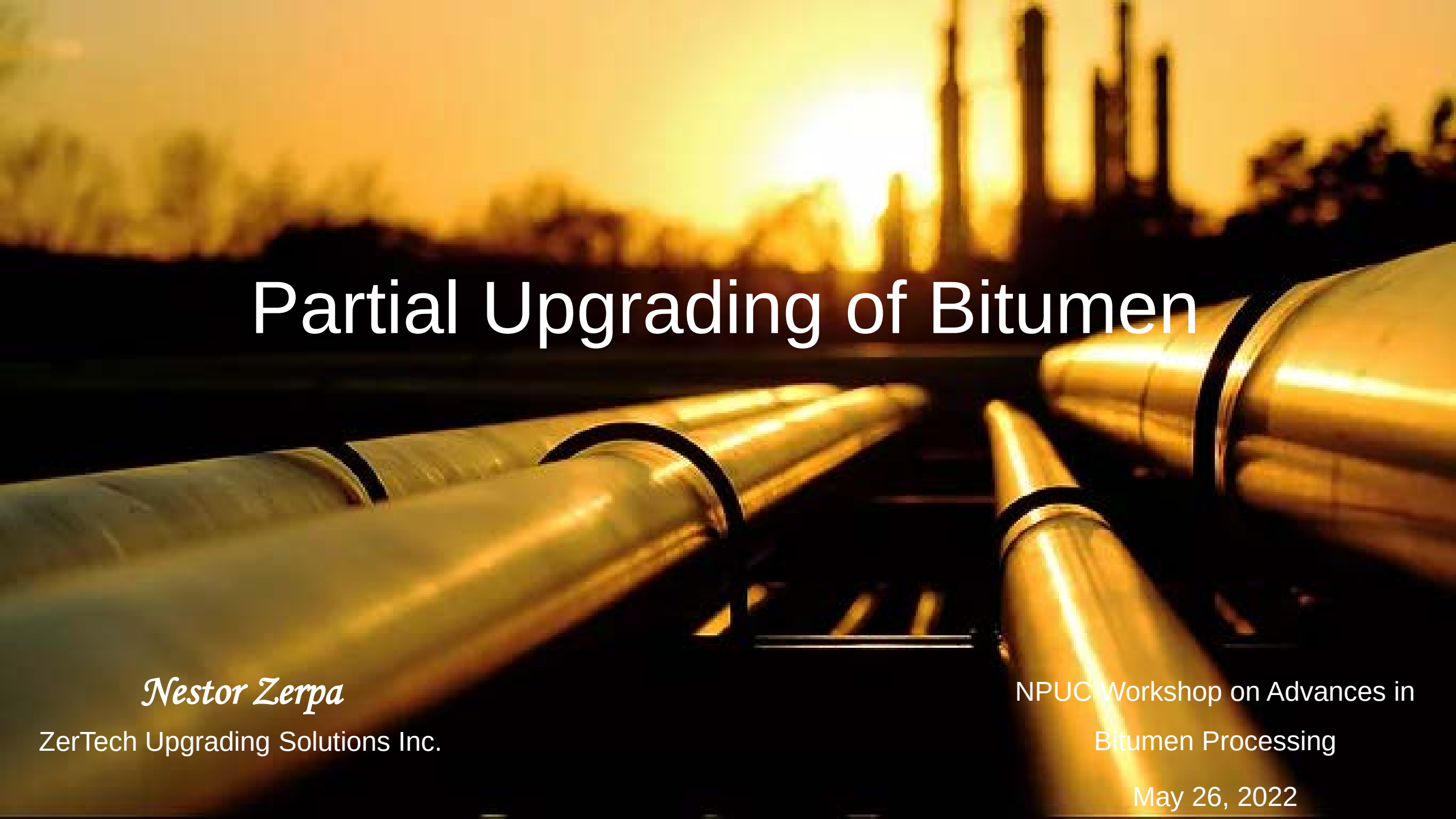

Partial Upgrading of Bitumen

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NPUC Workshop on Advances in Bitumen Processing

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Agenda

Transporting Bitumen – Technical and economic challenges of getting Bitumen to market

- Bitumen produced from oil sands is too heavy and viscous to flow through pipelines

	Pipeline Spec.	Bitumen
Density, Kg/m^3 @ 15°C	940 max.	> 1,000
µ, cSt @ 20°C	350 max.*	> 100,000
µ, cSt @ 7.5°C	350 max.*	> 1,000,000

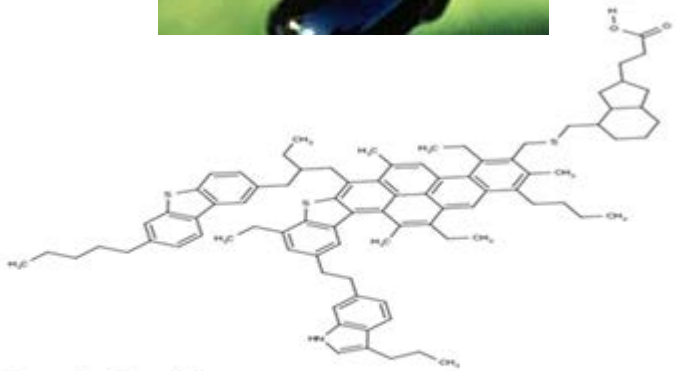
* Pipeline reference temperature (Summer 20°C / Winter 7.5°C)

Why is bitumen so viscous ?

Why is bitumen so viscous ? ... Asphaltenes

- Asphaltenes are a family of extremely heavy hydrocarbon components present in large quantities in bitumen;
- Asphaltenes are responsible for raising the viscosity of bitumen. The high energy and water requirement to produce a barrel of bitumen is a direct consequence of the high viscosity of the asphaltenes;
- Asphaltenes are responsible for **doubling** the amount of diluent needed to produce DilBit;
- Asphaltenes are also responsible for a large percentage of the “bad actors” or contaminants contained in bitumen (80%w of the metals, 60%w of the coke precursors, and 30% of the heteroatoms – sulphur, nitrogen and oxygen), making bitumen very challenging to process into clean and valuable products.

	Bitumen	DAO	Asphaltenes	
API	8.30	12.92	-14.56	
C5-Insol., %w	16.82	0.00	100.00	
C7-Insol., %w	10.54	0.00	68.17	
%w/%v	-	83.2/85.9	16.8/14.1	
µ, cSt @ 20°C	416,000	6,200	solid	
µ, cSt @100°C	190	31	solid	
µ, cSt @200°C	8	3	10x10^7	
H, %w	10.30	10.79	7.89	
S, %w	4.80	4.25	7.52	*
N, %w	0.46	0.29	1.31	*
O, %w	0.74	0.41	2.39	*
Ni+V, ppmw	337	71	1,650	*
CCR, %w	14.59	7.08	51.72	*
∑Bad Actors*, %w	20.62	12.04	63.09	



Example of Asphaltenes
Molecular Weight = 1,303
Molecular Formula = C88H103NO2S3
Elemental Composition, %w =
C 81.12; H 7.97; N 1.07; O 2.46; S 7.38
H:C = 1.17

Transporting Bitumen - Options

- DilBit - Diluent addition
- Rail
- Partial Upgrading
- Conventional Upgrading

DilBit to USGC by Pipeline			
	Price	1 BBL bitumen	Revenue
	$US/BBL	Volume ratios	$US/BBL bitumen
DilBit - Hardisty	56.22	x 1.44 (21 API)	80.96
Diluent - Edmonton	79.02	x 0.44 (diluent)	-34.77
Transportation	Pipeline Tariffs		
Edmonton to Site	2.17	x 0.44 (diluent)	-0.96
Site to Hardisty	1.61	x 1.44 (21 API)	-2.32
Hardisty to USGC	7.92	x 1.44 (21 API)	-11.40
Gross Margin			31.51

- Diluent is added at a ratio of 0.44 BBL to 1 BBL of bitumen to improve density and viscosity;
- Diluent transportation alone accounts for > 10 $US/BBL bitumen in operating costs;
- Diluent price is high, often at a premium to WTI. Refiners however, have very little use for Diluent. Thus, sales of DilBit are discounted relative to WCS;
- Diluent - DilBit price relationship is connected to Light-Heavy (WTI-WCS) differentials. Swings in the differential make for unreliable profitability of oil sands bitumen extraction.

Basis: WTI 80 $US, WCS 61.73 $US

Bitumen to USGC by Rail			
	Price	1 BBL bitumen	Revenue
	$US/BBL	Volume ratios	$US/BBL bitumen
Bitumen - Hardisty	49.10	x 1.10 (12 API)	54.01
Diluent - Edmonton	79.02	x 0.10 (diluent)	-7.90
Transportation	Pipeline/Rail Tariffs		
Edmonton to Site	2.17 (ppl)	x 0.10 (diluent)	-0.22
Site to USGC	18.00 (rail)	x 1.10 (12 API)	-19.80
Gross Margin			26.09
Δ Margin vs. DilBit			**-5.42**

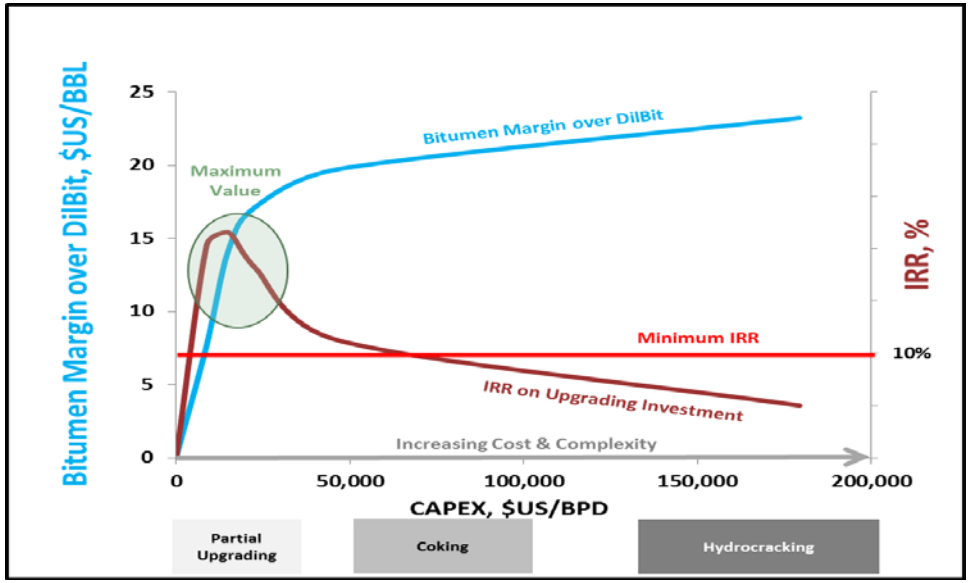
PUB to USGC by Pipeline			
	Price	1 BBL bitumen	Revenue
	$US/BBL	Volume ratios	$US/BBL bitumen
PUB – Hardisty	68.37	x 0.89 (21 API)	60.85
Diluent – Edmonton	79.02	x 0.02 (diluent)	-1.58
Transportation	Pipeline Tariffs		
Edmonton to Site	2.17	x 0.02 (diluent)	-0.04
Site to Hardisty	1.61	x 0.89 (21 API)	-1.43
Hardisty to USGC	7.92	x 0.89 (21 API)	-7.05
Δ OPEX vs. DilBit			-4.72
Gross Margin			46.03
Δ Margin vs. DilBit			**+14.52**

SCO to USGC by Pipeline			
	Price	1 BBL bitumen	Revenue
	$US/BBL	Volume ratios	$US/BBL bitumen
SCO - Hardisty	81.33	x 0.82 (32 API)	66.69
Diluent - Edmonton	79.02	x 0.00 (diluent)	-0.00
Transportation	Pipeline Tariffs		
Edmonton to Site	2.17	x 0.00 (diluent)	-0.00
Site to Hardisty	1.61	x 0.82 (32 API)	-1.32
Hardisty to USGC	7.92	x 0.82 (32 API)	-6.49
Δ OPEX vs. DilBit			-6.36
Gross Margin			52.52
Δ Margin vs. DilBit			**+21.01**

Margin economics is missing the effect of incremental CAPEX to complete the Value picture!

Transporting Bitumen – the case for Partial Upgrading

- Bitumen margin increases through upgrading. However, the rate of bitumen margin growth is not linear. At first, a high margin growth region is at play, driven by both diluent removal and improved oil properties. This region ends once diluent removal reaches 100%. From this point forward, margin growth slows to a very modest rate, driven solely by the incremental improvement in oil properties as upgrading continues;
- Capital cost of building in Alberta is 1.7 - 2 times vs. USGC. As complexity of upgrading increases, capital cost increase outpaces improvement rate in bitumen margin, making Conventional Upgrading uneconomic;
- A low complexity and thus low-cost Partial Upgrader, that targets making a pipelineable product as represented by those within the high margin growth region, has a chance to create value!

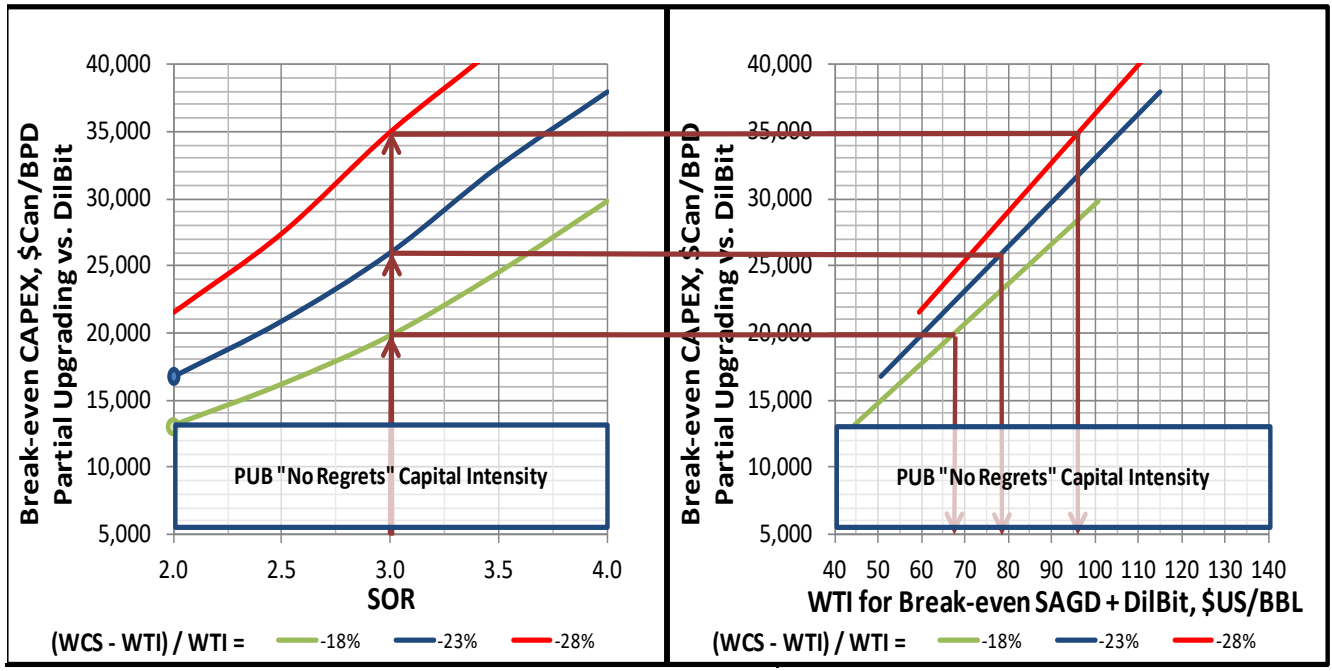


Economics are highly dependent on capital intensity!

Partial Upgrading

- **By partial upgrading what we mean is that the upgrading of bitumen is limited to only achieve a pipeline transportable oil with significant reduction of diluent use**. By doing so we limit our capital expenditures and by reducing or eliminating diluent use, we substantially reduce our operating costs. Furthermore, the quality of the oil is improved and thus a higher bitumen netback vs. DilBit production is realized.
- Capital cost for break-even economics vs. DilBit:
  - < 17,000 $Can/BPD bitumen
  - & preferably
  - < 13,000 $Can/BPD bitumen
- Technologies:

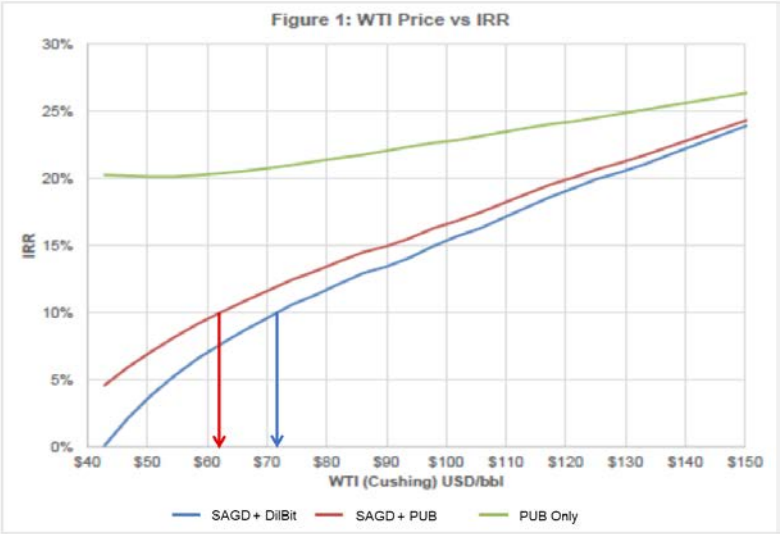
	Conversion	Capital Intensity
Visbreaking + Hydrotreating	X	✓
Delayed Coking + Hydrotreating	✓	X
Fluid Coking + Hydrotreating	✓	X
Fixed Bed Hydrocracking	✓	X
Ebbulated Bed Hydrocracking	✓	X
Slurry Bed Hydrocracking	✓	X
Gasification + Fischer-Tropsch + Hydrocracking	✓	X
Solvent De-asphalting + Visbreaking + Olefins Treating integrated to SAGD CPF/Mine PFT	✓	✓

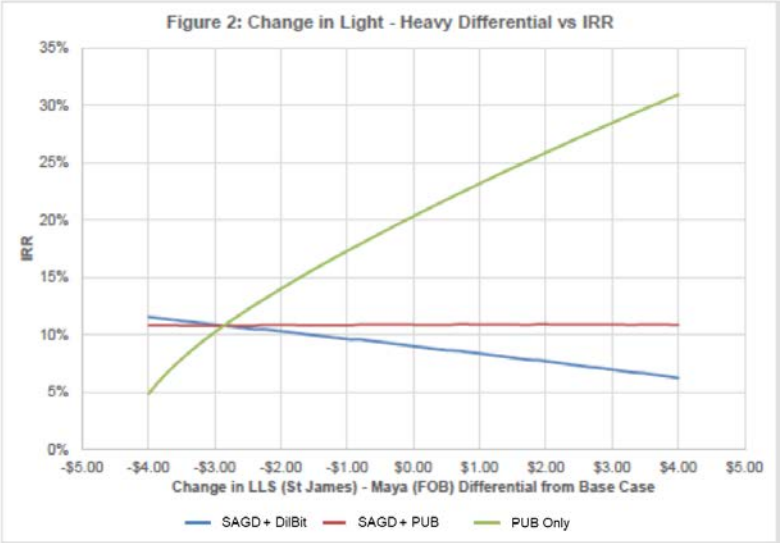


Critical in achieving profitability: a) low complexity & integration with SAGD CPF or Mine PFT; b) more cost effective ways to treat for olefins/fouling vis a vis hydrotreating; and c) suppress asphaltenes/coke formation/deposition when cracking

Value Proposition for Partial Upgrading

- ✓ Eliminates the need for diluent
- ✓ Partially upgraded product (PUB) priced at a premium of 7 to 12 $US/BBL to DilBit
- ✓ Enhances bitumen netbacks + 10 to 18 $US/BBL over DilBit
- ✓ The addition of partial upgrading to a SAGD project removes all the sensitivity of the combined project to heavy/light spreads
- ✓ Improves economics of a conventional SAGD project, lowering the breakeven price and makes a marginal SAGD project economic, enhancing project robustness
- ✓ Lifecycle GHG emissions per barrel of bitumen ~ 6 to 7% lower vs. DilBit
- ✓ Economically viable if capital cost < 17,000 $Can/BPD bitumen & preferably < 13,000 $Can/BPD bitumen





There is economic value in partial upgrading!