COMMODITY UPDATE: CRUDE OIL

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Future Options for Alberta's Bitumen Resources

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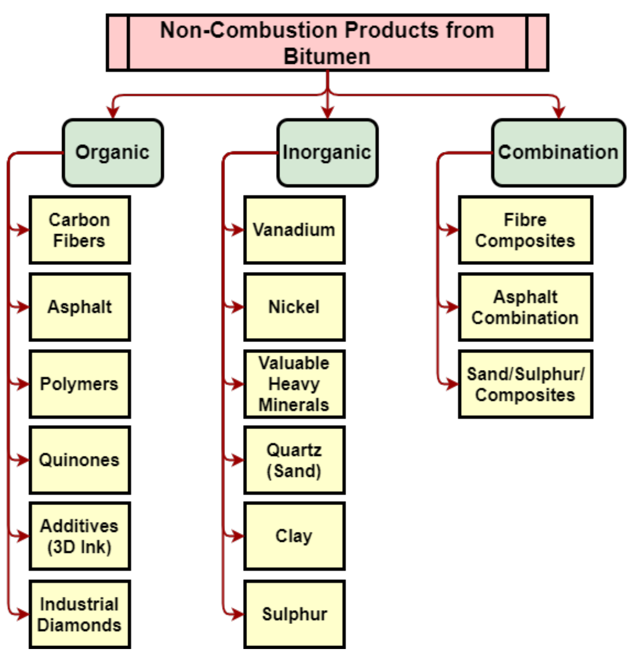
Bitumen reserves in Alberta are the third-largest oil reserves in the world, after Venezuela and Saudi Arabia, with 165.4 million barrels of proven reserves (Alberta Government 2020). The extraction and conversion of bitumen to fuel is one of Alberta's primary economic drivers (Alberta Innovates 2017). At present, over 90 percent of oil, including bitumen, is converted into combustion products, whereas the rest is used to make non-combustibles. The market for combustion products is experiencing a period of slow growth, even decline, due to the changes driven by various factors including climate change concerns, electrification of transportation, and global regulations regarding the use of petroleum-based fuels (Alberta Innovates 2017). Therefore, a long-term solution is needed to create new markets for oil constituents to achieve higher oil prices and reduce the detrimental environmental impact of oil sands production (Bakx 2018).

Diversifying oil uses and finding new/expanded markets for non-combustion products from bitumen are attractive strategies that work well whether the demand for combustibles goes up or down (Alberta Innovates 2017). Stantec (Stantec 2018) provides a detailed road map of potential non-combustion products, as shown in Figure 1. In general, three main categories of non-combustion products from bitumen are producible through different process technologies, which include organic (e.g., asphalt, polymers and carbon fibre), inorganic (e.g., metals and minerals), and combinations.

Figure 1. Potential Non-combustion Products from Bitumen



Source:(Stantec 2018), figure by CERI

Applying a two-step decision analysis process (COSIA 2018b), Stantec identified four major products with higher future potentials: Carbon fibre, Asphalt, Vanadium, and Polymers (Stantec 2018). The two-step decision analysis process includes:

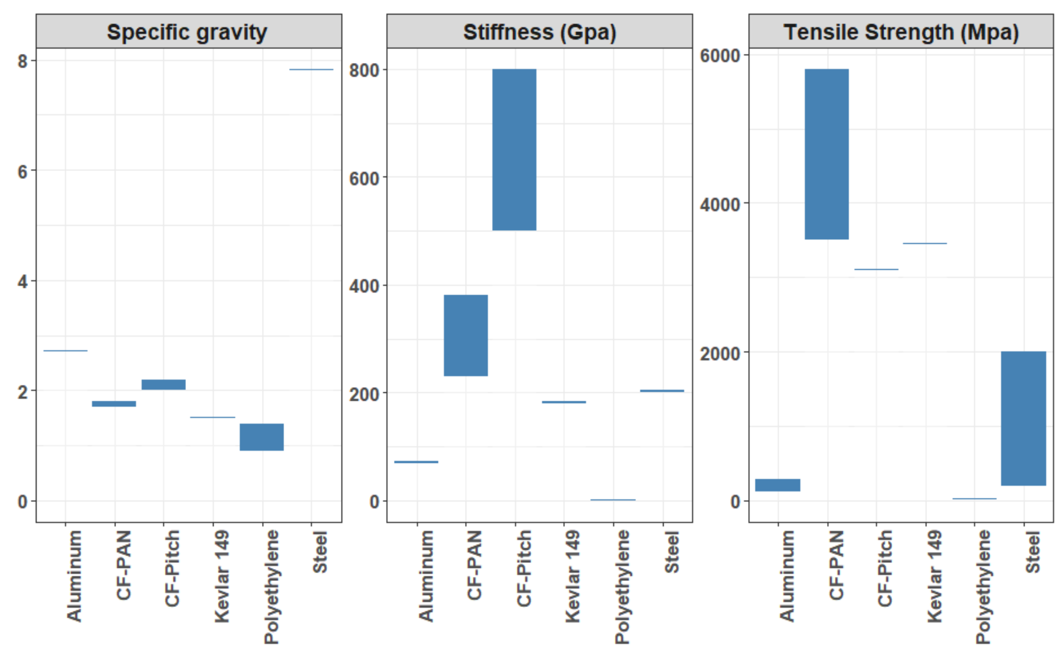
a) Forced ranking of assessment criteria to determine the importance of each criterion
b) The developed scoring methodology of assessment criteria for each product which includes 2030 market status, environmental net effects, social and economic factors, the costs, and technology readiness level (TRL)

In this article, we will review carbon fibre and its combination products in further detail.

Carbon Fiber (CF)

In CF, atoms are arranged in long layers of hexagonal carbon rings with a diameter ranging from five to 10 micrometres. These materials are typically spun into threads which are woven/layered and then converted into final products. They can also be used to reinforce other products (e.g., woods (CFRW), steel (CFRS), plastic (CFRP), and concrete (CFRC)) and create composites with additional properties (Stantec 2018). The bonding and interlocking occur among layers of carbon atoms giving CF unique properties (COSIA 2018a). As shown in Figure 2, CF has low specific gravity with high stiffness and tensile strength, making it more appealing for industrial applications, compared to other commodities such as aluminum, steel, Kevlar 149, and Polyethylene.

Figure 2. CF Properties versus Other Commodities



Source: (COSIA 2018a), figure by CERI
Note: CF is currently produced from two precursors[1]: polyacrylonitrile (PAN) and pitch.

[1] A precursor is a compound that participates in a chemical reaction that produces another compound (Wikipedia 2019).

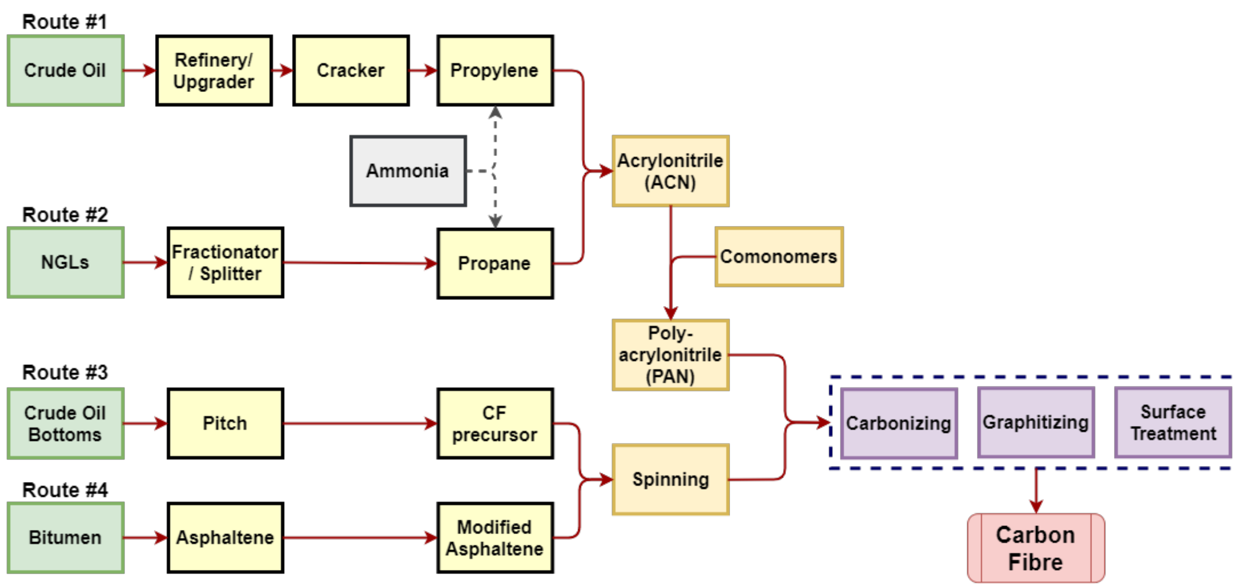
CF Market

CF has received a great deal of attention in recent years due to its desirable physical properties (e.g., weight and strength). The global production of CF was 100 thousand tonnes per annum (ktpa) in 2017, with a CAGR of 12.5% (COSIA 2018a). At present, CF is used at the medium (e.g., luxury automotive) to higher end (e.g., aerospace) of the market. The CF market size is projected to grow from US$4.7 billion in 2019 to US$7.8 billion in 2029, and Europe is expected to provide the largest market for this product (Research and Markets 2019).

CF Production Routes

The major precursors to manufacture CF are polyacrylonitrile (PAN) (produced from propylene and propane feedstocks) and a pitch-type feedstock. Currently, PAN is accounted as the principal material for CF production, and approximately 96% of the available CFs are produced using this precursor (Khayyam et al. 2020). After PAN, pitch is the most widely used precursor fabricated with either natural resources such as petroleum and coal (isotropic pitch fibres) or pyrolysis, hydrogenation and solvent extraction of synthetic polymers or isotropic pitch fibres (mesophase pitch fibres) (Khayyam et al. 2020). A potential pathway for CF production that has been introduced by Alberta Innovates (AI) and Stantec shows the possibility of CF production using oil sands bitumen as the feedstock (Stantec 2018; Meisen 2017). Figure 3 depicts the process routes for CF production using various feedstocks.

Figure 3. CF Production Processes using Different Feedstocks



Source: (COSIA 2018a), figure by CERI

In Route #1, conventional crude oil goes through a refinery and a cracker to produce propylene. The produced propylene reacts with ammonia through the ammoxidation process (BP Sohio technology) and produces Acrylonitrile (ACN), which is polymerized to PAN. Carbonization and graphitization are the final steps to fabricate CF. In Route #2, which is a margin pathway from Natural Gas Liquids (NGLs), the produced propane reacts with ammonia through Asahi Kasei technology and forms ACN. The rest of the process is the same as Route #1 (COSIA 2018a).

In Route #3, the produced pitch from the crude oil bottoms is spun, carbonized, and graphitized to form the final CF product. In Route #4, the heaviest fractions of bitumen (asphaltene[2]) are extracted and modified. Like Route #3, the modified asphaltene then goes through spinning, carbonization, and graphitization sequences to produce CF (COSIA 2018a). Note that during the carbonization and graphitization steps, the heat treatment temperature increases to 2900 °C to align the orientations, remove the impurities, and reorder the carbon structure to reach layered hexagonal structure (Stantec 2018). After graphitization, some treatments are conducted on the surface of CF to prepare it for bonding with another material in the composite fabrication process.

As the CF production from PAN and pitch (Routes #1 to #3) is currently in operation, TRL for these processes is 10, whereas, according to the Stantec report (Stantec 2018), TRL for CF from bitumen (Route #4) is three, which means that this process is in the experimental and proof of concept phase.

Cost of CF Production from Bitumen

One of the major markets for CF is the automotive industry. However, CF is mostly used in luxury vehicles due to its relatively high price (about US$8 to 16/lb). It has been discovered that if the CF price reduces to US$5/lb, then the scale of CF usage in the automotive industry will be much larger (COSIA 2018a).

At a very high level, the cost breakdown of CF products contains three components, including feedstock (35%-40%), the production process (30%), and the shaping of CF into the desired product (30%) (COSIA 2018a). The selling price of asphaltene is about US$0.02/lb (2017 raw coal price), approximately 400 times less than the price of CF. Thus, CF fabrication from bitumen, as the feedstock, can be considered as an excellent strategy to reduce the cost in the production process (Stantec 2018).

Alberta Innovates (AI) Initiative

The idea of producing non-combustion products from bitumen is at the early stages and further investigation is required to prove the feasibility of this technology and assess the global market potential for the products. For this purpose, AI (the technology arm of the Government of Alberta) takes the leadership role by introducing the Bitumen Beyond Combustion (BBC) program (Alberta Innovates 2017). This program, an AI sponsored initiative, which receives support from industrial partners, looks at how Alberta's oil sands can be used to serve non-combustion products' markets. The BBC initiative is based on four concepts (COSIA 2018b):

1. Diversify oil sands bitumen used to produce high value, large scale non-combustion products
2. Increase bitumen production in Alberta by creating new/expanded markets
3. Reduce greenhouse gas (GHG) emissions associated with bitumen uses
4. Address uncertain future markets for petroleum-based fuels

Figure 4 shows the progress achieved so far in the BBC initiatives since April 2017. Further details about the program and the competitions held for the development of this technology are available on the AI website (Alberta Innovates 2020).

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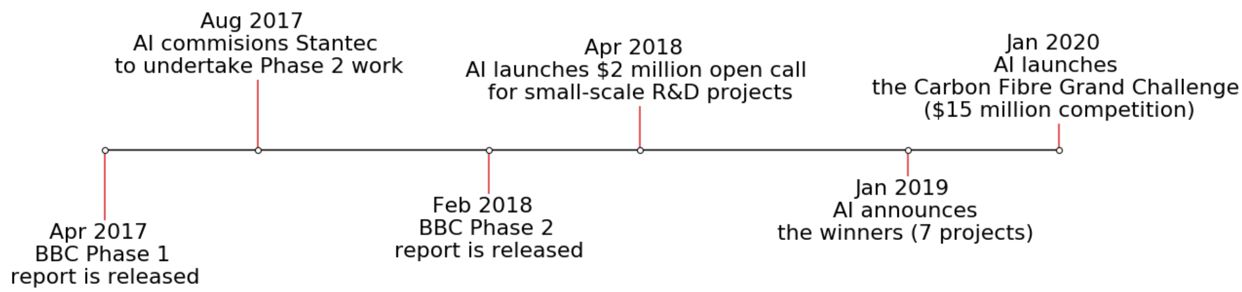
[2] Asphaltenes are a complex mixture of aromatic and complex compounds with high viscosity that compromise 20% of bitumen (COSIA 2018a).

Figure 4. BBC Timeline



Source: (COSIA 2018b; Alberta Innovates 2020), figure by CERI

Conclusion

As the growth of crude oil share in energy market outlooks is flattening or declining, there is a need to find a way to deal with the produced bitumen which is not converted into combustion products. Like the funded program introduced by the Government of Alberta in the 70s and 80s, that eventually led to the steam-assisted gravity drainage (SAGD) process, the BBC program is defined by AI as a long-term strategy to diversify bitumen uses and reduce GHG emissions. However, because these non-combustible bitumen products are in the early research stages, there are fundamental challenges around this program that could be categorized as follows:

- Complex process technologies to convert bitumen to the final products
- Commercialization of BBC products
- The market for the new products in terms of economic competitiveness

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