.
- **Bitumen** – Petroleum with a viscosity greater than 10,000 cP.
- **Extra-heavy oil** – Petroleum with a viscosity less than 10,000 cP, but with a density greater than 10° API.

Heavy oil, extra-heavy oil and bitumen are being developed at an accelerated pace throughout the world. The World Energy Council estimates that there are approximately 5.5 trillion barrels of extra-heavy oil and bitumen “in-place” (i.e. in the ground). This is approximately the same amount of conventional oil discovered since the birth of the industry. Of the discovered conventional oil, less than 20% or approximately 1 trillion barrels has already been produced. Only 24 billion

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\(^1\) “BP Statistical Review” – June 2015

\(^2\) Oil & Gas Journal – December 3, 2012
barrels at year-end 2008\(^3\) of the extra-heavy oil and bitumen have been produced.

Of the 5.5 trillion barrels of extra-heavy oil and bitumen in-place globally, the majority has been found in two countries: Canada and Venezuela. Canada contains over 40% of this total\(^3\), and the Canadian industry is expanding production capacity at a rapid pace.

Exploitation of this resource has historically been limited due to the high cost to develop, produce and transport it. It is technically difficult and economically challenging to produce, as cost-intensive enhanced oil recovery methods often being required. Once produced it is costly to refine into marketable products (i.e. mainly transportation fuels). In addition, it is difficult to transport from the remote oil fields to the large, centralized refineries. Heavy oils are difficult to transport due to their highly viscous nature.

The rise in oil prices between 2003 and 2008 provided considerable financial incentive to accelerate development of heavy oil resources. However, the technical and economic challenges of developing heavy oils and bitumen remain formidable. The heavy oil market requires new, reliable, cost-effective technologies that address these challenges.

**Canada**

Approximately 167 billion barrels or 40% of the known, global extra-heavy oil and bitumen that can be recovered is located in Canada\(^4\). The oil sands of Canada are world-renowned and are predominantly located in the province of Alberta. This resource, discovered many years ago, is responsible for more than one-half of Canada’s current oil production (e.g. 2015 oil sands production was 2.37 million barrels per day (bpd)\(^5\)). The Canadian Oil Sands are comprised of the three areas that contain extra-heavy oil and bitumen: Athabasca, Peace River, and Cold Lake (Figure 4).

There is an established oil sands “value chain” consisting of mining and in-situ production operations, gathering system pipelines and terminals, mid-stream upgraders, transportation pipelines, diluent infrastructure and refineries. Currently about two-thirds of all Western Canadian crude, including conventional oil, is refined in the United States. All industry experts forecast a large increase in Western Canadian crude production over the long term as the oil sands are further developed. Current demand forecasts indicate most of this increase in production will ultimately be transported to refineries in the United States. This will require major expansions of the pipeline and rail infrastructure as the current transportation infrastructure is inadequate to meet the growth in volumes\(^4\). Fractal’s technologies can deliver reductions in viscosity and density, which can provide greater capacity to many of these “value chain” systems.

There is currently a large Canadian market requiring heavy oil technologies. Despite the current weak oil price environment, the Canadian Association of Petroleum Producers forecasted oil sands production to grow over the next 15 years to over 3.6 million barrels per day\(^4\). Industry experts are forecasting that the bulk of this production growth will consist of higher acid content crudeas (e.g. TAN>1.0 mg KOH/g).

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\(^3\) “World Energy Council – 2010 Survey of Energy Resources”

\(^4\) “Canadian Association of Petroleum Producers - Crude Oil Forecast, Markets and Transportation”, June 2016 (www.capp.ca)
Other Countries

Heavy oil occurs in most hydrocarbon basins around the globe. Extra-heavy oil fields have been developed extensively in South America, the U.S., and Indonesia. A large share of the world’s known extra-heavy oil and bitumen resource is located in a shallow heavy oil belt that extends in an arc from Venezuela through Colombia, Ecuador and Peru (Figure 5).

Figure 5 – Heavy Oil Basins of South America

While Canada and Venezuela combine for about 85% of the total, there is notable growth in Colombia with heavy oils contributing over 750,000 bpd of production in 2014.

Heavy Oil Pricing

Global oil prices climbed to a new level during the period from 2003 to 2008 (Figure 6). While there is speculation that this increase in prices was due to concern over the world running out of oil (e.g. peak oil) there is little doubt that at least some of the increase is a direct result of greater dependence on non-conventional oils such as heavy oil and bitumen as well as conventional oils found in deep water. Both of these growing sources of oil are more costly to extract and transport to market than traditional sources.

Figure 6 - Historical Light Oil Pricing (Current dollars and money of the day)¹.

Heavy oil trades at a discount relative to common light oil benchmarks such as West Texas Intermediate (e.g. WTI) or Brent. Additionally, heavy oil prices tend to be regional in nature reflecting differences in quality or refining value (i.e. API, viscosity, magnitude of impurities such as sulfur, metals and acid content) and distance to refinery infrastructure. For those heavy oils with considerable volumes in the market a specification and a price benchmark is established in order to provide the transparency that efficient markets require. It is common along the U.S. Gulf Coast to see a Maya benchmark, which reflects the price paid for a common heavy oil from Mexico. Canada has several benchmark prices for heavy oil including Lloyd Blend (e.g. LLB) and more recently, Western Canadian Select (e.g. WCS).

The price discount observed between heavy crudes (Figure 7) and light crudes is called a heavy-to-light differential or just the heavy differential. The magnitude of the heavy differential is a key driver in Fractal’s value proposition.

Figure 7 – North American Heavy Oil Pricing Relative to WTI

North American Heavy Oil Prices vs. WTI
The heavy differential is volatile and is driven by a complex relationship among a number of factors including heavy oil supply growth, available deep conversion refining capacity (i.e. ability of a refinery to process heavy oil), and takeaway capacity to access the refining markets. WCS is discounted relative to other North American heavy crudes such as Maya principally due to the cost of transporting the Canadian blend from Alberta to the refining hubs in the US. The MSW (e.g. Mixed Sweet Blend) to WCS differentials, on a Canadian dollar and % basis, are presented in Figure 8. MSW is a conventionally produced light sweet crude for western Canada. It is often referenced on crude price reports as Edmonton Par Crude.

*Figure 8 – Historical Canadian Heavy to Light Oil Differentials*

The price received for heavy oil was discounted between 16% to 37% on an average annual basis relative to MSW over the past 10 years.

### Transporting Heavy Oil

The reason heavy oils are difficult to transport is due to their highly viscous nature. Viscosity is a measure of the oil’s resistance to flow. All pipelines have specifications that a producer must meet before the pipeline will transport the producer’s oil. Depending on the region the following specifications can be important - density, viscosity, vapor pressure and water and olefin content.

In many heavy, extra-heavy and bitumen oil provinces, it is common that the oil produced from the field will be too viscous and too dense to meet the pipeline’s requirements. In these cases, the heavy oil is often blended with enough light oil or diluent so that the mixture meets the viscosity and density specifications of the pipeline. The diluent is often gas condensate (e.g. liquids produced in conjunction with natural gas also known as heptanes plus, natural gasoline or C5+) that is very light and therefore requires less volume than heavier blending agents, such as synthetic crude, for the blend to meet the pipeline specification.

### Diluent Pricing

The second commodity price that is influential to Fractal’s value proposition is the price of condensate relative to light oil. As condensate prices increase the costs to transport the heavy oil blend also increases. The recent price history of condensate pricing in Canada illustrates the typical premiums producers pay to secure the blending agent required to transport raw bitumen.

*Figure 9 – Historical Condensate to WTI differential*

Over the 10-year period, the average annual condensate price ranged from a premium of C$10.11 to a discount of C$2.12/bbl. Once again price on both a dollar and percentage basis are very volatile. This volatility is detrimental to heavy oil development economics that require very large upfront investments and multi-year construction timelines. Returns are very exposed to commodity prices during the payout periods once production starts.
For the Canadian Oil Sands, it is typical to use almost one barrel of diluent for every two barrels of bitumen produced. The producer must pay a premium price for this diluent (i.e. 9% premium to Canadian par over the past 10 years).

In addition, producers pay pipeline owners a tariff or toll (i.e. a $ per barrel charge) to transport their heavy blend to market. In heavy oil areas where diluent is used, they also pay a tariff to transport the diluent to the field. Transportation tariffs to the US refining centers are one of the significant operating costs for a producer of bitumen in Canada. Once the blend arrives at the refinery the diluent content is typically discounted again as the diluent is not in demand in most North American refinery markets.

The Canadian Association of Petroleum Producers has forecast that an expansion of the existing transportation infrastructure is required to connect growing crude oil supply from Western Canada to new markets. Pipelines have traditionally been the primary mode of transportation for long-term movements of bitumen but the protracted regulatory processes continue to present a number of challenges. This is resulting in higher heavy-to-light discounts due to excess supply and insufficient takeaway capacity. Delays in start-up timing are providing the impetus for additional take-away capacity from railways to complement pipeline transport. JetShear has a significant impact on pipeline capacity debottlenecking by reducing the volume of diluent required to move the bitumen to market.

Fractal’s Technology Platform

Fractal Systems Inc. is a private Canadian company that is engaged in the business of upgrading heavy-oil and bitumen in the field, by applying simple, proprietary, patented technology. The company will be active in manufacturing and licensing its technology platform to oil producers and mid-stream companies in heavy oil basins around the globe, particularly in Canada and South America.

Fractal Systems is building a world-class company that will provide superior heavy oil technologies to the heavy oil industry. The company will achieve this by delivering the following:

- Commercialize the JetShear™ technology platform and rapidly grow license revenue.
- Expand relationships globally to capitalize on the value of company technologies.
- Assemble a top-quality team by supplementing and growing the company’s technical and commercial staff.
- Develop new heavy oil technologies that are ready for commercialization within the five-year planning horizon.
- Continuously improve the value of technologies by nurturing creativity within the organization.

Fractal Know-How

Fractal Systems combines the inventive minds of an entrepreneurial Canadian family, together with the experience and knowledge of veterans in the oil industry. The story of Fractal System begins with Dr. Esteban Chornet, the inventor of JetShear™ and co-founder of the company. From 1970 to 2007, he was Professor of Chemical Engineering at Université de Sherbrooke, which is located in Sherbrooke, Québec, Canada. Dr. Chornet taught and conducted advanced research in reaction engineering applied to alternate energy feedstocks and to environmental technologies. During his 37 years as a professor, he developed many ideas for building businesses in process related industries.

The potential for successfully commercializing his innovations began to be realized in 2003 with the launch of Enerkem. Enerkem has developed a unique clean gasification and catalysis technology that converts sorted municipal solid waste and biomass residues into cellulosic ethanol and other second-generation fuels. Enerkem has built and commissioned its first commercial plant in 2014 with the City of Edmonton, where it converts municipal waste into biofuels using proprietary technologies.

Dr. Chornet co-founded Fractal Systems in 2006 with his son, Michel Chornet. Michel Chornet is currently serving as interim President and is a Board member for the company in addition to having responsibilities of Vice-President of Engineering and Technology Development. In those roles, he oversees the development and commercialization of the JetShear technology platform. He was responsible for the installation and operation of the JetShear™ pilot and commercial demonstration facilities located in Alberta, Canada and directs the activities at the JetShear bench scale facility and laboratory in Sherbrooke, Quebec. He continues to develop new and innovative technology solutions and is the author of two granted patents with numerous others in various stages of approval.

JetShear Poised for Commercial Application

Fractal Systems’ development of the JetShear technology platform is at the commercial application stage. The company has systematically developed the technology through a logical, deliberate testing and validation program:
• Bench scale studies using a 1 to 30 barrels of oil per day system that successfully demonstrated the potential of the technology on various crudes provided by Alberta oil producing companies.

• The company subsequently validated the bench scale studies by processing heavy oil and bitumen in the field at a 300 barrel per day “Pilot Facility”. This facility was hosted in 2009-2010 by a significant mid-stream company in Alberta, Canada. The field performance effectively demonstrated that the bench scale results could be “scaled up” (e.g. 300:1) in a field facility.

• Over the period from 2012-2014 the company developed a relationship with a major oil sands producer and expanded the capacity of the 300 bpd Pilot Facility to a commercial scale pilot demonstration facility at 1,000 bpd capacity (Figure 10).

• In 2015 the company announced that it had competed testing of JetShear at the 1,000 bpd pilot demonstration facility with its partner. The 1,000 barrel per day facility commenced processing in April 2014 and operated for approximately 1 year demonstrating long-term reliability. During this period, the facility processed over 100,000 barrels of partially diluted bitumen that was trucked to the site in Provost, Alberta from Steam Assisted Gravity Drainage (SAGD) projects in the Athabasca region that are operated by Fractal’s partner.

**Figure 10 – Field Demonstration Facility near Provost, AB**

• The goal of the project was to achieve (1) > 40% diluent displacement, (2) desired nozzle life performance, (3) certain product quality targets (product stability, H2S content, acidity, and liquid yield) and (4) facility operability and throughput expectations with no safety or environmental incidents. All key targets were met or exceeded and the demonstration was deemed a success by the partnership (Figure 11).

**Figure 11 – Field Demonstration Milestones**

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure</th>
<th>Target</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSE</td>
<td>Lost time injuries</td>
<td>≥ 98 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Performance</td>
<td>Yield</td>
<td>≥ 1 %</td>
<td>1 %</td>
</tr>
<tr>
<td></td>
<td>Material balance closure</td>
<td>≥ 1 %</td>
<td>1 %</td>
</tr>
<tr>
<td></td>
<td>Throughput</td>
<td>1,000 bpd</td>
<td>930 bpd</td>
</tr>
<tr>
<td></td>
<td>Nozzle life</td>
<td>≥ 4000 hrs</td>
<td>&gt; 4100 hrs</td>
</tr>
<tr>
<td>Product quality</td>
<td>Diluent displacement</td>
<td>≥ 40 %</td>
<td>~ 42 %</td>
</tr>
<tr>
<td></td>
<td>H2S content</td>
<td>≤ 20 ppm</td>
<td>&lt; 20 ppm</td>
</tr>
<tr>
<td></td>
<td>TAN reduction</td>
<td>≥ 15 %</td>
<td>&gt; 15 %</td>
</tr>
<tr>
<td></td>
<td>Stability (P-Value)</td>
<td>≥ 1.5</td>
<td>&gt; 1.5</td>
</tr>
</tbody>
</table>

• Fractal Systems announced in March 2015 that Sustainable Development Technology Canada has awarded $3.7 million to the partnership to field-trial this improved version of JetShear (https://www.sdtc.ca/en/portfolio/projects/bitumen-diluent-reduction-using-jet-nozzle-technology-platform).

• The positive field demonstration of JetShear has led Fractal Systems and its partner to an expansion of the current technology platform to further increase diluent displacement and to reduce acidity (e.g. Total Acid Number or TAN) via proprietary technologies. The new platform is called Enhanced JetShear™ with ARP™ (e.g. Acid Reduction Process™) and targets diluent displacement up to 60%, olefin content less than 0.5 wt % and TAN levels less than 1 mg KOH/g while maintaining minimal yield loss and all other pipeline transportation specifications.

• The commercial demonstration facility was subsequently modified to allow JetShear™ and ARP™ operations (March - April 2016) and was commissioned in early Q3 2016 and will yield results over the remainder of the year.

• Performance objectives have been established with Fractal’s partner.

*Reduced target due to hydraulic limitation in peripheral equipment*
The JetShear Process

Fractal's JetShear facilities resemble blending skids that are currently in use at heavy oil operations in Western Canada. In Canada, blending skids are used to make Dilbit, a mixture of bitumen with enough diluent to meet the pipeline specification for viscosity and gravity (i.e. typically, 27 to 35% blend ratio depending on the quality of the bitumen). Most of the equipment used in Fractal's JetShear facilities are comprised of “off the shelf” oilfield equipment such as fractionation towers, heat exchangers, pumps, tanks and heaters. A proprietary, very small footprint, jet-nozzle package is added in the JetShear configuration to dramatically reduce the viscosity and, therefore, the amount of diluent required to meet the pipeline specifications.

Fractal’s simple process begins with typical under-diluted Dilbit coming out of Central Processing Facilities (CPF) at a SAGD production plant or Dilbit at a terminal. In Alberta, due to the low gravity of the bitumen, diluent is typically added to the produced bitumen-water emulsion at the CPF in order to separate the bitumen from the produced water. This under-diluted Dilbit blend is subsequently sent to a blending facility where more diluent is added to meet the pipeline specification for Dilbit. With JetShear, the under-diluted Dilbit is processed by first separating the blend using a simple atmospheric fractionation step (Figure 12). The light ends (e.g. the diluent added at the CPF) are routed around the plant to recycle back to the CPF or blended in the final JetShear product sales blend. The diluent-free bitumen is then routed to the core JetShear module where it is heated to just below thermal cracking temperatures and pumped through the proprietary jet-nozzle assembly where cavitation and mechanical shearing takes place. The JetShear product is then cooled in heat exchangers and sent to the sales tank for final blending, if required. By-product gases are stripped of any hydrogen sulfide (e.g. H₂S) in the H₂S stripping section and are used in the operations as a fuel source.

Figure 12 - JetShear Technology Platform
The Enhanced JetShear Process

The Enhanced JetShear Process is similar to the JetShear process but adds an additional processing step to remove olefins from the JetShear products. In Figure 13 the olefin reduction takes place by separating the naphtha stream from the rest of the light ends downstream of the JetShear nozzles. The naphtha cut contains the bulk of the olefins that are generated due to heating the bitumen upstream of the jet-nozzle package. The naphtha stream is then processed in a low pressure catalytic hydrogen polishing unit before being cooled and recombined with the JetShear product or otherwise routed back to the CPF. By incorporating this low capital intensity processing step, higher diluent displacement can be achieved as the generation of olefins in the naphtha cut is no longer limiting the aggressiveness of the treatment conditions through the base JetShear configuration (e.g. nozzles and heater).

Figure 13 – Enhanced JetShear PFD

The Acid Reduction Process (ARP)

Many heavy oils in Canada and around the world have high acid content. Total Acid Number or TAN\(^5\), is an indicator of the acidity present in the heavy oils. To overcome challenges in refining high TAN crudes refiners discount the price they are willing to pay as a function of the magnitude of the TAN number. The acidic components that influence the magnitude of the TAN number are mainly alkylated naphtenes and are typically concentrated in the above 260\(^\circ\)C cut (e.g. 500\(^\circ\)F) with the highest concentrations being reported in 316-427\(^\circ\)C boiling range (e.g. 600 – 800\(^\circ\)F). These acids are problematic in refineries due to increased corrosion of specific materials in certain temperature ranges. To combat the increased corrosion from high TAN crudes refiners will utilize three mitigation techniques: 1) corrosion resistant metallurgy, 2) chemical treatment with corrosion inhibitors and 3) dilution with low TAN crudes.

Refiners apply a price discount that is a function of the TAN number. Although the magnitude of this discount is not readily transparent and is influenced by market conditions (e.g. supply/demand balance and high TAN processing capacity), in a balanced

\(^5\) TAN is defined as milligrams (mg) of potassium hydroxide (KOH) needed to neutralize the acid in one gram of crude. “High TAN” crudes are defined as having TAN > 1.0 mgKOH/g.
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market industry experts will typically assign from $1.00 to $4.00 discount for each TAN increment between 1.0 (e.g. maximum allowable for WCS).

In addition, as high TAN crudes are introduced refineries will also apply an introductory discount to mitigate the risk of processing the new high TAN crude streams in their refineries. In Canada, as higher TAN streams were introduced (e.g. period from 2005-2014) the introductory discounts have ranged from $1.00 - $15.00/bbl. Although these introductory discounts seem to diminish as refiners get comfortable with the processing risk, the timing of the discounts early in the productive life of high capital intensity oil sands projects challenges the project returns. The magnitude of these discounts represents a significant opportunity for producers to mitigate the negative economic impact of high TAN discounts via new technology solutions.

The ARP process is a simple, field deployed, technology solution that can be designed into a JetShear facility. The ARP module consists of a simple configuration of pre-fractionation and a soaker drum (Figure 14). The soaker drum provides the residence time where the naphthenic acids are thermally destroyed at temperatures below onset of cracking. In combination with Enhanced JetShear’s hydropolishing step, any additional olefins generated with ARP processing can be effectively addressed to meet pipeline specifications.

*Figure 14 – Acid Reduction Process with Enhanced JetShear PFD*
The Science of JetShear

The objective of JetShear is to change or modify the structure of bitumen and heavy oils to reduce viscosity and improve its value. It accomplishes this by targeting modifications of the asphaltene microstructures, which comprises the heaviest fraction of heavy oils. Maltenes surround these extremely complex microstructures and the arrangement of these molecules in the maltenes result in the observed high viscosities of heavy oil and bitumen.

JetShear uses a low severity hybrid approach relying on hydrodynamic cavitation and the application of heat to structurally modify the asphaltene molecules. Thermal disorder, below incipient cracking temperatures, is first introduced followed by cavitation through a nozzle. Due to the rapid change in pressure, microbubbles form around nucleation sites. Nucleation sites can be suspended submicron particulate matter, colloidal micelles, or pre-existing microbubbles. The forces that hold the liquid together need to adjust to these rapid changes in pressure. The resulting kinetic energy from cavitation is liberated into sufficient chemical energy to modify the microstructure and the state of aggregation of the initial heavy oil components.

The processing of heavy oil with JetShear results in a de-structuring of the asphaltene microstructures, leading to new and beneficial properties (i.e. decrease in viscosity and lower bulk density) with essentially no change in the chemical composition and negligible volumetric yield loss.

Applying JetShear

Fractal’s JetShear technology is best applied in the field where heavy oil or bitumen is blended with diluent for transportation via pipeline or rail. JetShear can dramatically reduce the amount of diluent that is otherwise required to transport the heavy oil to market.

Tests run in Fractals’s laboratory in Sherbrooke, Quebec and validated in commercial scale field pilot facilities indicate that JetShear™ can reduce the diluent required for meeting a pipeline’s viscosity specifications. Laboratory tests indicate up to 60% of diluent can be eliminated for a typical Canadian bitumen (i.e. 6.5 - 8.0 API).

The company has confirmed the bench scale results at 300 and 1,000 barrel per day field demonstration pilot facilities in Alberta, Canada. These results provide an operator the confidence that they have the ability to materially reduce costs and environmental impact associated with transporting the heavy oil to market while at the same time having a negligible impact on volumetric yield. In addition, the stable JetShear products have other quality improvements including reduced density, sulfur, TAN and olefins content below pipeline specification (Figure 16). Tariff costs (e.g. costs pipelines charge to transport the oil to market) and environmental impacts are reduced due to reduced volumes being handled.

Figure 16 – Typical Product Properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>Raw Bitumen</th>
<th>Dilbit</th>
<th>JetShear</th>
<th>Enhanced JetShear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (°API)</td>
<td>7.5</td>
<td>19-20</td>
<td>19-20</td>
<td>19-20</td>
</tr>
<tr>
<td>Viscosity (cSt) @ 12° C</td>
<td>200,000-1,500,000</td>
<td>≤350</td>
<td>≤350</td>
<td>≤350</td>
</tr>
<tr>
<td>Diluent content (%)</td>
<td>n/a</td>
<td>+30</td>
<td>~17</td>
<td>~13</td>
</tr>
<tr>
<td>Diluent displacement (%)</td>
<td>n/a</td>
<td>n/a</td>
<td>~42</td>
<td>~55</td>
</tr>
<tr>
<td>Olefin content (wt %)</td>
<td>0</td>
<td>0</td>
<td>&lt;1%</td>
<td>~0</td>
</tr>
<tr>
<td>Acid Number (mgKOH/g)</td>
<td>2.5</td>
<td>1.75</td>
<td>1.25</td>
<td>&lt;1.0 wt ARP</td>
</tr>
<tr>
<td>Sulphur content (wt %)</td>
<td>4.75</td>
<td>3.33</td>
<td>4.28</td>
<td>3.8</td>
</tr>
</tbody>
</table>

The tariff costs (e.g. costs pipelines charge to transport the oil to market) and environmental impacts are reduced due to reduced volumes being handled.

Conventional Blending Netback with JetShear

For the purpose of illustrating how the reduction of diluent contributes to a reduction in transportation costs, an example using Athabasca bitumen and Dibit follows below.

From a high level, there are three components that contribute to the net value addition attributed to diluent avoidance. There is the reduced diluent required to meet pipeline viscosity and density specifications, the reduced tariff attributed to transporting less volume, and a reduction in value due to the operating expense for operating the JetShear facility. An illustration of the reduced transportation costs attributed to a 55% reduction of the diluent required to meet the prevailing pipeline specification through the application of Enhanced JetShear is provided below.
Example - 10 bpd basis and 55% reduction of diluent with JetShear

Typical Blend Ratio: 7 bbls of bitumen + 3 bbls of imported diluent = 10 bbls of Dilbit.

With JetShear and 55% diluent avoidance: 7 bbls of bitumen + 1.35 bbls of diluent = 8.35 bbls of JetShear product.

Assuming the following average 2015 calendar year pricing reported by CAPP and internal company estimates:

- Dilbit (e.g. WCS - C$2.50/bbl) = $42.32/bbl
- Diluent (e.g. condensate) = $60.28/bbl
- Dilbit tariff = $2.00/bbl
- Diluent tariff = $1.50/bbl
- JetShear operating expense = $0.82/bbl

Diluent savings = $3.65/bbl
Tariff savings = $0.82/bbl
Less JetShear operating expense = $0.82/bbl
Value add per bbl = $3.65/bbl

There are additional value drivers that are not considered in this simple analysis and shown in Figure 16. The improved distillation curve (Figure 17) and reduced TAN will contribute to and further improve the netbacks to the heavy oil operator. In addition, significant pipeline debottlenecking can be achieved through the adoption of JetShear. This effectively increases the bitumen throughput capacity of existing pipelines.

Figure 17 – JetShear product distillation curve vs. typical bitumen

Capital Intensity

Various higher severity techniques ranging from visbreaking, coking, hydrocracking, and solvent deasphalting have traditionally been applied across the heavy oil industry to modify the structure and composition of heavy oils. These technologies require very large scale in order to reduce their capital intensity and are therefore almost exclusively deployed in refineries or in very large scale “upgraders” at oil sands mine sites or close to ports (i.e. Venezuela). Conversely, due to the small footprint and low capital intensity of the JetShear technology platform Fractal is able to deploy plants adjacent to heavy oil field production facilities in remote heavy oil basins.

Feasibility studies and a Class 4+ capital estimate have been completed with Fluor, a major EPC firm. The technology can be deployed in JetShear modules as low as a few thousand bpd up to 50 thousand bpd. The design approach employed by Fluor has incorporated the latest advancements in modular, closely coupled skids. In addition, the technology can be installed in larger fields, as they are developed, by installing multiple modular systems in parallel. This ability allows the technology to be “right sized” without any upper limitation due to scale.

The Class 4+ capital estimates, for both a Canadian oil sands (Figure 18) and US Gulf Coast locations, (Figure 19) assume a brownfield site adjacent to an operating heavy oil production facility. The estimates have been developed for several scales from 45,000 to 10,000 barrels per day feed of Athabasca bitumen (e.g. as of Q2 2015).
The estimates were developed for both JetShear as well as for Enhanced JetShear with ARP (assumed a 10% increase in capital for ARP using internal estimates).
Life Cycle Greenhouse Gas Assessment

The JetShear technology platform reduces overall greenhouse gas (GHG) emissions on a wells-to-refinery basis by 5.4 - 11% by removing a significant volume of diluent from the system (i.e. up to 60%) thereby reducing the GHG impacts of sourcing, transporting and processing the bitumen blend at the refinery (i.e. less diluent is being transported to site and to the refinery).

In the most recent inventory data available, Alberta’s emissions of 267 Mt in 2013 accounted for approximately 37% of Canada’s total emissions, and this number and share is expected to grow. While Canada’s emissions are forecasted to increase by 16% from 2013 levels by 2030, Alberta’s emissions are expected to grow by 20%. If these projections hold, the 53 Mt of growth in Alberta emissions will account for 60% of the total growth in Canadian emissions.\(^6\)

To positively affect the sustainability of the oil sands sector, more stringent regulation under Alberta’s recently announced Climate Leadership Plan will include:

- a carbon price applicable to all transportation and heating fuels starting at CA$20/tonne on January 1, 2017, increasing to CA$30/tonne on January 1, 2018, and continuing to increase in real terms each year after that;\(^7\)

- a transition from the Specified Gas Emitters Regulation facility-specific historical emissions-intensity reduction approach to product-based performance standards in 2018;

- a commitment to legislate an emissions limit for the oil sands of 100 Mt in any year (with additional provisions for cogeneration and new upgrading capacity); and

- a reduction of methane emissions by 45% from oil and gas operations by 2025.

A legislated emissions limit is considered a necessary step and is widely supported by a broad spectrum of stakeholders from industry and civil society including, Canadian and international leaders in both Alberta’s oil sand industry and environmental organizations. Supporters believe that the new policy will help change the debate about Alberta’s most important export and the infrastructure needed to get it to market.

Fractal Systems engaged ClimateCHECK\(^8\) to perform a wells-to-refinery GHG assessment to the highest Canadian standards that follow the System of Measurement and Reporting for Technologies (SMART) developed by Sustainable Technology Development Canada (SDTC) and good practice guidelines established by other leading agencies, including ISO Guidelines for the International Standard for GHG Project Quantification, Monitoring and Reporting. In the study, a Base Case of a typical Canadian SAGD sourced dilbit was compared with a SAGD project integrated with Base and Enhanced JetShear to determine the wells-to-refinery GHG impacts.

For the wells-to-refinery scenarios, ClimateCHECK determined that Fractal’s JetShear technology can reduce GHG emissions from 4.9% to 11%, depending on the technology application, transportation mode and refinery location. It is clear that in addition to the commercial benefits associated with diluent avoidance (i.e. cost savings, infrastructure utilization) that significant reductions in the GHG footprint can also be achieved, as there are large GHG impacts associated with the production, processing and transportation of diluent in North America.

Figure 21 shows the comparison for Base and Enhanced JetShear to the dilbit Base Case. Figure 22 shows the summary results for different refining markets and transportation modes (e.g. P/P assumes pipeline from AB and diluent return via pipe, R/R assumes rail to and from AB).

\(^6\) Source: Government of Alberta, Climate Leadership (http://www.alberta.ca/climate.cfm)

\(^7\) Source: Government of Canada, Environment and Climate Change Canada (http://ec.gc.ca/)

\(^8\) Founded in 2007, ClimateCHECK has delivered a wide range of services to 100s of companies across nearly all sectors including global emissions inventories, international capacity building, due diligence for innovative cleantech projects, and supporting corporate leaders on climate change and sustainability.
GHG reductions on a barrel of bitumen produced are important for the sustainably of the oil sands. According to CAPP’s oil sand volume growth scenario, the 2015 and 2030 forecasted production volumes are 1,340,000 bpd and 2,140,000 bpd respectively. By employing Enhanced JetShear GHGs could be reduced by 5.26 Mt CO$_2$e per year in 2015 and 9.41 Mt CO$_2$eq per year in 2030, assuming all volumes are transported via pipeline to and from the US Gulf Coast refining complex.

New technologies and approaches will be required to manage the sustainable growth in the oilsands for the benefit of Canada, the rest of North America, and the world. New legislation in Alberta, Canada limiting the annual GHG levels attributed to the oil sands, may ultimately limit the growth of this critical energy source in the 21st century. Fractal’s JetShear technology can play a vital role in the continuous improvement in the GHG footprint associated with oilsands development.
Beyond JetShear - Future Fractal Technologies

Fractal continues to invest in new ideas and concepts related to the processing and upgrading of heavy-oil and bitumen, by applying simple, proprietary technology to further expand its technology platform and value proposition. This work is focused in the following areas:

- Enhanced JetShear™ and ARP™ commercial field demonstration in 2016
- Patent application filed for Enhanced JetShear™
- Patent application filed for Acid Removal Process (ARP™)
- Expanding the JetShear™ technology platform to achieve further upgrading and Total Diluent Displacement (TDD™)

The company has a technology development plan with milestones that include new and continuing patent filings. Although the nature of technology development makes predicting the commercialization timeline for innovations very difficult, the company and management team has a proven track record in developing new technologies and intellectual property.

Near-term activities remain focused on the field demonstration of Enhanced JetShear and the Acid Reduction Process and protecting innovations with patents.
1. **Patent application title:** Process for treating heavy oils  
   **Patent Number:** 20080217211  
   **Provisional Application:** March 6, 2007  
   **Filing Date:** November 13, 2007  
   **PCT Application:** January 8, 2008  
   **Published Date:** September 11, 2008  
   **National Filings:** September 2009: (Brazil, Colombia, Ecuador, Mexico, Europe, China, Oman)  
   **Provisional Application No:** 60/905,171  
   **Application No:** US: 11/983,842 Canada: 2,611,251  
   **Patent Number:** US 8,105,480  
   **Date of Patent:** January 31, 2012  

   **Abstract:** A process for treating a heavy oil which comprises subjecting a heavy oil to cavitation to reduce the viscosity of the heavy oil. The treated heavy oil, which has a reduced viscosity and specific gravity, thus is more pumpable and transportable, which facilitates further processing. The treated heavy oil also can be fractionated with less severity than untreated heavy oil.

2. **Patent application title:** Treated oils having reduced densities and viscosities  
   **Patent Number:** 20080314796  
   **Provisional Application:** June 22, 2007  
   **Filing Date:** December 6, 2007  
   **PCT Application:** January 11, 2008  
   **Published Date:** December 25, 2008  
   **Provisional Application No:** 60/936,826  
   **Application No:** US: 11/999,671 Canada: 2,617,985  
   **Patent Number:** US 7,943,035  
   **Date of Patent:** May 17, 2011  

   **Abstract:** A treated oil, such as a treated heavy oil, which has a viscosity which is lower than the viscosity of the oil prior to the treatment thereof (i.e., the initial oil). The temperature at which 80 mass % of the treated oil has
boiled is within 25° C of temperature at which 80 mass % of the oil prior to the treatment thereof has boiled. Thus, the treated oil and the oil prior to the treatment thereof, have distillation curves or boiling point curves which are the same as or approximate to each other.

3. Patent application title: Heavy oils having reduced total acid number and olefin content
   Provisional Application: August 9, 2013
   Filing Date: August 5, 2014
   PCT Application: August 8, 2014
   Published Date: March 5, 2015
   Provisional Application No: 61/864,118
   Application No: US: 14/451,787   Canada: 2,858,705
   Patent Number: tbd
   Date of Patent: tbd

   Abstract: A process for treating a heavy oil by heating a feedstock comprising a heavy oil in order to separate from the heavy oil a first fraction. The first fraction contains no more than 25% of the total number of acid groups of the heavy oil. A second fraction contains at least 75% of the total number of acid groups of the heavy oil. The second fraction then is treated under conditions that provide a heavy oil that has a total acid number, or TAN, that does not exceed 1.0, or is at least 50% lower than the total acid number prior to treatment, an olefin content that does not exceed 1.0 wt %, and a P-value of at least 50% of the P-value of the heavy oil prior to treatment, or a P-value that is at least 1.5.

4. Patent application title: Treatment of Heavy Oils to Reduce Olefin Content
   Patent Number: US 2015/0060333 A1
   Provisional Application: August 12, 2013
   Filing Date: August 7, 2014
   PCT Application: August 11, 2014
   Published Date: March 5, 2015
   Provisional Application No: 61/864,827
   Application No: US: 14/454,001   Canada: 2,858,877
   Patent Number: tbd
   Date of Patent: tbd
Abstract: A process for treating heavy oil to provide a treated heavy oil having a reduced density and viscosity, as well as an olefin content that does not exceed 1.0 wt %. The process comprises separating the initial heavy oil into a first fraction, which in general contains lower-boiling components, and a second fraction. The second fraction comprises a heavy oil having a P-value of at least 5% greater than the P-value of the initial heavy oil prior to separating the initial heavy oil into the first fraction and the second fraction, and the second fraction has an aromaticity that is no more than 5% less than the aromaticity of the initial heavy oil prior to separating the initial heavy oil into the first fraction and the second fraction. The second fraction then is upgraded to reduce the density and viscosity of the heavy oil. After the second fraction is upgraded, it is recombined with at least a portion of the first fraction to provide a treated heavy oil having an olefin content that does not exceed 1.0 wt %. The separation of the initial heavy oil into first and second fractions enables one to achieve improved reduction of the density and viscosity of the treated heavy oil while maintaining the olefin content at an acceptable level.