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Maximizing Heavy-Oil Value While Minimizing Environmental Impact with HTL Upgrading of Heavy-to-Light Oil

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Abstract

Ivanhoe Energy, Inc.'s proprietary HTL upgrading technology is designed to cost-effectively process heavy oil in the field and produce a stable, significantly upgraded synthetic oil that meets pipeline requirements. By-product energy from the process can be used to generate steam or electricity. In developed markets, HTL improves the economics of heavy-oil production by reducing or eliminating the need for natural gas and diluent, and by capturing the majority of the price differential for heavy-to-light oil. In remote areas, integrated HTL production frees otherwise stranded resources. HTL accomplishes all of this at a much smaller scale and at lower per-barrel capital costs compared with conventional technologies.

In addition to the foregoing, integrated HTL heavy-oil production provides environmental benefits, particularly related to greenhouse gas (GHG) emissions. This value-added element of HTL integration has taken on significant importance given the dramatic increase in heavy-oil production worldwide and the growing pressures related to GHG emissions.

After years of piloting, development and commercial demonstration, the HTL upgrading process is ready for full-scale application. This paper provides a description of the HTL Upgrading Process, along with its economic and environmental benefits to the producer and a detailed analysis of HTL GHG life-cycle advantages.

Introduction

In mid-2005, Ivanhoe Energy Inc. acquired a new patented process, called Rapid Thermal Processing (RTP™), for the field-located upgrading of heavy oil and bitumen. This patented process was rebranded by Ivanhoe as HTL™, or Heavy-to-Light upgrading, and will be deployed worldwide to economically enhance the development of the huge heavy-oil resource base that is expected to be developed to meet global energy demand.

HTL technology can enable profitable exploitation of vast, worldwide quantities of stranded or economically constrained accumulations of heavy crude and bitumen. Much of the remaining unexploited petroleum reserves are heavy and extra heavy (bitumen). Canada and Venezuela have extensive heavy-oil reserves that compare in size to current reserves in the Middle East. As conventional, lighter crude oil supplies decline, they are expected to be replaced by heavier crudes. As heavy crude production increases, deep conversion capacity also will have to be expanded.[1]

The high capital cost to construct large upgrading facilities using traditional technologies, combined with current lower heavy-to-light-oil price differentials has resulted in challenging economics and, in some cases, cancellation or deferral of upgrading projects processing heavier feedstocks. The HTL upgrading technology consists of field-located modules with capacities as low as 10,000 to 15,000 barrels per day (bpd), allowing producers the ability to dramatically improve project economics and reduce the risk of heavy-oil development and upgrading in a capital-efficient manner. HTL provides an attractive option to build upgrading capacity, integrated with field development.

HTL: Process Description and Advantages

The HTL process, depicted in Figure 1, begins by pre-fractionating the light components from the whole crude oil or bitumen in the feed atmospheric and vacuum distillation towers. Valuable components with a boiling point below 1000 degrees F are sent to product storage, while the heavy residue (resid) that remains is sent to the HTL reactor for upgrading. The resid enters the reactor and comes in contact with the hot circulating sand, where it undergoes a short-residence-time thermal-cracking process. As the product exits the reactor, cracking reactions are quenched and the upgraded product is sent to a product fractionator. Here any remaining resid can be separated and recycled to the reactor as necessary to meet final product specifications. Lighter, upgraded products are sent to product storage.

In the upgrading process, by-product coke is formed on the sand and a minor portion of the feedstock converts to cracked gas. The coke-covered sand is regenerated in the reheater where the thin coke layer is burned off, allowing for the recovery of substantial heat that can be used for steam or electricity generation to support in-situ thermal recovery processes. Product gases can be burned or routed to sales, allowing capture of additional by-product energy or revenues.

The HTL process uses a circulating transport bed of hot sand to quickly heat the heavy feedstock and convert it to lighter, more valuable products. Mechanically, the HTL process is very similar to fluidized catalytic cracking (FCC) and resid fluidized catalytic cracking (RFCC). The major differences are that HTL is non-catalytic and less complicated compared with FCC technology. A detailed technical description of the HTL process can be found in the 2008 WHOC conference proceedings.[2]

Because of the short-residence-time exposure to thermal-cracking conditions, the HTL liquid products are more stable in comparison with alternative thermal-cracking technologies that have longer residence time, such as delayed coking. HTL upgrading significantly improves feedstock qualities, such as API, viscosity, Total Acid Number (TAN), metals, sulphur and nitrogen. HTL processing essentially eliminates problematic asphaltenes. Viscosity is reduced by several orders of magnitude, allowing for pipeline transportation without the need for diluent. Depending on the feedstock and reservoir conditions, by-product energy frequently is adequate to supply the energy necessary for in-situ, thermal-enhanced oil recovery. Details of product qualities and the process have been previously described in the references.[2, 3]

HTL Economic and Environmental Advantages

Economic Improvements

HTL upgrading, when used as a field upgrader associated with a SAGD or other thermal recovery facility, adds tremendous economic value. The key drivers leading to improved economics include:

1. The elimination of costly diluent needed for transportation of high-density, high-viscosity heavy oil.
2. The significant reduction or elimination of natural gas to produce the bitumen and heavy oil.
3. The capture of a significant portion of the price differential for heavy-tolight oil.
4. The reduction in fluctuations of cash flow due to the highly variable nature of heavy oil, diluent and natural gas prices.
5. The expansion of markets for heavy crude to those refiners that do not have resid conversion capacity.

HTL products are of significantly higher quality compared with Dilbit (bitumen with diluent added to enable transportation) and other heavy oils. Many of the contaminants such as heavy metals, sulphur and nitrogen that typically concentrate in the resid portion of the crude are not transported to the refiner because HTL eliminates much of them. TAN reduction in the HTL products also can allow for less stringent metallurgy in the refinery.

Previous work[2] describes the dramatic improvement in project economics associated with the integration of HTL technology with a producing operation. HTL upgrading can improve the netback on bitumen by more than $10 per barrel, which can result in profitable heavy-oil projects even in times of distressed oil prices. The internal rate of return (IRR) also is improved for a typical Athabasca bitumen SAGD project, thereby providing more robust project financing returns.

Environmental Benefits of HTL

Transportation Wastes, Footprint and Products

By upgrading in the field, HTL eliminates the additional energy requirement associated with transporting high-carbon crude oil and bitumen resid through the pipeline. In addition, because of the high viscosity of heavy oil and bitumen, a diluent additive is usually necessary to enable pipeline transportation. For example, based on a typical Canadian Dilbit using 0.44 barrels of diluent per barrel of bitumen and HTL upgraded liquid product yield of 82%, HTL frees up more than 40% of pipeline capacity and reduces a commensurate amount of energy consumption associated with pumping liquid products to market. In addition, in some locations, diluent is returned to the field, resulting in additional energy input and pipeline requirements.[4] HTL is able to achieve the pipeline specification with minimal additional site infrastructure, compared with the significant investment in infrastructure such as diluent and Dilbit pipelines, that otherwise would be needed.

HTL-processed crudes do not contribute to coke production in the refinery and the associated coke stockpiles. Coke stockpiles are recognized as significant emission sources of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs).[5, 6, 7] Additionally, considerably less water consumption and waste water treatment are necessary with HTL processing compared with typical coking technologies. By eliminating resid in the field, HTL provides cleaner products to the refinery and eliminates waste associated with heavy oil and bitumen contaminants and resid.

Greenhouse Gas Advantages of HTL

Greenhouse gas (GHG) emissions are a key environmental – and potentially economic – challenge facing the heavy-oil industry. For simplicity, only the CO_2 portion of total GHG emissions are considered in this paper. The increased focus on GHG has led stakeholders to adopt a life-cycle approach to better understand the overall GHG footprint of producing and consuming oil. This comprehensive "well-to-wheels" view (Figure 2) starts from resource recovery at the well and ends with the use of refined products by consumers, and accounts for direct and indirect GHG contributions. A number of studies have been done to assess the GHG footprint of the Athabasca oil sands industry.[8, 9, 10]

An independent, third-party assessment commissioned by Ivanhoe Energy using this Life-Cycle Analysis (LCA) recently has been completed.[11] The analysis compared two life-cycle pathways as shown in Figure 2: 1) producing and upgrading bitumen using the HTL process and processing the upgraded product at refineries ("integrated HTL process"); 2) producing bitumen via traditional in-situ thermal-recovery technology and shipping a bitumen/diluent blend to refineries ("traditional stand-alone process"). The underlying assumption in the LCA approach is that all the carbon in the produced bitumen is ultimately emitted – including the refinery petroleum coke, of which a significant portion is used as a substitute for coal in cement and power generation industries.[12, 13] The third-party assessment assumed that the coke from the marginal barrel of heavy crude produced is used for such purpose.

Figure 3 shows that, for every cubic meter of bitumen produced, the integrated HTL process has a life-cycle GHG footprint that is 15% smaller than that of the traditional process. Breaking down the life cycle into stages shows:

- *Bitumen extraction stage:* The integrated HTL process has a larger GHG footprint in this stage due to the combustion of coke by-product to generate steam, as opposed to (lower carbon) natural gas, the typical source of energy for the traditional stand-alone in-situ thermal-recovery process.
- *Ship to refinery:* The traditional stand-alone process requires pipeline shipment of a much larger volume compared to the integrated HTL process, as noted above; thus, it has a larger energy requirement and GHG footprint.
- *Refinery processing:* The two cases have virtually the same GHG footprint at this stage.
- *Product and by-product end use:* The case of the integrated HTL process has a smaller GHG footprint than the traditional stand-alone process in terms of by-products, because the HTL upgraded crude does not generate additional by-product coke at the refinery.

Another common LCA benchmarking metric compares GHG emissions from different processes based on the amount of transportation fuels produced (i.e., gasoline, jet fuel, diesel). The yields of these products from the integrated HTL process are smaller than those of the traditional stand-alone process, hence a larger feed volume is required for the integrated HTL process to achieve the equivalent product volume. Figure 4 shows that, on this "equivalent fuels product" basis, the GHG footprint of the integrated HTL process still is 9% smaller than that of the traditional process.

Path to Commercialization

HTL technology has evolved from rapid thermal processing (RTP^{TM}) of biomass to application in petroleum feedstocks. Years of development in biomass led to the initial testing of HTL in pilot plants in Ottawa, Ontario, starting in 1998. These pilot tests continued for several years until a 1000-bpd commercial demonstration facility (CDF) was commissioned in late 2004 in the super-giant Belridge heavy-oil field in southern California. By 2007, the CDF had validated the pilot-plant results and demonstrated the scalability of the HTL process. Further background is described elsewhere.[2, 3] In late-2008, Ivanhoe Energy commissioned a Feedstock Test Facility (FTF) at Southwest Research Institute in San Antonio, Texas, to further facilitate testing of various heavy-crude feedstocks from around the world. This facility provides full functionality for feedstock processing, including pre-fractionation capabilities not available at the CDF. The 10-15-bpd whole-crude capacity (5-bpd vacuum residue capacity) allows for the physical production of the full spectrum of HTL products. The scale of the plant is much more conducive to receiving and testing of feedstocks from around the world. One of the drawbacks of the CDF is the difficulty in transporting several hundred barrels of feedstock to the plant for testing. The FTF requires a feedstock volume that is much more manageable for transportation. The FTF will be used as a cost-effective means to test third-party feedstocks, optimize processing parameters and generate additional intellectual property. Technical improvements and additional intellectual property developments already have been realized at the FTF and they will be the subjects of future publications.

Parallel with FTF developments, the basic engineering design for the first full-scale, 20,000-bpd commercial HTL facility has been completed and the front-end engineering design (FEED) will be completed in late 2009. This work is being completed in conjunction with Ivanhoe Energy's Tier 1 contractor, AMEC, and integrated with the upstream basic design for Ivanhoe Energy's Tamarack Project in the Athabasca Oil Sands in Alberta.

Conclusion

The key advantages that the HTL technology affords to the heavy-oil and bitumen producer are:

1. Ability to capture the majority of the price differential between heavy and light oil.
2. Reduced operating cost and complexity by eliminating diluents or blending agents used to move the product through a pipeline.
3. Reduced operating and infrastructure capital costs by using by-product energy to generate steam and/or electrical power.
4. Reduced risks and increased capital efficiency via small-scale, field-sited upgrading capacity that grows with resource development (minimum scale of 10,000-15,000 bpd).
5. Reduced environmental impact compared with conventional production and transportation of heavy oil and bitumen.

These features of the HTL technology enable viable exploitation of reserves where economics otherwise may be marginal, and where environmental and transportation issues may prevent the marketability of crude products.

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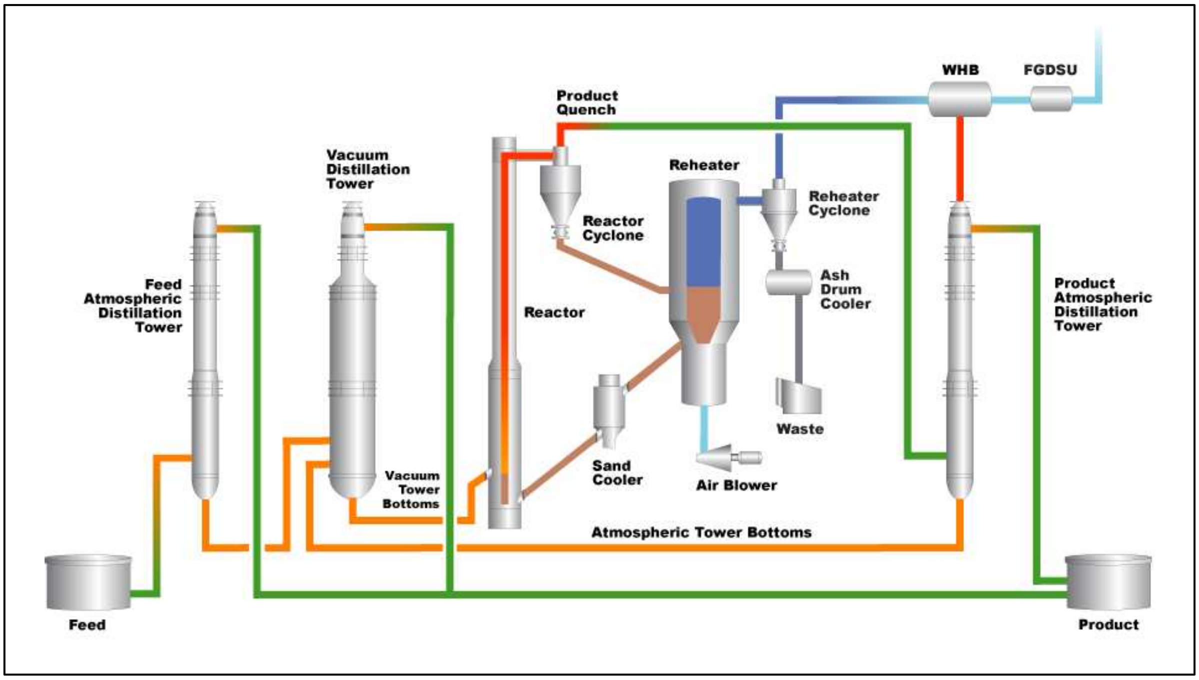
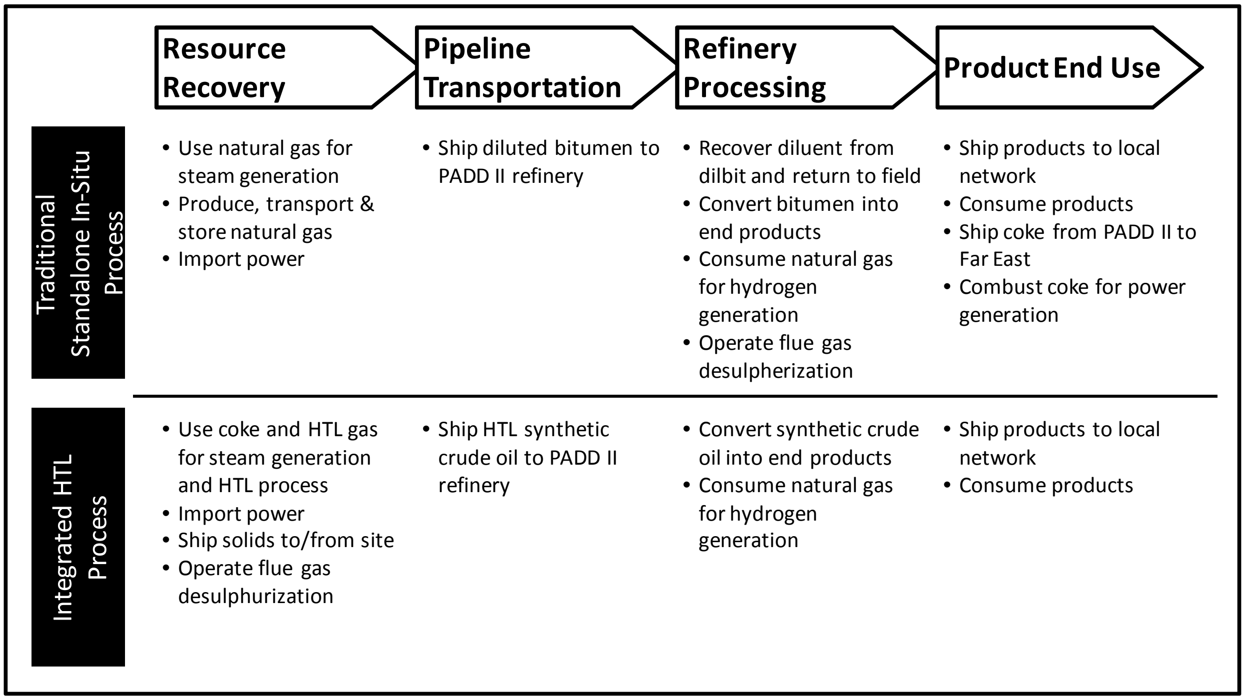


Figure 1: HTL Simplified Process Flow Sketch. Feed is routed to the feed atmospheric distillation tower with straight-run, light distillates routed to tankage for blending, and atmospheric bottoms routed to the feed vacuum distillation tower. Straight-run vacuum gas oils are routed to tankage for blending. Vacuum tower bottoms are routed to the HTL reactor where short-contact thermal cracking on the circulating sand takes place in less than five seconds. Reactor products are quenched at the exit of the reactor cyclone and routed to the product atmospheric distillation tower where distillates and lighter materials are sent to the product tank and blended with straight-run distillates and gas oils. Sand is returned to the reheater, where the coke is burned off. Sand is cooled to optimum reaction temperature and returned to the reactor. Product atmospheric tower bottoms can be recycled to the front end of the vacuum distillation tower, depending on the site-specific energy and product specification requirements. Not shown for simplicity: light gases from columns are routed to the waste-heat boiler; water flows to and steam generation from column pump-arounds, sand cooler, waste heat boiler; and, power-generation alternatives.



	Resource Recovery	Pipeline Transportation	Refinery Processing	Product End Use
Traditional Standalone In-Situ Process	• Use natural gas for steam generation • Produce, transport & store natural gas • Import power	• Ship diluted bitumen to PADD II refinery	• Recover diluent from dilbit and return to field • Convert bitumen into end products • Consume natural gas for hydrogen generation • Operate flue gas desulpherization	• Ship products to local network • Consume products • Ship coke from PADD II to Far East • Combust coke for power generation
Integrated HTL Process	• Use coke and HTL gas for steam generation and HTL process • Import power • Ship solids to/from site • Operate flue gas desulphurization	• Ship HTL synthetic crude oil to PADD II refinery	• Convert synthetic crude oil into end products • Consume natural gas for hydrogen generation	• Ship products to local network • Consume products

Figure 2. Life cycle approach to assessing greenhouse gas footprint, comparing a traditional standalone in-situ process to an integrated HTL process.

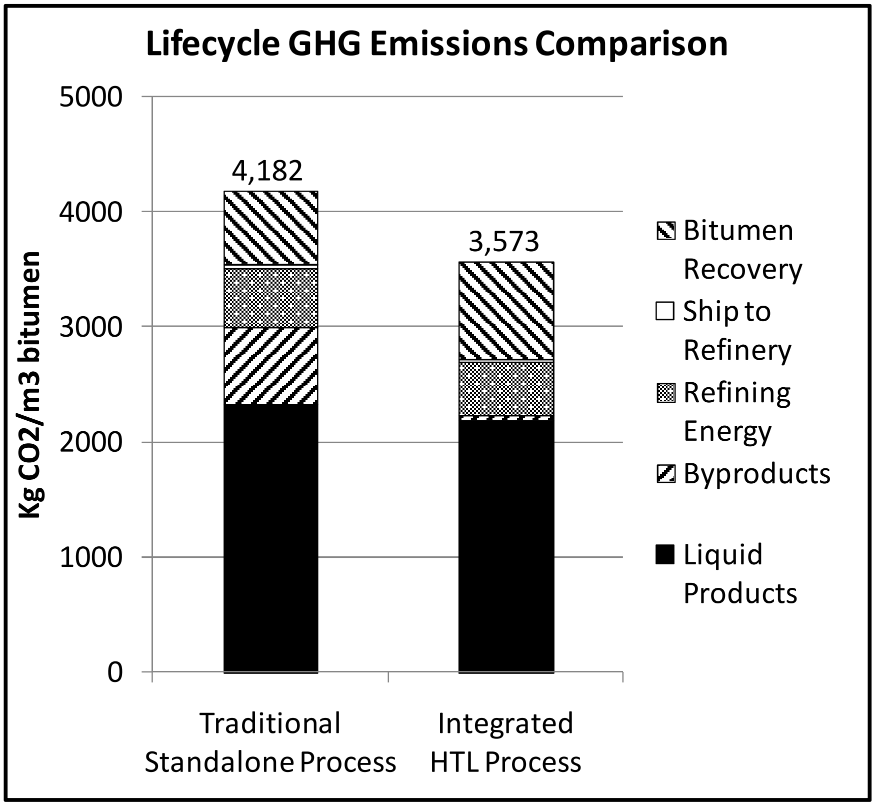


Figure 3. Comparison of life-cycle GHG emissions. The integrated HTL process has a 15% improvement compared to the traditional stand-alone in-situ process over the life-cycle of a cubic meter of bitumen produced (based on the inclusion of power recovery in the HTL processing).[11]

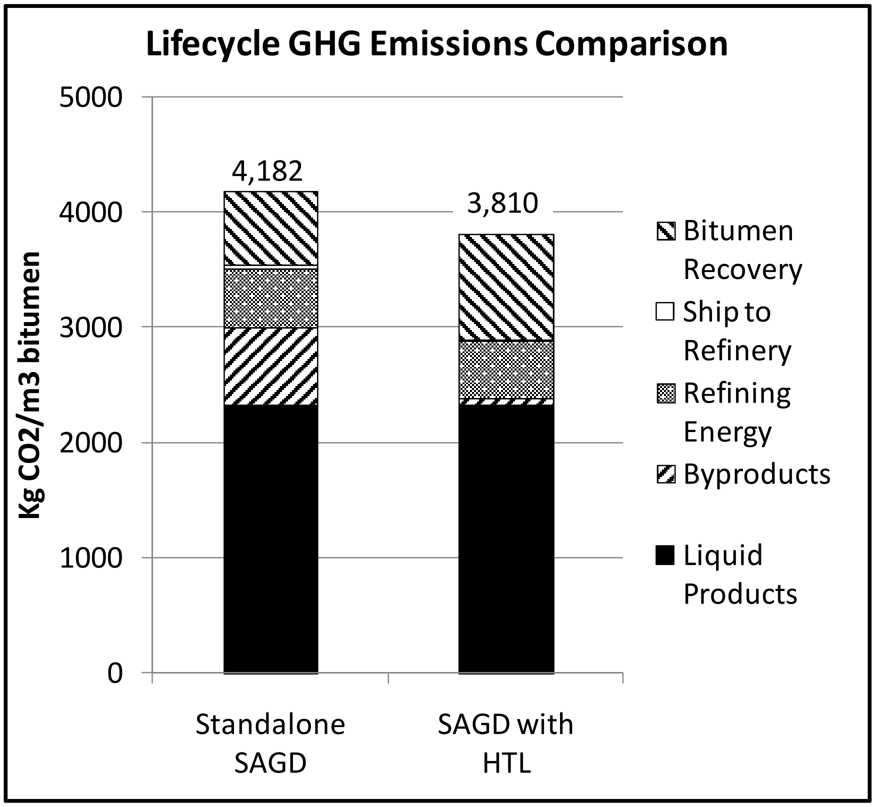


Figure 4. Comparison of life-cycle GHG emissions. The integrated HTL process has a 9% improvement compared to the traditional stand-alone in-situ process over the life-cycle for the equivalent amount of transportation fuel produced from a cubic meter of bitumen.[11]