

The Case for Exporting Partially Upgraded Bitumen Offshore

By Jim Hutton MSc. P. Eng.

Introduction

The best way to sell our petroleum products to customers other than the United States is to build a pipeline to the Pacific coast through British Columbia. Pipelines are the safest, most economical and most efficient means of transporting petroleum products. Of all means of transport, pipelines have the least environmental impact. Access to Asian markets from the west coast for the export of Alberta's petroleum products is urgently needed as part of the continuing development of the oilsands industry. Shipping partially upgraded bitumen (PUB) rather than diluted bitumen has significant economic and environmental benefits and advantages for business and all Albertans.

There are certain criteria that should be met in the design and construction of any pipeline to the west coast. These are as follows:

- 1) The design should have the least environmental impact on land, air and water.
- 2) The design should minimize the risk of a spill over land and over water.
- 3) The design should have appropriate capital and operating costs so as to be attractive to producers and to purchasers of the product.
- 4) The construction of the pipeline should have the least impact on the environment.
- 5) The product should have minimal processing requirements for conversion into refined products. To be attractive, the product should be one that offers minimal financial risk to the purchasers.
- 6) The project should offer the maximum benefit to Canadians.
- 7) The pipeline design concept should be aligned with **responsible oilsands development** as articulated by the Province of Alberta.

What is partially upgraded bitumen (PUB)?

Bitumen is the raw hydrocarbon resource that is recovered from mined oilsands and insitu production. The raw bitumen contains certain unique physical properties, chemical properties and impurities that reduce the transportability and value. Some of these properties include;

1. Low density (6° to 8° API) requiring significant hydroprocessing to generate transport fuels.
2. High carbon content Conradson Carbon (CCR = 15 to 20% of unit weight) which represents the bottom fraction of the bitumen barrel that would turn to coke and limits the useable portion of the barrel that is converted to lighter, usable refined products such as gasoline and diesel fuel.
3. High viscosity (greater than 1,000,000 cST @ 15C). High viscosity means that bitumen cannot be pumped and will not flow under normal temperature conditions.

- Bitumen typically requires blending with 25 to 50 volume % of a lighter diluent to lower viscosity to less than 350 cST @15C for pipeline transport.
4. High content of heavy metals, such as nickel and vanadium, which causes a deterioration of catalyst used in refinery hydro-processing, and thereby restricting the amount of bitumen that can be processed.
 5. high naphthenic acid content (TAN > 3) –the high acidic bitumen crude causes extensive corrosion and fouling in the refinery equipment.

Partial Upgrading is a bitumen processing unit that has the minimum processing capabilities to upgrade the bitumen density from 8° API to 20° to 22° API and viscosity reduced to less than 300 cST @ 15°C to meet the minimum pipeline specifications without the addition of external diluent, commonly referred to as Partially Upgraded Bitumen (PUB). A 21° API crude will have a specific gravity of 0.93 or less than 1.0, allowing it to separate under normal environmental conditions and float on water. A further preferred desire for a PUB product is that the entire bitumen resource should be converted to high value synthetic hydrocarbon with minimal bottom fraction (CCR < 4wt%), significant heavy metals reduction (>70% reduction) and elimination of corrosion concerns. (TAN < 1.0).

The PUB product with the above properties would be considered as highly valued and environmentally safe crude product that would demand a price relatively comparable to WTI and a premium price to WCS crude on west coast tidewater.

What is involved in shipping partially upgraded bitumen to Asia?

A 36" diameter pipeline designed to ship 363 thousand barrels per day of partially upgraded bitumen from the Fort Saskatchewan area of Alberta to Kitimat would cost \$3.5 billion. The pipeline would require 15 – 5,750 HP pumps and draw 25.4 MW of electricity. The fully powered capacity of the pipeline would be 850,000 barrels per day. PUB has a viscosity of 300 cSt, which negates the need for a second pipeline to return diluent to Alberta. There are many other benefits that will be demonstrated later in this paper.

Exporting PUB requires a partial upgrader in Alberta likely situated in the Redwater, Bruderheim, Fort Saskatchewan area. The partial upgrading of 332,000 BPD of bitumen would produce 363,000 BPD of PUB assuming technologies are applied that fully convert all of the bitumen. Such technologies are well known and solve the problem with resid and coke disposition by converting all of the asphaltene components in the bitumen to marketable products.

The Kitimat terminal would require one berth and 7 – 426 thousand barrel storage tanks. A total of 112 ocean tanker trips would be required annually. The terminal at the receiving end in Asia needs one berth and a transporting pipeline to a refinery. A diluent recovery unit and a return diluent pipeline from the refinery to the receiving terminal are not needed.

The number of ocean tankers required would be 3 – VLCCs, 7 – Suezmax and 3 Aframax. Tanker carrying capacities are:

VLCC	2,000,000 bbls
Suezmax	1,000,000 bbls
Aframax	680,000 bbls

The estimated ocean tanker fuel consumption is 293 thousand tons per year.

What is involved in building a partial bitumen upgrader?

Preliminary estimates indicate that a partial upgrader with a feed capacity of 332,000 BPD of bitumen would have a capital cost of \$8 to \$9 billion subject to site selection. There are several partial upgrading technologies that could be used. All except one leave either a coke or heavy resid disposal problem for which there are few if any solutions. There is one technology that involves the integration of solvent deasphalting, gasification of asphaltenes and conversion of syngas using Fischer Tropsch technology that converts all asphaltenes to merchantable hydrocarbons. Using Fischer Tropsch technology results in a minimum net increase in the salable product of 31,000 BPD and provides an opportunity to make diesel fuel with a cetane rating greater than 50 and higher quality jet fuel. The partial upgrader in Alberta will reduce the sulphur content by at least 25% and will remove more than 75% of the heavy metals from the partially upgraded product. The result is that the cost of upgrading in Asia is reduced by greater than half and there is no requirement for the disposal of coke and heavy resid. See Appendix C for a block flow diagram.

What are the environmental benefits of exporting PUB?

The GHG emissions from the generation of electrical power for the pipeline would be less than 25% of the power generation emissions for a diluted bitumen pipeline. The reduction of emissions from ocean tankers would be 50% because the absence of diluent results in half the number of ocean tanker trips. The overall reduction in GHG emissions from upgrading operations in Alberta and refinery operations in Asia is approximately 50% or greater (depending on the specific upgrader comparison) if the Fischer Tropsch technology is applied for partial upgrading.

The reduction in risk from a pipeline rupture is 50%. The reduction in risk of a spill in the Douglas Channel is 50% because of the reduced number of ocean tanker trips. The consequences of a spill of partially upgraded bitumen are less severe because there are no components in PUB that have a greater specific gravity than that of seawater. This means that no bitumen components would sink to the bottom of the ocean.

Summary of the advantages of exporting PUB.

1. The risk of a pipeline leak overland is reduced by 50% because of the elimination of the condensate pipeline.

2. The risk of an incident in the Douglas channel is reduced by 50% because of the reduction in the number of shipments and the absence of any ocean tankers returning with diluent.
3. The consumption of electricity to power the PUB pipeline is less than a quarter of that needed to power a diluted bitumen pipeline. (Note 5 below).
4. The total fuel consumption by ocean tankers is almost half the fuel needed for shipping diluted bitumen.
5. Similarly Greenhouse gas (GHG) emissions from the ocean tankers are reduced by almost half of the emissions from shipping diluted bitumen.
6. GHG emissions from power generation would be reduced by 152,000 tons per year.
7. A single pipeline can be constructed with a narrower right of way reducing the construction environmental impact.
8. A single, PUB pipeline has much lower capital and operating costs than a dual diluted bitumen pipeline.
9. The need for purchasers to invest in fewer ocean tankers and less costly processing facilities at the receiving end, makes PUB a more attractive product.
10. PUB is also more attractive to purchasers because it is compatible with conventional refinery operations and requires less additional refining capacity to produce high value transportation fuels such as gasoline, diesel and jet fuel. Other properties such as low heavy metal content and low CCR increase the potential value of PUB. Sulphur compounds are reduced by 25%. PUB is compatible and stable with all crude streams as it is bottomless and can be blended at any volume ratio with any other crude feed.
11. Locating a partial bitumen upgrader in Alberta will create thousands of person years of construction employment and at least 2000 permanent high paying jobs. Secondary employment will add another 2000 permanent jobs and very possibly more.

Appendix A provides data for comparison of diluted bitumen and partially upgraded bitumen shipping to Asia.

What are the economics for both concepts?

The cost to ship a barrel of bitumen from Alberta to Asia is calculated at \$11.07. Included in this cost is a rate of return to the pipeline owner of 12% on \$6 billion. Also included are the pipeline operating costs, the charter costs for ocean transportation, the operating costs and return on capital for the terminal and pipelines in Asia and the operating cost and return on capital of diluent recovery facilities in Asia. If one assumes that the price for a barrel of bitumen is \$65, the netback to the producer is \$30.64 after royalties, transportation and blending and operating costs for producer operated facilities. The total capital cost for the diluted bitumen transportation system is \$8.7 billion. Refer to Case 1 in Appendix B.

If the partial upgrader is considered on a guaranteed cost of service similar to the pipeline and receives a rate of return of 12%, then the cost to deliver a barrel of bitumen in the pipelines and for ocean transportation is \$5.99/bbl of bitumen. The partial upgrading cost

including the rate of return for a barrel of bitumen is \$15.84/bbl of bitumen for a total cost of \$21.83/bbl of bitumen. However, when one considers the additional revenue from the increase in value of PUB to \$75/bbl (compared to \$65/bbl of bitumen) and the additional revenue from the swell volume increase of 31,000 bbls/day as additional revenue to the producer, the netback to the producer is \$36.88/bbl of bitumen feed to the partial upgrader. By comparison, producer netbacks today, vary from \$30 to \$40/bbl of bitumen with much lower transportation and blending costs than those needed to ship a barrel of bitumen to Asia. The total capital cost for the transportation system and the Partial Upgrader is \$13.906 billion. Refer to Case 2 in Appendix B.

The economics can be looked upon in several ways but if the Partial Upgrader purchases the bitumen and pays the producer an amount such that the netback to the producer is the same as Case 1 for diluted bitumen, then the annual netback to the Partial Upgrader is \$1.836 billion and the return on investment is 20.4%. Refer to Case 2A in Appendix B.

Conclusion

The partial upgrading of bitumen is the most economical and environmentally acceptable approach to exporting petroleum products to Asian markets. The producers of bitumen will receive a better price for their product and governments will receive increased revenue from the resource. Very good high paying jobs will remain in Alberta and across Canada. Emissions will be reduced and the project risks to the environment would be substantially reduced. Partial upgrading of bitumen makes better use of the existing pipeline capacity to export petroleum from Alberta to PAD II and to Vancouver and the Northwestern U.S. Costs to ship to eastern Canada under the TransCanada proposal would be reduced and the capacity to move product through the Line 9 Reversal would be increased.

Appendix A

Comparison of PUB Pipeline with Diluted Bitumen Pipeline to Kitimat

	Diluted Bitumen	Condensate	Total Dil Bit and Cond.	PUB (36")	Difference
Pipeline Sizes	36"	20"		36"	
Pipeline Length Km	1,177	1,177	1177	1177	
Design Capacities Bbls/d	525,000	193,000	718,000	363,000	355,000
Pipeline Stl 1000s of Tons	495	112	607	495	112
Pump Stations (Note 1)	7	9	9	6	3
5,750 HP Pumps	28	18	46	15	31
Pipeline Power draw MW	77	25	102	25.4	76.6
426,000 Bbl Storage Tanks	11	3	14	7	7
Storage Tk Steel 1000s Tons			17.2	8.6	8.6
No. of Trips per year	137	87	224	112	112
No. of Aframax Tankers			6	3	3
No of Suemax Tankers			14	7	7
No of VLCCs			6	3	3
No of Berths at Kitimat	1	1	2	1	1
Tanker Fuel Consumption T/Yr.			577,000	293,000	284,000
GHG P/L Tons/Yr. (Note 2)	462,000	150,000	612,000	153,000	459,000
GHG Tnkr Tons/Yr. (Note 3)			2,116,000	1,066,340	1,049,660
P/L Capital Cost \$Billions			6	3.5	2.5
Risk of a pipeline spill (Note 4)			1	<0.5	>0.5
Risk of an ocean tanker spill (Note 4)			1	0.5	0.5

Note 1. There are 7 pump stations that pump both diluted bitumen and condensate. There are 2 pump stations at the Kitimat end of the line for condensate only.

Note 2. There will likely be an unknown amount of electrical power provided by hydro. The number provided for GHG emissions assumed that all electrical power would be provided from coal fired boilers.

Note 3. GHG emissions for tankers are based on the fuel consumption estimates.

Note 4. If the risk for the diluted bitumen case is arbitrarily set at a dimensionless value of 1, the risk for the PUB case is a fraction of the diluted bitumen Case.

Note 5. The power consumption figures are calculated from a mathematical model created by the author for comparison purposes. The model is based on the information provided in the

Northern Gateway Pipeline application and has been subsequently confirmed with information provided by Enbridge. Pump head curves were not found in the NEB application.

The pipeline pump efficiency will vary with the speed of the pump and where it is operating on the head curve. An average efficiency of 70% seems to fit the available data best and as such was used in the calculations.

The maximum viscosity of 350 cSt at 15 deg. C for diluted bitumen was used for the calculations.

A maximum viscosity of 302 cSt for PUB was used in the calculations.

Appendix B

COST COMPARISON FOR EXPORTING DILUTED BITUMEN v. PARTIALLY UPGRADED BITUMEN THROUGH BRITISH COLUMBIA FOR EXPORT TO ASIA

Case 1 - Diluted Bitumen

Transportation System Capital Costs for 525,000 bpd of Diluted Bitumen (332,000 bpd Bitumen)

System Description

Diluted bitumen (21 deg. API gravity) containing 37% diluent is received at Ft. Saskatchewan and transferred to a 36" pipeline for transport to Kitimat B.C. The diluted bitumen is loaded onto ships and transported to an offloading terminal in Asia. From the receiving terminal, the diluted bitumen is transferred by pipeline to an upgrader where 192,000 bpd of diluent is separated and returned to the receiving terminal. From the receiving terminal the diluent is shipped back to Kitimat using dedicated ocean tankers. At Kitimat the diluent is offloaded and transferred back to Ft. Saskatchewan and subsequently back to the producer.

Pipeline costs from Fort Saskatchewan to Kitimat including diluted bitumen loading and condensate off loading facilities	\$6,000,000,000
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Ocean Tankers

6 - VLCCs @ \$120,000,000 ea.	\$720,000,000
14 - Suezmax @ \$66,000,000 ea.	\$924,000,000
6 - Aframax @ \$52,000,000 ea.	\$312,000,000
Capital Cost for Ocean Tankers Sub Total	\$1,956,000,000

Offloading and Pipeline Facilities in Asia (Note 2)	\$500,000,000
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Diluent Return Pipeline and Loading Facilities in Asia (Note 2)	\$50,000,000
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Cost of Diluent Recovery Facilities in Asia	\$200,000,000
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Total Capital Cost for Transportation System	\$8,706,000,000
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Annual Operating Costs for Transferring 332,000 bpd of Bitumen

Pipeline shipper expected rate of return	12%
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Return cost	\$720,000,000
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Pipeline electrical power cost 102MW @ \$100/MW hr	\$89,352,000
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Maintenance, Management and Operating Costs	\$45,000,000
Pipeline Operating Costs Sub Total	\$854,352,000
Ocean Tankers	
6 VLCCs Charter Cost @ \$50,000/day	\$109,500,000
14 Suezmax Charter Cost @ \$35,000/day	\$178,850,000
6 Aframax Charter Cost @ \$27,000/day	\$59,130,000
Ocean Tanker Charter Cost Sub Total	\$347,480,000
Asian Pipeline and Diluent Return Facilities Operating Costs	\$100,000,000
Transportation System Operating Costs	\$1,301,832,000

Calculation of Transportation and DRU operating costs per barrel of bitumen shipped

Bitumen Shipped in bbls/year	121,180,000
Total Transportation Cost to Asia per bbl	\$10.74
Operating Cost for Diluent Recovery Unit in Asia	\$40,000,000
DRU operating cost per bbl bitumen	\$0.33
Net Cost to Deliver a barrel of bitumen to Asia	\$11.07

Calculation of Netback to the Producer

Average price per bbl	\$65.00
Royalties	\$11.79
Transportation and blending	\$11.07
Operating costs	\$11.50
Netback to the producer per barrel of bitumen	\$30.64

Case 2 - Partially Upgraded Bitumen

System Description

525,000 bpd of diluted bitumen is received at the partial upgrader in the Ft. Saskatchewan area. The diluent is separated and returned to the producer and 332,000 bpd of bitumen is partially upgraded to 363,000 bpd of PUB. The PUB is shipped by through a 36" pipeline to a receiving terminal in Kitimat where it is loaded onto ocean tankers and delivered to a receiving terminal in Asia. From the receiving terminal the PUB is transferred by pipeline to a refinery for medium conversion refining.

Transportation System Capital Costs for 332,000 bpd of Diluted Bitumen

to the Partial Upgrader

Bitumen feed to the Partial Upgrader in bpd	332,000
Production of Partially Upgraded Bitumen in bpd	363,000
36" Pipeline from Ft. Saskatchewan to Kitimat	\$3,500,000,000

Ocean Tankers

3 VLCCs @ \$120,000,000 ea.	\$360,000,000
7 Suezmax @ \$80,000,000 ea.	\$560,000,000
3 Aframax @ \$62,000,000 ea.	\$186,000,000
Ocean Tankers Capital Cost Sub Total	<u>\$1,106,000,000</u>
Offloading and Pipeline Facilities in Asia (Note 2)	\$300,000,000
Diluent Recovery Facilities in Asia (not required)	\$0
Total Capital Cost for Transportation System	<u>\$4,906,000,000</u>
Capital Cost for the Partial Upgrader	\$9,000,000,000
Total Capital Cost for the Upgrader and Transportation System	<u>\$13,906,000,000</u>
Operating Costs for the Transportation System	
Pipeline shipper expected rate of return	12%
Return cost	\$420,000,000
Pipeline electrical power cost 25.4MW @ \$100/MW hr	\$22,250,400
Maintenance, Management and Operating Costs	\$35,000,000
Pipeline Operating Costs Sub Total	<u>\$477,250,400</u>
Ocean Tankers	
3 VLCCs Charter Cost @ \$50,000/day	\$54,750,000
7 Suezmax Charter Cost @ \$35,000/day	\$89,425,000
3 Aframax Charter Cost @ \$27,000/day	\$29,565,000
Ocean Tanker Charter Cost Sub Total	<u>\$173,740,000</u>
Asian Pipeline Operating Costs including 12% rate of return	\$75,000,000
Total Transportation System Operating Costs	\$725,990,400
Total Transportation Costs/bbl of feed bitumen to the Partial U/G	\$5.99
Operating Costs for the Partial Upgrader (Cost of Service)	
Return for the Partial Upgrader @ 12%	\$1,080,000,000
Oxygen tons/day @ \$50/ton	7516 \$137,167,000
Natural Gas MMSCFD @\$4,000/MMSCF	399 \$582,540,000
Electricity (Generated in the reformer from waste heat)	\$0
Management, Maintenance, Mat'l's and Labour	\$120,000,000
Total Partial Upgrader Operating Costs	<u>\$1,919,707,000</u>
Total Partial Upgrader Operating Costs/bbl of Bitumen Feed	\$15.84
Transportation + Partial Upgrading Operating Cost/bbl feed bit'n	\$21.83
Total Transportation System and Partial Upgrader Operating Costs	<u>\$2,645,697,400</u>
Volume swell in bbls/day	31,000
Total annual Revenue from volume swell	\$848,625,000.00
Revenue per barrel of bitumen feed to the Partial Upgrader	\$7.00
Calculation of Netback to the Producer	
Average price per bbl Incl added value of \$10/bbl	\$75.00

Royalties	\$11.79
Transportation and blending	\$21.83
Operating costs	\$11.50
Revenue per barrel of bitumen from volume swell	\$7.00
Netback to the producer per barrel of bitumen	\$36.88

The basis for this analysis is that all revenue from partial upgrading accrues to the producer and the partial upgrader is contracted on a take or pay basis with a guaranteed rate of return of 12%.

Case 2A Partially Upgraded Bitumen

If the business arrangement is that the partial upgrader purchases bitumen feed and pays \$65/bbl less the diluted bitumen transportation cost of \$11.07/bbl and the Partial upgrader exports the PUB, the partial upgrader economics are as follows:

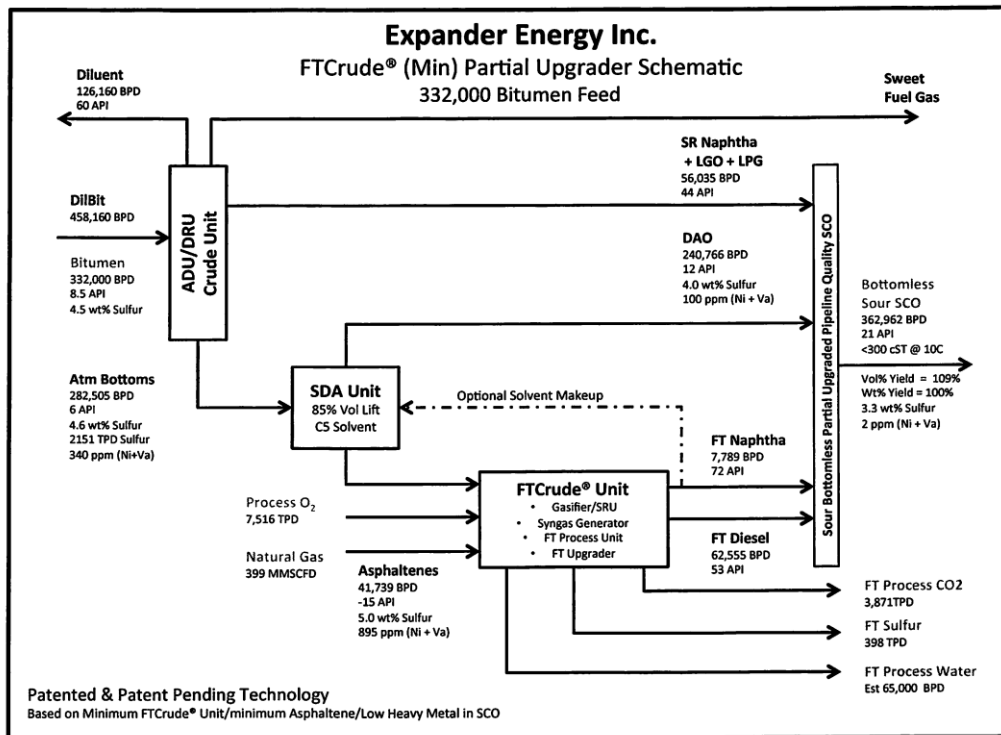
Bitumen feed rate bbls per day		332,000
Bitumen feed price \$65 less \$11.07 transportation cost		\$53.93
Annual bitumen feed cost to the partial upgrader		\$6,535,237,400
Oxygen tons/day @		
\$50/ton	7516	\$138,079,500
Natural Gas MMSCFD @\$4,000/MMSCF	399	\$582,540,000
Electricity (generated in the reformer from waste heat)		\$0
Management, Maintenance, Mat'l's and Labour		\$120,000,000
	Total Partial Upgrader Operating Costs	\$7,375,856,900
	Transportation system operating costs	\$725,990,400
	Total annual Partial Upgrader Costs	\$8,101,847,300
Revenue for the Partial Upgrader		
Avg price per bbl PUB Incl added value of \$10/bbl		\$75.00
PUB product rate		363,000
PUB		
revenue		\$9,937,125,000
Netback to the Partial Upgrader		\$1,835,277,700
Rate of Return to the Partial upgrader		20.4%

NOTES

1. Ocean Tanker Costs Source is the Yale School of Business <http://qn.som.yale.edu/content/what-keeps-the-worlds-ships-going>
2. Since we do not know the delivery location in Asia, the cost of P/L facilities in Asia is only the author's speculation.
3. The partial upgrader capital cost is estimated at \$8 billion - \$24,000 per barrel day of bitumen feed, for a central Alberta or Edmonton area location subject to specific

- site or unusual infrastructure requirements. A capital cost of \$9 billion - \$27,000 per barrel day is used in the economic analysis to provide contingency.
4. An argument could be made that the Partial Upgrader in Alberta, substantially reduces the cost of the Upgrader in Asia. This analysis does not recognize any reduction in the cost of the Asian upgrader other than a \$200M cost of the Asian DRU.
 5. If the Fischer Tropsch process were used, the lift in product value is attributable to the asphaltene being converted to paraffinic products from which very high quality diesel and jet fuels can be made. Further the PUB is bottomless, not requiring any disposition of coke or heavy resid. The \$10/bbl of bitumen lift in value used in the economic analysis is likely low.
 6. All partial upgrading processes will result in some degree of product swell. The Fischer Tropsch process maximizes swell because all of the asphaltene is converted to product. The estimate of swell volume and revenue is considered to be very conservative.
 7. The source of product prices and producer costs is "Quarterly Financials" in "Oilsands Review" April 2013 issue.
 8. The source of capital costs is Expander Energy.

Appendix C



About the author

Jim Hutton is a professional engineer registered in Alberta and has 40 years experience in the design and construction of facilities for the petroleum industry.

After retirement from Colt Engineering he accepted a position as an adjunct professor of chemical engineering at the University of Alberta where he taught process design and project development for six years.

Among the projects related to the pipeline industry, he was a process design engineer on the Trans Mountain Oil Pipeline LPG Terminal in Burnaby BC.

He was the design engineer responsible for the hydraulic design and pumping facilities for the Norman Wells pipeline in the early 80s. He was the design engineer and project engineer for the La Cory diluted bitumen storage and pumping facility for the Cold Lake Pipeline. He was responsible for the conceptual process design of gas processing and compression facilities for the Mackenzie Valley pipeline the late 90s. He was the engineering manager and general manger of CoSyn Technology, an engineering organization dedicated to Syncrude in a strategic alliance.