

Third-Party Review of Gibson/USD Group Operational Value Chain Carbon Emissions Model

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1.0 Executive Summary

Gibson and USD have collaborated to develop an Excel-based model to quantify the operational CO_{2e} emissions associated with transporting bitumen by pipeline and rail from near Hardisty, Alberta to near Port Arthur, Texas, utilizing current pipeline and railroad routes. The model analyzes four scenarios:

- 1) Shipping diluted bitumen (Dilbit) from Hardisty, Alberta to the U.S. Gulf Coast market through the Enbridge Mainline pipeline and returning diluent to Hardisty, Alberta through the Southern Lights pipeline from the Gulf Coast.
- 2) Shipping Dilbit from Hardisty, Alberta to the U.S. Gulf Coast market through the Keystone pipeline and returning diluent to Hardisty, Alberta through the Southern Lights pipeline from the Gulf Coast.
- 3) Shipping Dilbit from the Hardisty Rail Terminal (HRT) near Hardisty, Alberta to the Port Arthur Terminal (PAT) in the U.S. Gulf Coast market via rail, returning empty railcars, and returning diluent to Hardisty, Alberta through the Southern Lights pipeline from the Gulf Coast.
- 4) Shipping minimally-diluted bitumen (DRUbit™) from HRT to PAT via rail and returning empty railcars. Diluent is recovered at the diluent recovery unit at the Hardisty Energy Terminal (HET) in Alberta near Hardisty.

The operational CO_{2e} emissions model is based on the contracted processing rate of 50,000 bbl/d of Dilbit at HET. The model includes diluent recovery at HET in Alberta; rail transport including car counts and locomotive performance from HRT to PAT; pipeline transport including electrical grid intensity; railcar unloading, blending, and product delivery at PAT; and diluent recovery at the end-user refinery. The model is based on factored emissions from fuel or energy consumption; this is standard industry practice. Upstream bitumen production CO_{2e} emissions and downstream refinery processing emissions beyond diluent recovery are not included as they are outside the Gibson/USD value chain.

Modeled CO_{2e} emissions from HET and PAT are based on the engineering design calculations for the respective facility at the 50,000 barrel per day rate. Emissions for rail transport are based on the railcar loading capacities for Dilbit and DRUbit™, locomotive fuel efficiency for the rail route and the return of empty railcars to Alberta. Emissions for pipeline transport are based on calculated pumping power requirements for Dilbit and diluent with average electrical grid intensity for each pipeline section. Emissions for diluent recovery/recycle at the refinery in Texas are assumed to be the same as HET.

The assessment methodology followed standard review practice, each section or process of the model was examined independently for calculation errors, data integrity, and quality of references. Over the course of the review with Gibson and USD, data sources were updated to the latest publicly available information and the pipeline transport analysis was improved and updated with 2020 capacities.

Overall, the model is well-organized and comprehensive with appropriate assumptions and supporting data, providing a robust basis for the results. Specific and credible information in the model includes HET and PAT design information from Gibson and USD; rail route, locomotive, and rail car information from Canadian Pacific and publicly reported information by CP and KCS, the rail carriers for DRUbit™; pipeline information from Gibson and publicly reported information from the included pipelines; and information from publications by the University of Calgary’s Energy Technology Assessment Research Group on their COPTeM pipeline emissions model.

The model indicates that the DRUbit™ scenario above saves between 20% – 36% of operational CO_{2e} emissions compared to the Dilbit rail and pipeline scenarios. Against the Dilbit by rail scenario, the model predicts that the DRUbit™ scenario saves approximately 63,000 metric tonnes CO_{2e}/year (20%, 69,000 U.S. tons/year). Against the Keystone scenario, the model predicts that the DRUbit™ scenario saves approximately 92,000 metric tonnes CO_{2e}/year (27%, 101,000 U.S. tons/year). Against the Mainline scenario, the model predicts that the DRUbit™ scenario saves approximately 137,000 metric tonnes CO_{2e}/year (36%, 151,000 U.S. tons/year).

These savings are achieved by removing the diluent required to enable pipeline transport and replacing those pipeline transport emissions with rail transport emissions. Diluent is recovered at the upstream HET location instead of the downstream end-user refinery, removing the diluent transport loop and associated emissions. A comparison of the predicted total emissions for each scenario is shown in Figure 1 below.

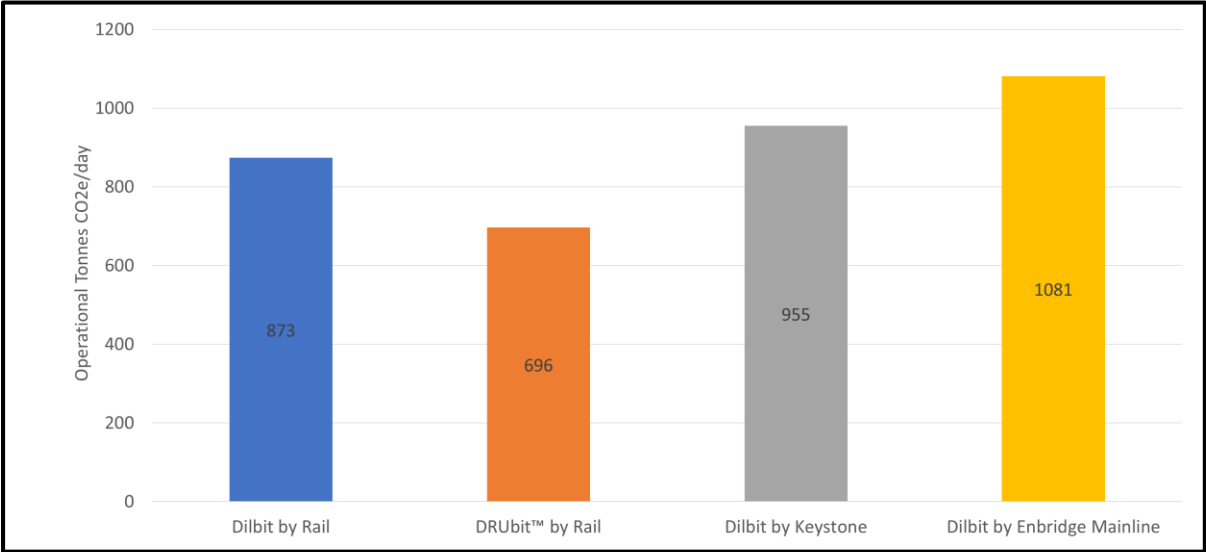


Figure 1

2.0 Purpose and Overview

Gibson and USD developed a GHG emissions model, based on equivalent CO₂ emissions (CO_{2e}), to compare the operational CO_{2e} emissions of DRUbit™ shipped by rail to the current standard practice of shipping Dilbit by rail or by pipeline. Gibson developed the pipeline transport model and the Hardisty Energy Terminal emissions model. USD developed the emissions model for the Port Arthur Terminal and worked with Canadian Pacific to develop the rail transport model.

3.0 Model Review

3.1 Assumptions

The model is based on the following assumptions:

- 1) All scenarios ship the same amount of bitumen to Texas.
- 2) The majority of diluent imported into Alberta is sourced from fractionation facilities in Mont Belvieu, Texas.
- 3) The current market scenario of diluent recycle from Mont Belvieu is compared with the new scenario of diluent recovery and recycle at the Hardisty Energy Terminal (HET) in Alberta.
- 4) The same volume of diluent is recovered from Dilbit at the HET as is recovered from Dilbit in Texas.
- 5) GHG emissions for diluent recovery at the HET are the same as GHG emissions for diluent recovery in Texas.
- 6) Diluent is currently recycled to Alberta from Texas to Illinois via the Explorer pipeline and then from Illinois to Alberta through the Southern Lights diluent return dedicated pipeline.
- 7) Minor emissions from pipeline transport between facilities or custody transfer in Texas (e.g. Port Arthur and Mont Belvieu) are ignored.
- 8) DRUbit™ delivered by rail into the Port Arthur market displaces Dilbit delivered by rail into Port Arthur.
- 9) Railcars are dedicated to DRUbit™ or Dilbit transport and are returned to Alberta empty.
- 10) The rail route for DRUbit™ and Dilbit by rail is the same.
- 11) The analysis is agnostic of third-party rail or pipeline transport investments in renewable power purchase agreements, renewable energy certificates or other offsets and uses published grid and rail emissions intensities.
- 12) The model calculates operational emissions and does not include construction or decommissioning emissions.

These assumptions are reasonable, valid and necessary for developing a model to analyze the relative CO₂e emissions of multiple shipping pathways. The assumptions enable a consistent basis for analysis and capture the principles of the bitumen and diluent markets.

An equivalent bitumen basis for the calculations is appropriate. Refiners buy Dilbit to upgrade the cheap bitumen fraction to high-value products like gasoline and diesel. The diluent in Dilbit is used only to enable pipeline transport by reducing viscosity. Diluent has minimal value to refiners because very little can be blended into gasoline and none into diesel. The low value of diluent at refineries combined

with the high value of diluent in Alberta for Dilbit blending enables the business model for diluent return pipelines like Southern Lights.

Assuming diluent recycle from Mont Belvieu in Texas is appropriate. Although significant diluent is recycled to Alberta from the Illinois area refineries, the Gibson/USD business model ships DRUbit™ by rail to Port Arthur, Texas and the diluent recycle should be analyzed with the same market region.

Assuming the same diluent recovery volume at the HET and in Texas is appropriate. There is no reasonable way to estimate what fraction of diluent is retained by individual refineries in the Texas market, this will vary depending on their configuration and feed crude blend. As stated above, refiners can only blend small quantities of diluent into gasoline.

Assuming the same emissions footprint for diluent recovery at the HET and in Texas is appropriate. Refineries have different configurations but are all efficient at fractionation and recovery. The HET is a new facility designed for efficient recovery of diluent and the associated emissions are a reasonable estimate of the equivalent refinery emissions to do the same job.

The diluent recycle pipeline route from Texas to Illinois to Alberta is appropriate. There are no diluent return pipelines running a direct route from Texas to Alberta.

Ignoring minor emissions for pipeline transport between facilities in Texas is appropriate. The US Gulf Coast region has a complex network of pipelines for transporting liquids over short distances. It is impossible to identify a specific route and the distances are short.

Assuming DRUbit™ displaces Dilbit in the Port Arthur market is appropriate. The Gibson/USD business does not influence bitumen production volume, so the market volume of bitumen remains constant regardless of the delivery path.

The assumption of dedicated railcars returning empty is appropriate. Railcars designed for hydrocarbon liquids cannot be temporarily reused for other liquids and diluent is not recycled by rail to Alberta.

The assumption of the same rail route for DRUbit™ and Dilbit is appropriate in order to compare transport emissions on the same basis.

It is not possible to incorporate third-party renewable credits into the emissions model without exact information on whether credits are applied, where they are applied, what their offset is and how they are allocated to the liquids being transported. This information is not available.

Calculation of operational emissions without infrastructure construction or decommissioning emissions is appropriate. The pipeline and rail transport infrastructure in the model is complex, has existed for

decades and will continue to operate into the foreseeable future. Quantifying and allocating non-operational emissions for such a long commercial life is difficult, whereas operational emissions are much clearer.

3.2 Model Components

There are seven CO₂e calculation components in the overall model. They are:

- 1) Dilbit Transport by Rail (including empty rail car return)
- 2) DRUbit™ Transport by Rail (including empty rail car return)
- 3) Southern Lights Diluent Return Pipeline
- 4) Enbridge Mainline Pipeline
- 5) Keystone Pipeline
- 6) Hardisty Energy Terminal (HET)
- 7) Port Arthur Terminal (PAT)

The componentized approach enables straightforward construction and comparison of transport and processing pathways. Note that the model calculates in combined U.S. and Metric units. It is assumed the reader is familiar with both systems and descriptions are made in the units employed in the individual calculation components. There is some repetition in the descriptions below; each description is intended to be independent of the others and not require cross-referencing.

3.2.1 Dilbit Transport by Rail

This component estimates the CO₂e emissions resulting from the transport of 50,000 bbl/d of Dilbit from Hardisty, Alberta to Port Arthur, Texas, in railcars, plus the CO₂e emissions resulting from the return of empty railcars on the same route.

The rail route begins in Hardisty, Alberta and follows the Canadian Pacific (CP) Northern Main Line to Kansas City. This leg is 1810.3 miles. From Kansas City, Kansas City Southern (KCS) rail ships the railcars to Port Arthur, Texas. This leg is 787.2 miles. The rail route distances are taken from CP's Product Management guide. Empty railcars are assumed to be returned on the same route.

Railcar maximum product capacity for Dilbit is stated as 190,643 pounds, provided by USD Group for 117J cars with a 25,600 gallon capacity. For Dilbit, this rail car type meets the volume limit before it meets the weight limit. Railcar tare mass (i.e. empty) is 85,000 pounds, for a total weight of 275,643

pounds. Absolute maximum railcar weight is generally 286,000 pounds across North America, subject to bridge reductions.

The specific gravity (SG) of Dilbit is stated as 0.92 (920 kg/m³). This is appropriate for Cold Lake Dilbit, although the SG for this Dilbit seasonally varies between 0.915 to 0.938 according to Crude Monitor. This is an insignificant variation. At a railcar product capacity of 190,643 pounds and SG of 0.92, the Dilbit load per railcar is calculated to be 590.9 barrels. With a 50,000 barrel shipment, 84.6 railcars are required.

Fuel efficiencies are taken from the CP Rail 2019 Annual Report and the KCS Rail 2019 Annual Report. CP Rail efficiency is 0.955 U.S. gallons per thousand Gross Ton-Miles (1,000 GTM). This means that a locomotive will consume 0.955 gallons of diesel hauling a load of 1,000 U.S. tons for one mile. The corresponding KCS Rail efficiency is 1.31 gallons/1,000 GTM.

The total average weight of a loaded railcar in this scenario is 137.8 tons. The GTM of the railcars over the CP portion of the route is calculated as 21,112,529 ton-miles. At the CP fuel efficiency this requires 76,322 liters of diesel per day.

The GTM of the railcars over the KCS portion of the route is calculated as 9,180,679 ton-miles. At KCS fuel efficiency this requires 45,527 liters of diesel per day.

Diesel CO_{2e} emissions are calculated on a Well-To-Wheels (WTW) basis. A WTW basis accounts for the production, refining and consumption of a liquid fuel. WTW values for diesel are taken from “Well-to-wheel life cycle assessment of transportation fuels derived from different North American conventional crudes”, Kumar et al, 2015. An average diesel emissions value is calculated as 96.88 gCO_{2e}/MJ. WTW values are generally presented on an energy content basis. The heating value of diesel is 38.6 MJ/L (this value can vary by a few percent), producing an emissions factor of 3,740 gCO_{2e}/L.

The model calculates emissions for the CP portion of the route at 285.4 tonnes CO_{2e}/day and for the KCS portion of the route at 170.3 tonnes CO_{2e}/day.

Empty rail car return is then calculated on the same GTM and diesel basis, using the empty weight of 85,000 pounds per rail car. Over the KCS portion of the return route the model calculates 2,831,045 GTM and over the CP portion of the route the model calculates 6,510,468 GTM. This becomes 52.5 tonnes CO_{2e}/day for the KCS portion of the return route and 88.0 tonnes CO_{2e}/day for the CP portion of the return route.

3.2.2 DRUbit™ Transport by Rail

This component estimates the CO_{2e} emissions resulting from the transport of 35,386 bbl/d of DRUbit™ from Hardisty, Alberta to Port Arthur, Texas, in railcars, plus the CO_{2e} emissions resulting from the return of empty railcars on the same route. The emissions from diluent recovery are reviewed in section 2.2.6.

The rail route begins in Hardisty, Alberta and follows the Canadian Pacific (CP) Northern Main Line to Kansas City. This leg is 1810.3 miles. From Kansas City, Kansas City Southern (KCS) rail ships the railcars to Port Arthur, Texas. This leg is 787.2 miles. The rail route distances are taken from CP's Product Management guide. Empty railcars are assumed to be returned on the same route.

Railcar maximum product capacity for DRUbit™ is stated as 193,060 pounds, provided by USD Group for 117J cars with a 25,600 gallon capacity. For DRUbit™, this rail car type meets the weight limit before it meets the volume limit, which is why the maximum product capacity is slightly higher when compared to Dilbit. Railcar tare mass (i.e. empty) is 85,000 pounds, for a total weight of 278,060 pounds. Absolute maximum railcar weight is generally 286,000 pounds across North America, subject to bridge reductions.

The SG of DRUbit™ is stated as 0.997 (997 kg/m³). At a railcar capacity of 193,060 pounds and SG of 0.997, the DRUbit™ load per railcar is calculated to be 552.2 barrels. With a 35,386 barrel shipment, 64.1 railcars are required.

Fuel efficiencies are taken from the CP Rail 2019 Annual Report and the KCS Rail 2019 Annual Report. CP Rail efficiency is 0.955 U.S. gallons per thousand Gross Ton-Miles (1,000 GTM). This means that a locomotive will consume 0.955 gallons of diesel hauling a load of 1,000 U.S. tons for one mile. The corresponding KCS Rail efficiency is 1.31 gallons/1,000 GTM.

The total average weight of a loaded railcar in this scenario is 139.0 tons. The GTM of the railcars over the CP portion of the route is calculated as 16,129,807 ton-miles. At the CP fuel efficiency this requires 58,309 liters of diesel per day.

The GTM of the railcars over the KCS portion of the route is calculated as 7,013,967 ton-miles. At KCS fuel efficiency this requires 34,782 liters of diesel per day.

Diesel CO_{2e} emissions are calculated on a Well-To-Wheels (WTW) basis. A WTW basis accounts for the production, refining and consumption of a liquid fuel. WTW values for diesel are taken from "Well-to-wheel life cycle assessment of transportation fuels derived from different North American conventional crudes", Kumar et al, 2015. An average diesel emissions value is calculated as 96.88

gCO_{2e}/MJ. WTW values are generally presented on an energy content basis. The heating value of diesel is 38.6 MJ/L (this value can vary by a few percent), producing an emissions factor of 3,740 gCO_{2e}/L.

The model calculates emissions for the CP portion of the route at 218.1 tonnes CO_{2e}/day and for the KCS portion of the route at 130.1 tonnes CO_{2e}/day.

Empty rail car return is then calculated on the same GTM and diesel basis, using the empty weight of 85,000 pounds per rail car. Over the KCS portion of the return route the model calculates 2,144,095 GTM and over the CP portion of the route the model calculates 4,930,711 GTM. This becomes 39.8 tonnes CO_{2e}/day for the KCS portion of the return route and 66.7 tonnes CO_{2e}/day for the CP portion of the return route.

3.2.3 Southern Lights Diluent Return Pipeline

This component estimates the CO_{2e} emissions resulting from the transport of diluent from Mont Belvieu, Texas to Hardisty, Alberta, via the Explorer pipeline system from Mont Belvieu, Texas to Manhattan, Illinois, then from Manhattan to Hardisty, Alberta via the Southern Lights Pipeline.

The Explorer pipeline length was estimated to be 1,831 km using Google Maps. The total length of Southern Lights from Manhattan, Illinois to Edmonton, Alberta is 2,556 km, from Enbridge's Energy Infrastructure Assets publication. The Hardisty offtake is 175 km before Edmonton and the final distance from Manhattan to Hardisty is 2,381 km. The total pipeline distance is 4,212 km. Southern Lights is a 20 inch (0.508 m) diameter pipeline with a capacity of 180,000 bbl/d. The Explorer pipeline has varying diameters, the complete configuration is not published. Average diluent density from Crude Monitor in the last 12 months is 667 kg/m³ and viscosity is 0.34 cSt. Diluent shipping volume is stated as 14,114 bbl/d, based on HET diluent recovery from 50,000 bbl/d of Dilbit.

The University of Calgary's Energy Technology Assessment Research Group began work on a pipeline emissions model in 2018, called the Crude Oil Pipeline Transport Emissions Model (COPTeM). The COPTeM model has not yet been released, the team has indicated that it requires further development. Initial results and the model basis is described in "Supporting Information: COPTeM: A Model to Investigate the Factors Driving Crude Oil Pipeline Transportation Emissions", Levy, et al, 2018. The COPTeM model describes a metric for quantifying pipeline emissions performance based on electrical emissions intensity, measured in gCO_{2e}/(bbl-km). The reference also provides average grid emissions intensity factors for 62 major pipelines across North America.

The average grid emissions intensity for the Southern Lights pipeline route is stated as 0.721 tonnes CO_{2e}/MWh in the COPTeM reference. The Explorer pipeline is not described in the reference.

However, there are emissions available for other pipelines near the Explorer system and a length-based average was calculated to be 0.763 tonnes CO_{2e}/MWh for overall diluent recycle and applied to the Southern Lights pipeline.

The calculation component for the Southern Lights pipeline estimates the emissions factor to be 1.10 gCO_{2e}/(bbl-km). This emissions factor is also applied to the Explorer pipeline section length because no other information is available. The model calculates total emissions to be 65.2 tonnes CO_{2e}/day for 14,114 bbl/d of diluent.

3.2.4 Enbridge Mainline Pipeline

This component estimates the CO_{2e} emissions resulting from the transport of Dilbit from Hardisty, Alberta to the U.S. Gulf Coast through the Enbridge Mainline System. This system has five major segments with varying diameters, lengths and capacities, taken from Enbridge's Energy Infrastructure Assets publication:

- Canadian Mainline 67: 36 inch (0.914 m) diameter, 1790 km, 800,000 bbl/d.
- Canadian Mainline 61: 42 inch (1.067 m), 744 km, 996,000 bbl/d.
- Canadian Mainline 55: 22-24 inch (0.559 – 0.610 m), 938 km, 193,000 bbl/d.
- Seaway: 30 inch (0.762 m), 846 km, 350,000 bbl/d.
- ECHO: 30 inch (0.762 m), 161 km, 750,000 bbl/d.

Dilbit density is stated as 920 kg/m³ and viscosity is stated as 350 cSt, the limiting pipeline viscosity specification. Dilbit shipping volume is the same as the HET facility capacity of 50,000 bbl/d.

The University of Calgary's Energy Technology Assessment Research Group began work on a pipeline emissions model in 2018, called the Crude Oil Pipeline Transport Emissions Model (COPTeM). The COPTeM model has not yet been released, the team has indicated that it requires further development. Initial results and the model basis is described in "Supporting Information: COPTeM: A Model to Investigate the Factors Driving Crude Oil Pipeline Transportation Emissions", Levy, et al, 2018. The COPTeM model describes a metric for quantifying pipeline emissions performance based on electrical emissions intensity, measured in gCO_{2e}/(bbl-km). The reference also provides average grid emissions intensity factors for 62 major pipelines across North America.

The calculation component assumes that each segment of pipeline is carrying only Dilbit at the pipeline rated capacity, even though the segments are batched with varying types of crude with different densities and viscosities, all lower density and viscosity than Dilbit. This is appropriate because the purpose of the overall emissions model is to specifically compare Dilbit versus DRUbit™ transport and

not the average performance of the pipeline on an average mix. Dilbit requires more power to pump than lighter crudes; if an average, lighter mix is used, Dilbit-specific emissions would not be allocated correctly.

The average grid emissions intensities for each segment are taken from the COPTeM reference. The ECHO pipeline is not described in the COPTeM reference, however it is in the same geographical area as Seaway and the grid intensity is assumed to be the same.

- Canadian Mainline 67: 0.762 tonnes CO_{2e}/MWh.
- Canadian Mainline 61: 0.744 tonnes CO_{2e}/MWh.
- Canadian Mainline 55: 0.741 tonnes CO_{2e}/MWh.
- Seaway: 0.822 tonnes CO_{2e}/MWh.
- ECHO: 0.822 tonnes CO_{2e}/MWh.

The model calculates the following emissions factors for each segment:

- Canadian Mainline 67: 4.28 gCO_{2e}/(bbl-km).
- Canadian Mainline 61: 3.01 gCO_{2e}/(bbl-km).
- Canadian Mainline 55: 3.21 gCO_{2e}/(bbl-km).
- Seaway: 2.59 gCO_{2e}/(bbl-km).
- ECHO: 9.98 gCO_{2e}/(bbl-km).

The ECHO emissions factor is significantly higher than the other segments; this is because it has more than double the capacity of Seaway at the same diameter and requires almost four times more power to maintain the higher rates. This is feasible over a short distance.

Based on these emissions factors the model calculates total emissions to be 835 tonnes CO_{2e}/day for 50,000 bbl/d of Dilbit.

3.2.5 Keystone Pipeline

This component estimates the CO_{2e} emissions resulting from the transport of Dilbit from Hardisty, Alberta to the U.S. Gulf Coast through the Keystone Pipeline. This system has three major segments with varying diameters, lengths and capacities:

- Keystone Phase 1: 30 inch (0.762 m) diameter, 2761 km, 435,000 bbl/d.
- Keystone Phase 2: 36 inch (0.914 m), 480 km, 600,000 bbl/d.
- Cushing Marketlink: 36 inch (0.914 m), 784 km, 700,000 bbl/d.

Dilbit density is stated as 920 kg/m³ and viscosity is stated as 350 cSt, the limiting pipeline viscosity specification. Dilbit shipping volume is the same as the HET facility capacity of 50,000 bbl/d.

The University of Calgary's Energy Technology Assessment Research Group began work on a pipeline emissions model in 2018, called the Crude Oil Pipeline Transport Emissions Model (COPTeM). The COPTeM model has not yet been released, the team has indicated that it requires further development. Initial results and the model basis is described in "Supporting Information: COPTeM: A Model to Investigate the Factors Driving Crude Oil Pipeline Transportation Emissions", Levy, et al, 2018. The COPTeM model describes a metric for quantifying pipeline emissions performance based on electrical emissions intensity, measured in gCO_{2e}/(bbl-km). The reference also provides average grid emissions intensity factors for 62 major pipelines across North America.

The calculation component assumes that each segment of pipeline is carrying only Dilbit at the pipeline rated capacity, even though the segments are batched with varying types of crude with different densities and viscosities, all lower density and viscosity than Dilbit. This is appropriate because the purpose of the overall emissions model is to specifically compare Dilbit versus DRUbit™ transport and not the average performance of the pipeline on an average mix. Dilbit requires more power to pump than lighter crudes; if an average, lighter mix is used, Dilbit-specific emissions would not be allocated correctly.

The average grid emissions intensities for each segment are taken from the COPTeM reference. The Cushing Marketlink pipeline is not described in the COPTeM reference. The COPTeM reference does have the Seaway pipeline, which is in the same geographical area with a similar route and Seaway grid emissions are used.

- Keystone Phase 1: 0.756 tonnes CO_{2e}/MWh.
- Keystone Phase 2: 0.857 tonnes CO_{2e}/MWh.
- Cushing Marketlink: 0.822 tonnes CO_{2e}/MWh.

The model calculates the following emissions factors for each segment:

- Keystone Phase 1: 3.61 gCO_{2e}/(bbl-km).
- Keystone Phase 2: 2.92 gCO_{2e}/(bbl-km).
- Cushing Marketlink: 3.59 gCO_{2e}/(bbl-km).

Based on these emissions factors the model calculates total emissions to be 709 tonnes CO_{2e}/day for 50,000 bbl/d of Dilbit.

3.2.6 Hardisty Energy Terminal (HET)

This component estimates the CO_{2e} emissions resulting from recovering diluent from 50,000 bbl/d of Dilbit feed. The calculations are based on Gibson Energy's proprietary design for their Diluent Recovery facility and includes all heater and flare emissions and electrical loads. Refinery emissions for diluent recovery are assumed to be the same as calculated in this component.

This facility is located in Canada and emissions are based on Canadian calculation guidelines. Emissions are calculated based on a known natural gas composition and following the most recent guidelines published by Environment Canada in "TECHNICAL GUIDANCE ON REPORTING GREENHOUSE GAS EMISSIONS – 2019 DATA". This is the latest version of the publication. The calculated emissions include Global Warming Potential factors for NO_x combustion emissions as CO_{2e}, as well as base CO₂ combustion emissions.

The direct CO_{2e} combustion emissions are calculated to be 159.1 tonnes CO_{2e}/day. The electrical load emissions are calculated to be 21.8 tonnes CO_{2e}/day.

3.2.7 Port Arthur Terminal (PAT)

This component estimates the CO_{2e} emissions resulting from unloading railcars containing Dilbit and DRUbit™, and blending unloaded bitumen to refinery feed specifications. The calculations are based on USD Group's proprietary design for their unloading facility and includes all heater, vapor combustion, storage tank and emergency engine emissions and electrical loads.

This facility is located in the U.S. and emissions are based on U.S. calculation guidelines. Combustion emissions are calculated based on natural gas emissions factors and global warming potentials in the most recent Emissions Factors for Greenhouse Gas Inventories published by the US EPA. Electrical emissions are calculated based on current emissions factors in the EPA's Simplified Emissions Calculator spreadsheet.

The Dilbit unloading combustion emissions are calculated to be 30.7 tonnes CO_{2e}/day for 50,000 bbl/d. The DRUbit™ unloading combustion emissions are calculated to be 50.3 tonnes CO_{2e}/day for 35,386 bbl/d. DRUbit™ is heavier and more viscous than Dilbit and requires heating to a higher temperature to unload, which in turn requires more energy and emissions. Electrical load emissions are calculated to be 10.9 tonnes CO_{2e}/day for both scenarios.

3.3 Model Scenarios and Results

The model analyzes four scenarios:

- 1) Shipping diluted bitumen (Dilbit) from Hardisty, Alberta to the U.S. Gulf Coast market through the Enbridge Mainline pipeline and returning diluent through the Southern Lights pipeline from the Gulf Coast. This is a standard Dilbit shipping route for producers in Alberta. This scenario utilizes the Enbridge Mainline Pipeline component (3.2.4), the Southern Lights Diluent Return Pipeline component (3.2.3) and the Hardisty Energy Terminal component (3.2.6) to estimate diluent recovery emissions at the refinery.
- 2) Shipping Dilbit from Hardisty, Alberta to the U.S. Gulf Coast market through the Keystone pipeline and returning diluent through the Southern Lights pipeline from the Gulf Coast. This is a standard Dilbit shipping route for producers in Alberta. This scenario utilizes the Keystone Pipeline component (3.2.5), the Southern Lights Diluent Return Pipeline component (3.2.3) and the Hardisty Energy Terminal component (3.2.6) to estimate diluent recovery emissions at the refinery.
- 3) Shipping Dilbit from the Hardisty Rail Terminal (HRT) near Hardisty, Alberta to the Port Arthur Terminal (PAT) in the U.S. Gulf Coast market via rail, returning empty railcars, and returning diluent through the Southern Lights pipeline from the Gulf Coast. This is an alternative shipping route for producers in Alberta under pipeline capacity constraints. This scenario utilizes the Dilbit Transport by Rail component (3.2.1), the Southern Lights Diluent Return Pipeline component (3.2.3), the Port Arthur Terminal component (3.2.7) and the Hardisty Energy Terminal component (3.2.6) to estimate diluent recovery emissions at the refinery.
- 4) Shipping minimally-diluted bitumen (DRUbit™) from HRT to PAT via rail and returning empty railcars. Diluent is recovered at the diluent recovery unit at the Hardisty Energy Terminal (HET) in Alberta near Hardisty. This is a new transport route developed by Gibson/USD as an alternative to pipeline or rail transport of Dilbit. This scenario utilizes the DRUbit™ Transport by Rail component (3.2.2), the Southern Lights Diluent Return Pipeline component (3.2.3), the Hardisty Energy Terminal component (3.2.6) and the Port Arthur Terminal component (3.2.7).

The overall results are provided on the next page in Figure 3.

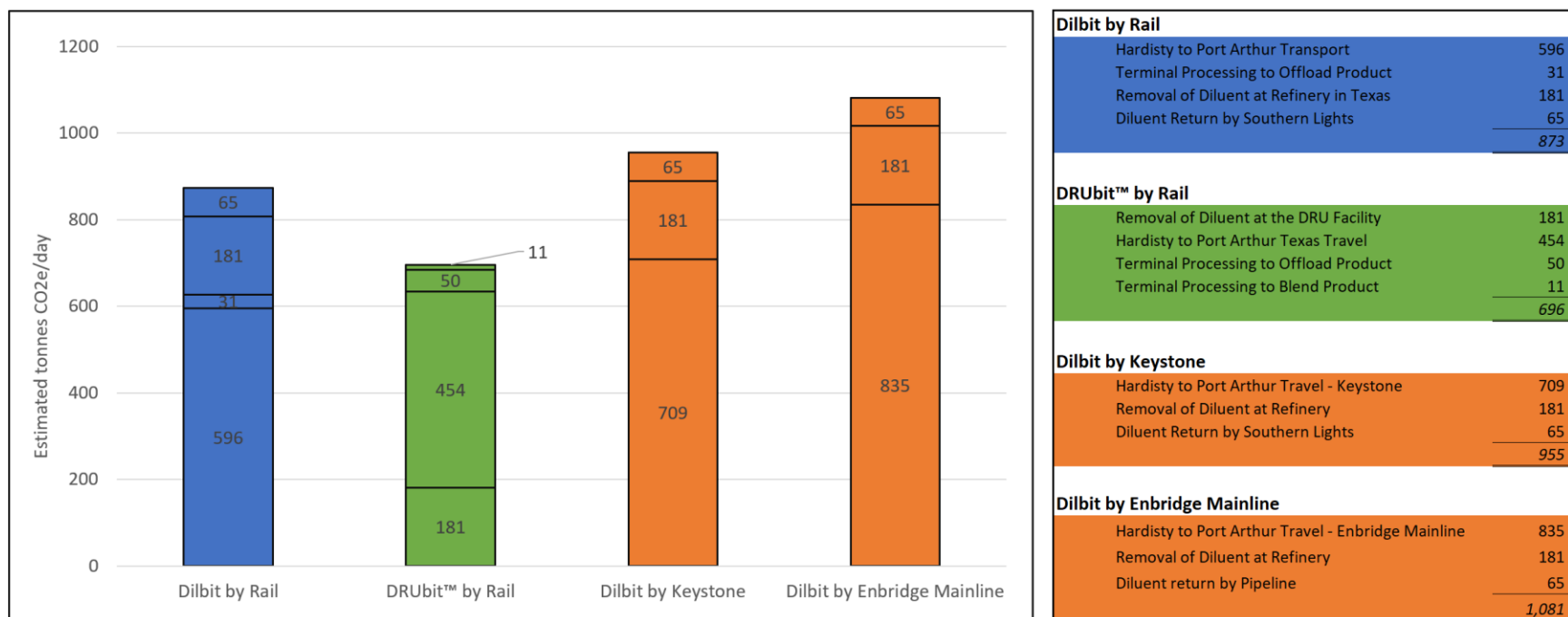


Figure 3

The model indicates that the DRUbit™ scenario above saves between 20% – 36% of operational CO₂e emissions compared to the Dilbit rail and pipeline scenarios. Against the Dilbit by rail scenario, the model predicts that the DRUbit™ scenario saves approximately 63,000 metric tonnes CO₂e/year (20%, 69,000 U.S. tons/year). Against the Keystone scenario, the model predicts that the DRUbit™ scenario saves approximately 92,000 metric tonnes CO₂e/year (27%, 101,000 U.S. tons/year). Against the Mainline scenario, the model predicts that the DRUbit™ scenario saves approximately 137,000 metric tonnes CO₂e/year (36%, 151,000 U.S. tons/year).

These savings are achieved by removing the diluent required to enable pipeline transport and replacing those pipeline transport emissions with rail transport emissions. Diluent is recovered at the upstream HET location instead of the downstream end-user refinery, removing the diluent transport loop and associated emissions.



4.0 Conclusions

Overall, the model is well-organized and comprehensive with appropriate assumptions and supporting data, providing a robust basis for the results. Specific and credible information in the model includes HET and PAT design information from Gibson and USD; rail route, locomotive, and rail car information from Canadian Pacific and publicly reported information by CP and KCS, the rail carriers for DRUbit™; pipeline information from Gibson and publicly reported information from the included pipelines; and information from publications by the University of Calgary's Energy Technology Assessment Research Group on their COPTeM pipeline emissions model.

The model is based on standard industry practice for operational emissions estimation. I conclude it generates appropriately accurate estimates of CO₂e emissions for the four scenarios discussed.

This report is based on the model version from August 17th 2021. Modifications to model assumptions and calculations, inputs or scenarios will change results.

5.0 References

CP Rail 2019 Annual Report

https://s21.q4cdn.com/736796105/files/doc_financials/Annual-Report/2019/CP_AnnualReport2019.pdf

KCS Rail 2019 Annual Report

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Enbridge Energy Infrastructure Assets

https://www.enbridge.com/~media/Enb/Documents/Factsheets/FS_EnergyInfrastructureAssets.pdf

TECHNICAL GUIDANCE ON REPORTING GREENHOUSE GAS EMISSIONS – 2019 DATA

https://publications.gc.ca/collections/collection_2020/eccc/En81-29-2019-eng.pdf

Emissions Factors for Greenhouse Gas Inventories

https://www.epa.gov/sites/default/files/2018-03/documents/emission-factors_mar_2018_0.pdf

EPA Simplified Emissions Calculator

https://www.epa.gov/sites/production/files/2015-08/sgec_tool_v3_2.xls

6.0 Appendix – GHG Emission Scopes

GHG emissions are classified into three scopes for analysis. Scopes are based on the boundaries shown in Figure 2 below, from the “Corporate Value Chain (Scope 3) Accounting and Reporting Standard” published by the World Business Council for Sustainable Development and World Resources Institute.

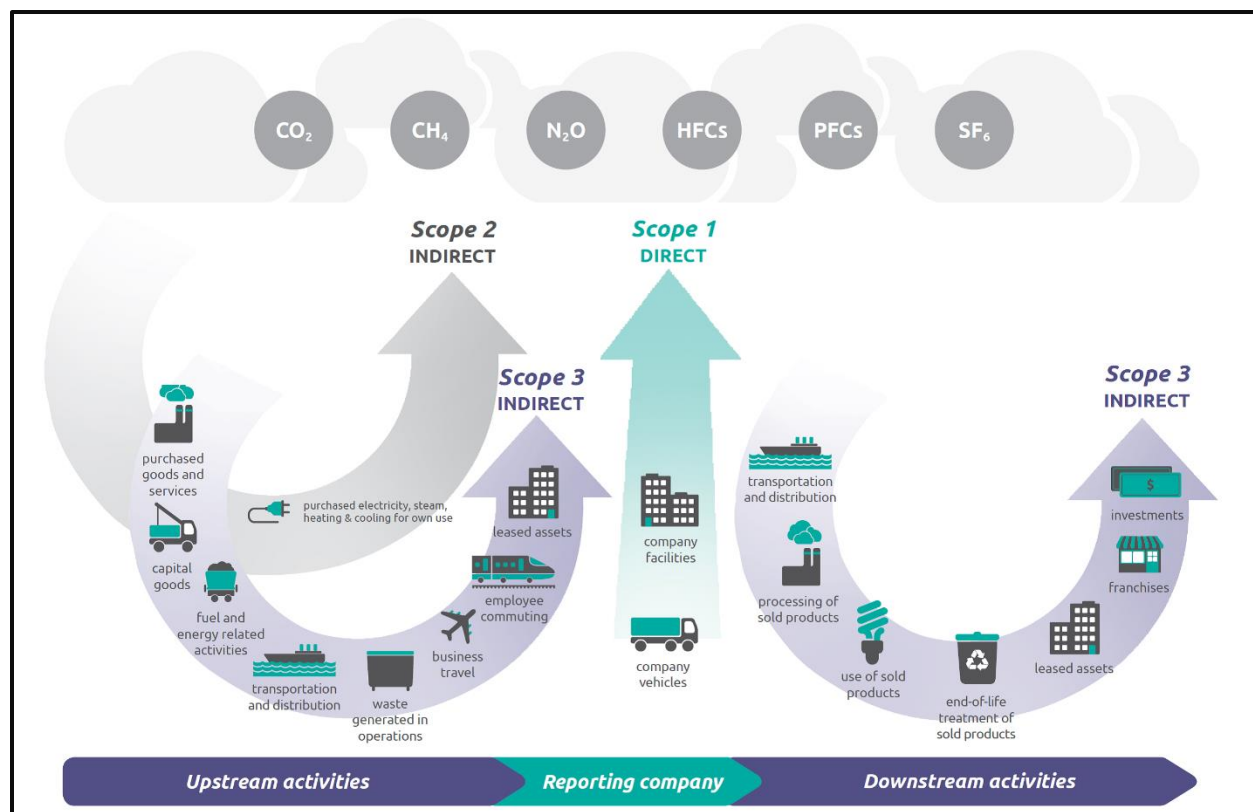


Figure 2

A definition of Scope 1, 2 and 3 emissions are provided by the U.S. EPA Center for Corporate Climate Leadership:

“Scope 1 emissions are direct greenhouse (GHG) emissions that occur from sources that are controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, vehicles). Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling. Although scope 2 emissions physically occur at the facility where they are generated, they are accounted for in an organization’s GHG inventory because they are a result of the organization’s energy use.”

“Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly impacts in its value chain. Scope 3 emissions include

all sources not within an organization's scope 1 and 2 boundary. The scope 3 emissions for one organization are the scope 1 and 2 emissions of another organization. Scope 3 emissions, also referred to as value chain emissions, often represent the majority of an organization's total GHG emissions."

Based on these definitions, the model includes scope 1, 2 and 3 emissions from the perspective of a business entity shipping Dilbit or DRUbit™ from Alberta to the U.S. market.

From the perspective of Gibson/USD as a combined business organization, the relevant operational emissions scopes are:

- The calculations for diluent recovery for the Hardisty Energy Terminal estimate scope 1 emissions for fuel combustion and scope 2 emissions for purchased power.
- The calculations for diluent recovery and/or unloading at the Port Arthur Terminal estimate scope 1 emissions for fuel combustion and scope 2 emissions for purchased power.
- The calculations for rail transport of DRUbit™, Dilbit and the return of empty railcars estimate scope 3 emissions from diesel combustion.
- The calculations for pipeline transport of Dilbit and recycle of diluent estimate scope 3 emissions from purchased power.

The model is specific to the Gibson/USD combined business, value chain and equipment and process configuration. The model does not attempt to estimate other indirect scope 1, 2 or 3 operational emissions, for example facility maintenance, electricity consumption to operate railway signals, fuel consumption for rail shunting operations or emissions associated with pipeline repairs and maintenance. The model assumes that the direct transport and processing emissions are the most significant contributing factors.