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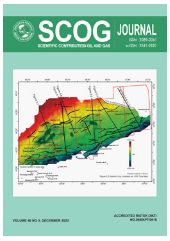

Downstreaming Buton Asphalt Into Heavy Oil Production: A Techno-Economic Analysis Approach

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ABSTRACT - Oil production from the extraction of Buton Asphalt (Asbuton) becomes for oil production is an attractive subject in bitumen to study considering that the use of exploration. Currently, Asbuton usage is currently still relatively limited for asphalt needs with absorption of to meeting only 0.9% of national asphalt needs, of course this is a contradiction considering Asbuton demand. This restriction is significant given the considerable deposits reach, totaling 667 million tons. Another factor is additionally the high price of crude oil encouraging the use of has stimulated interest in bitumen as an alternative to crude oil, especially, specifically in the context of heavy crude oil. The bitumen reserves contained in Asbuton are capable of meeting oil refinery needs of 50,000 BOPD or the equivalent of 4.3% of domestic refinery capacity requirements for a substantial period of 20 years. There are two options for bitumen equivalent to 50,000 BOPD. Therefore, this study aimed to enhance understanding of the potential contribution of Asbuton to future crude oil production the 2 production options from Asbuton, namely all production comes from included full-scale open pit mining or as well as a combination of production from open pit mining (40%) and in situ extraction (60%). The Techno-economic analysis was prepared with the assumption that the Asbuton production area is was integrated into part of the Oil and Gas Working Area with, operating under a Cost Recovery Production Sharing Contract (PSC) scheme. The development of Bitumen production from The results showed that Asbuton provides feasible economic indicators with NPV = viability, as evidenced by such as $ 973 million NPV and IRR = 15.2% IRR. During the contract period, the government received gained revenue of $ 14.7 billion and the contractor was projected to receive $ 12.0 billion. This economic feasibility study is expected to enrich further our understanding over Buton asphalt utilization in support of crude oil production in the future.

Keywords: downstreaming, asphalt extraction, support national oil production, alternative scenarios.

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INTRODUCTION

Downstreaming of natural resources is poses a global issue faced by many challenge for numerous producing countries, including Indonesia. Currently included. At present the Indonesian government is pushing for championing a policy of that focuses on downstreaming mining products, including specifically asphalt, a hydrocarbon substance that is considered similar to bitumen. In general, asphalt is usually used to support asphalt discovers widespread application in supporting infrastructure development including roads, but, especially in road construction. However in the oil and gas industry, asphalt is general definition officially defined as, "A naturally occurring hydrocarbon of very viscous character. They may occur, occuring as the high boiling point residuum of an oil pool after the lighter fraction has evaporated. Bitumen, on the other hand is a naturally occurring hydrocarbon with tar-like hydrocarbon mineral of properties and an indefinite composition. It ranges, varying in consistency from a thick liquid to a brittle solid" (Whitten and Brooks 1978, as cited in Widarsono et al., 2023). Asphalt/bitumen can be produced derived as crude oil which can then be processed is subsequently subject to processing into either fuel or industrial raw materials. Asphalt/bitumen this substance is a byproduct of the result of biodegradation from of light or medium crude oil so that asphalt/bitumen can still be processed, , enabling its transformation into crude oil or various petroleum products (Meyer et al., 2007; Chopra et al., 2020; Sierra-Gracia and de-Olivera 2013; Zhang et al., 2019; Hadimuljono and Firdaus 2021).

Since the 1980s, large-scale production of asphalt in the form of oil sand/tar sands has been carried out conducted by Canada in the Alberta region (Masliyah et al., 2004; Chopra et al., 2010; Bedair, 2013). In 2018, Canada the country had an oil sand extraction capacity of up to three million barrels per day and continues to grow. Meanwhile, the production process for in situ oil sand reserves through various exploitation techniques (Santos et al., 2014) also continues to develop technologically. On a smaller scale, several countries are also trying attempted to produce oil sand/tar sands. An example is production in, such as asphalt-Ridge, in the United States using open pit mining and the application of closed cycle solvent extraction (Coleman and Adams, 2004; Ralston, 2021).

Indonesia is one of the countries that has potential accumulations of heavy/non-conventional oil such as, namely asphalt/bitumen (Ma et al., 2021). The largest deposits are found most extensive reserves of this resource exist in the form of natural asphalt informations of Lawele, Buton Island, Southeast Sulawesi Province, commonly referred

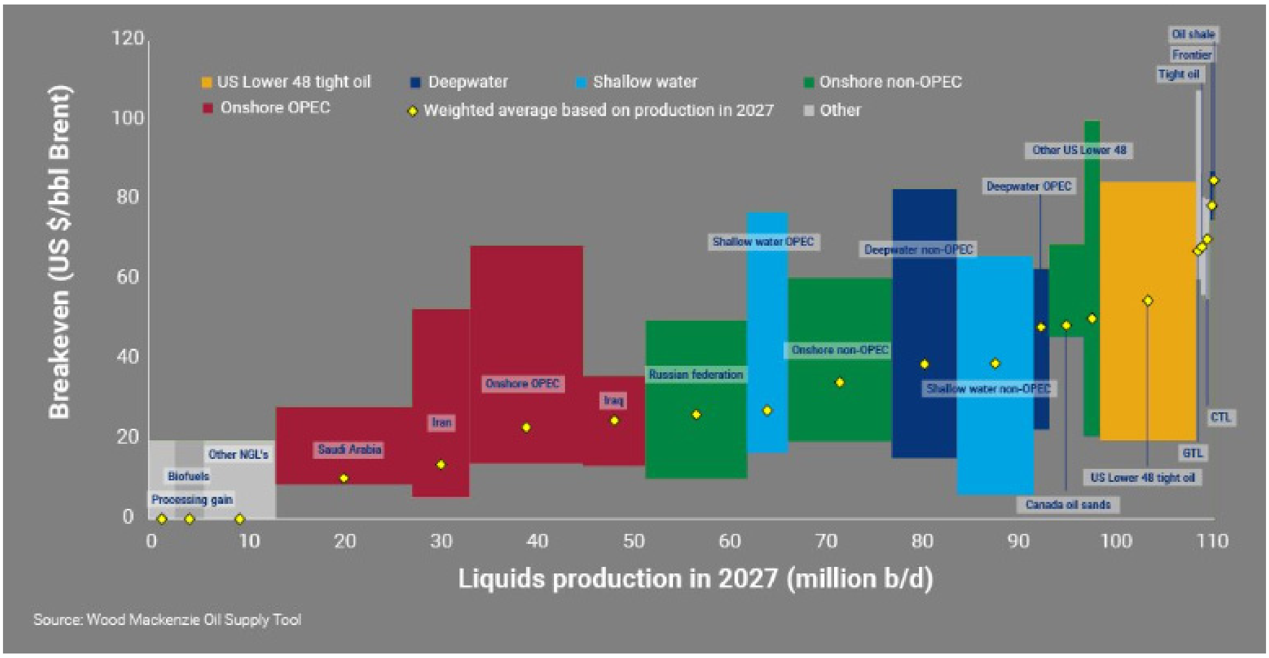

Figure 1
Estimated price of oil sands products along with the breakeven price range (Paton 2018). Like crude oil, the price of oil sands oil also fluctuates, so to take a value that represents the selling price it is necessary to determine the average value over a certain period.

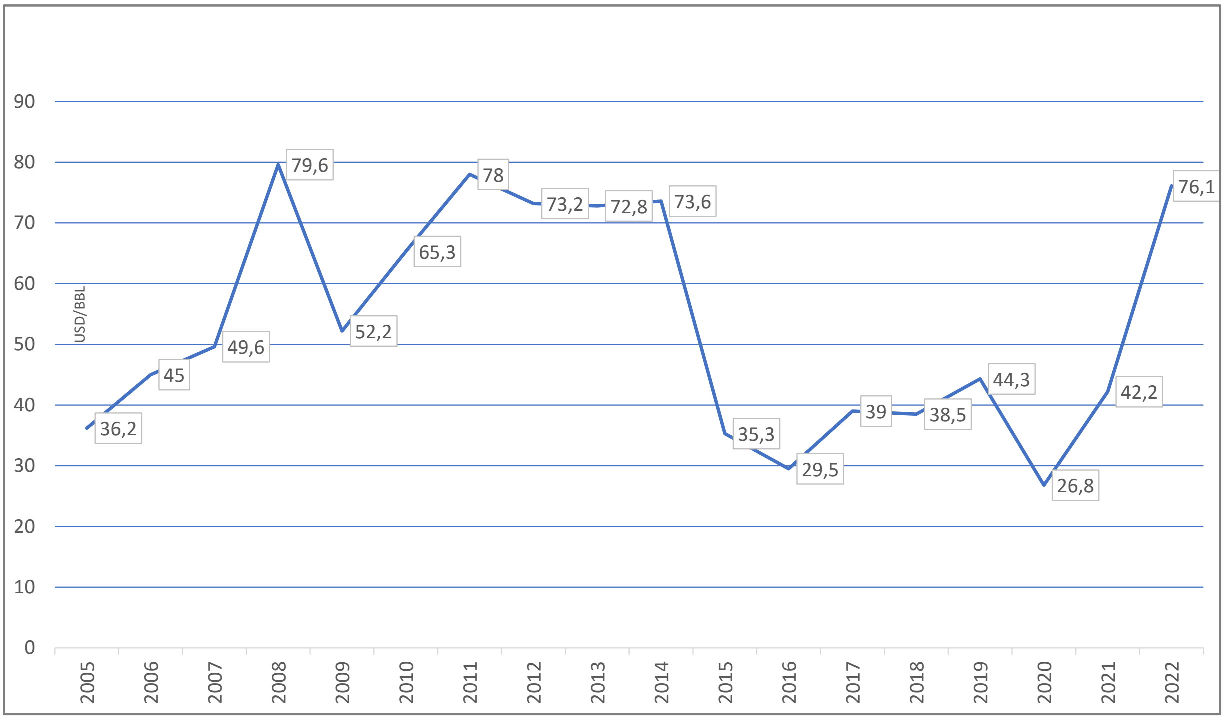

Figure 2
Observation of the price of oil from oil sand extraction per year in the period of 2005 - 2022 (18 years). This shows that in 2022 the price of extracted oil almost reached 80 USD per barrel.

to as 'Asbuton' (Siswosoebrotho et al., 2005), often termed as 'Asbuton'. Currently, the use of asphalt is still less than optimal, so research on asphalt is underdeveloped and presently, the utilization of this substance remains below its potential, primarily limited to its function for highways. Studies exploring the application in highway construction. This limited use means that research tends to focus on matters relating to restricted usage has prompted investigations into the characteristics and performance of asphalt for road construction. These include research on the performance and modification mechanisms of Buton rock asphalt (Lv et al., 2019, Guoqiang et al., 2020), and mixing Buton rock asphalt. Furthermore, blending this material with petroleum asphalt which aims to modify the asphalt to produce has shown promise in enhancing the production of a porous mixed asphalt product (Mabui et al., 2020). Viewed from the standpoint of the oil and gas industry, asphalt extraction comprises methods such as hot water injection of hot water, steam, solvents, or combustion to produce yield crude oil (Tumanyan et al., 2014). Numerous studies have delved into various aspects of asphalt extraction (i.e in the context of oil sands extraction for their asphalt), such as as seen in Canada, the United States, Venezuela, and China (Fan and Bai, 2015; Liu et al., 2019; Vishnumolakala, 2020; Ma et al., 2021). This foundational understanding sets the stage for the starting point of discussion in this report.

In addition to socio-environmental problems, another main problem which is seen as an obstacle to challenges, the economic feasibility of oil production from asphalt/bitumen accumulation is the economic feasibility aspect of production poses a significant obstacle. One of the most important factors in economic calculations is determining product selling prices that follow the trend of crude oil prices. The selling price means that, reflecting the extraction results in the form of synthetic crude oil (SCO) and/or diluent-bitumen (dilbit) really determine profoundly influences the economics of the exploitation project. Figure 1 shows the production volume and price range of Canadian oil sands compared to other crude oil prices (Paton, 2018), on which the projected oil sands production in 2027 is estimated to reach 3.5 million barrels of oil per day (barrel oil per day, BOPD) with an average breakeven price of USD 50 per barrel referenced to Brent oil. This production increases from and surpassing the 2022 level of 3.25 million BOPD.

Figure 2 shows oil sands price fluctuations over the last 18 years, namely from 2005 to 2022 (Figure 2). The average value for oil sands prices during this period was USD 53.2 per barrel. The highest and lowest recorded price occurred in 2008, reaching USD 79.6 per barrel, while the lowest price occurred in 2020 at and USD 26.8 per barrel. As part of occurred in 2008 and 2020, respectively. Similar to crude oil, the factors determining the prices of oil sands are in accordance with crude oil where there are influenced by fundamental factors elements such as supply and demand. Apart from that, there are also, as well as non-fundamental factors such as, including the policies of oil exporting countries (Muradov, 2019).

The Buton Island region has significant potential for asphalt/bitumen in the Buton island area is very large seen from the existing, as demonstrated by substantial reserves and resources of asphalt/ bitumen, both in the category that can be mined openly (i.e. termed ‘accessed through open pit mining’) and in the category mining or in situ and must be produced through a methods. This calls for stimulated conventional oil and gas exploitation as well as enhanced oil recovery schemes (EOR) (Widarsono et al., 2023; Suharni et al., 2022). Based on considerations regarding considering the size of asphalt resources/the reserves in the Buton island area and the global trend of asphalt/bitumen-based oil production and prices globally, this study has been conducted with the aim of providing an aims to provide the economic picture of Buton Asphalt (Asbuton) downstreaming through the by screening, development concept and estimation stages. Cost estimations through economic modeling/simulation and techno-economic analysis is performed are conducted in accordance with the Association for the Advancement of Cost Engineering/AACE standards (Christensen, et al., 2020). The results of this study may are expected to provide an overview of the economic landscape of Asbuton so that it can be followed up with the exploitation of facilitating subsequent action in crude oil production from asphalt/bitumen on Buton Island.

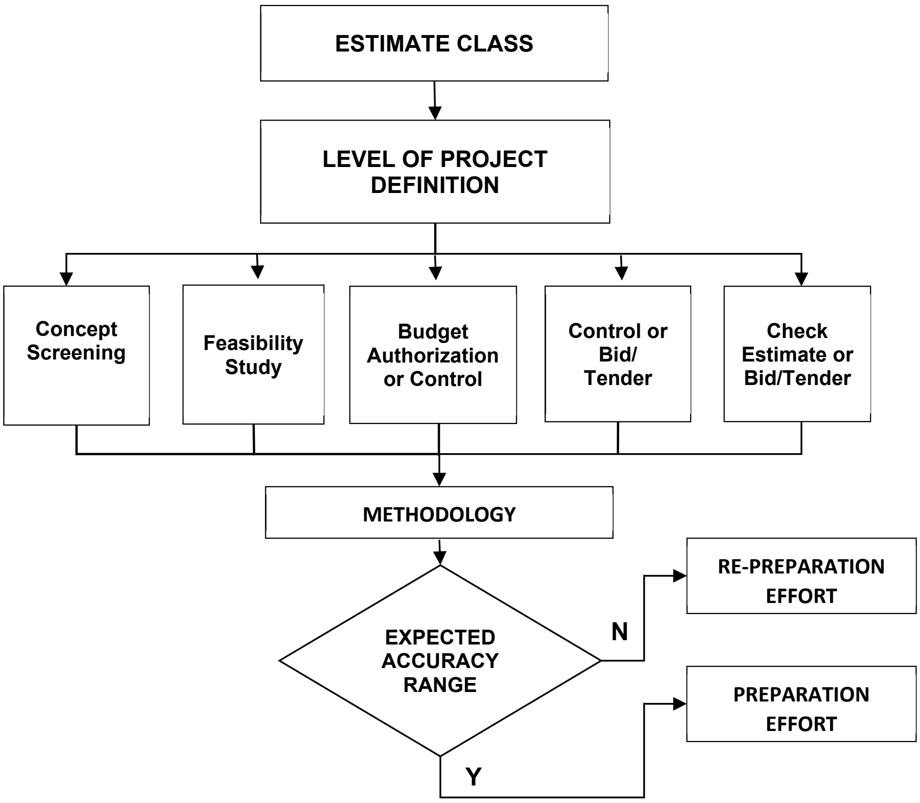

Figure 3
Flowchart methodology for cost estimation based on AACE International.

METHODOLOGY

The economic analysis of cost estimates adopted the Rough Order of Magnitude Estimate, which estimates carried out approach, conducted at the initiation stage of a project cycle with limited data. The resulting estimates had an accuracy range of -25% and +75%. Additionally, this estimation method incorporates Analogous and Parametric Estimation. Capacity Factored is a technique in Parametric Estimation (AACE International, 2020) was used comparing the capacity of similar projects as a reference with the capacity of the project to those to be built. Economic calculations using the Cost Recovery Profit Sharing Scheme are carried out were conducted using the Techno Economic Analysis method. This method for includes method for analyzing the economic performance of a business based on technical, technological and financial aspects. The flowchart of the methodology for cost estimation is presented in Figure 3.

RESULT AND DISCUSSION

Assumptions for estimated asbuton production

The potential for natural bitumen which is equivalent to Estimated Ultimate Reserves (EUR) mineable was estimated at 787 million barrels (Widarsono et al., 2023). Based on the explanation and the preanalysis that has been carried out conducted, the estimate of Asbuton bitumen production per day equivalent to heavy crude oil can be described on the following basis.

1. Bitumen production projections were grounded in the size of the planned refinery planned to be built, namely size, set at 100,000 barrels per day (BOPD).
2. The minimum refinery production capacity was assumed to be 45,000 barrels per day (BOPD).
3. The refinery The refinery location was assumed to be in proximity close to the consumer market in the Special Economic Zone Gresik, East Java.

The essence of natural bitumen production in this study is to treat the bitumen as heavy crude oil in downstreaming efforts to feed oil refineries or alternative processes such as gasification, methanation, and fine chemicals production. This aims to enhance the added value of natural bitumen.

In the production scheme, a realistic phasing can be carried out with includes initiating open pit mining and gradually increasing capacity in line with to the

Table 1
Physical properties of Asbuton from Kabungka and Lawele.

Testing	Testing Results	
	Solid Asbuton (Kabungka)	Solid Asbuton (Lawele)
Asphalt content (%)	20	30.8
Penetration, 25ºC, 100g, 5 seconds, 0,1 (mm)	4	36
Soft point (Ring and Ball test) (ºC)	101	59
Ductility, 25ºC, 5 cm/minute, (cm)	<140	>140
Solubility in CHCl (%)	-	99.6

Source: Siswosoebrotho and Kusnianti (2005) in Muhamad (2016)

Table 2
Chemical properties of Asbuton bitumen from Kabungka and Lawele.

Testing	Test results	
	Solid Asbuton Kabungka	Solid Asbuton Lawele
Nitrogen (%)	29.04	27.01
Parafin (saturated) (%)	8.86	11.23
Malten (%)	2.06	1.50
Asphaltene, (%)	49.92	39.45

administrative and commercial phases of bitumen ore product purchases from Buton Island asphalt mining area. The production scheme is anticipated to peak at an asphalt/bitumen the capacity of 50,000 BOPD before transitioning to asphalt from the in situ extraction process will be produced.

The following were planned stages of the description of downstreaming Buton Asphalt technology are planned as follows:

- Extraction
- Bitumen transportation
- Upgrading
- Field production plan

Extraction

The main consideration for extracting bituminous Asbuton includes the physical and chemical properties with the characteristics as detailed in Table 1.

By understanding the characteristics of Asbuton bitumen, the study of extraction technology focused on 3 types of approaches, namely

- Extraction using organic solvent;
- Extraction using a weak acid (best is formic acid);
- Extraction using a weak acid (best is formic acid (surfactant dodecyl trimethyl ammonium bromide (DTAB)) and organic solvent (toluene).

Table 3
Requirements for transporting bitumen using pipes (Zerpa, 2022). Stark discrepancies between pipeline flow requirement and typical bitumen charactistics underline the need for bitumen dilution.

Properties	Pipeline flow requirement	Bitumen typical characteristics
Density (kg/m^3@T=15ºC)	940 max	> 1,000
Viscosity @20ºC, cSt	350 max	> 100,000
Viscosity @7.5ºC, cSt	350 max	>1,000,000

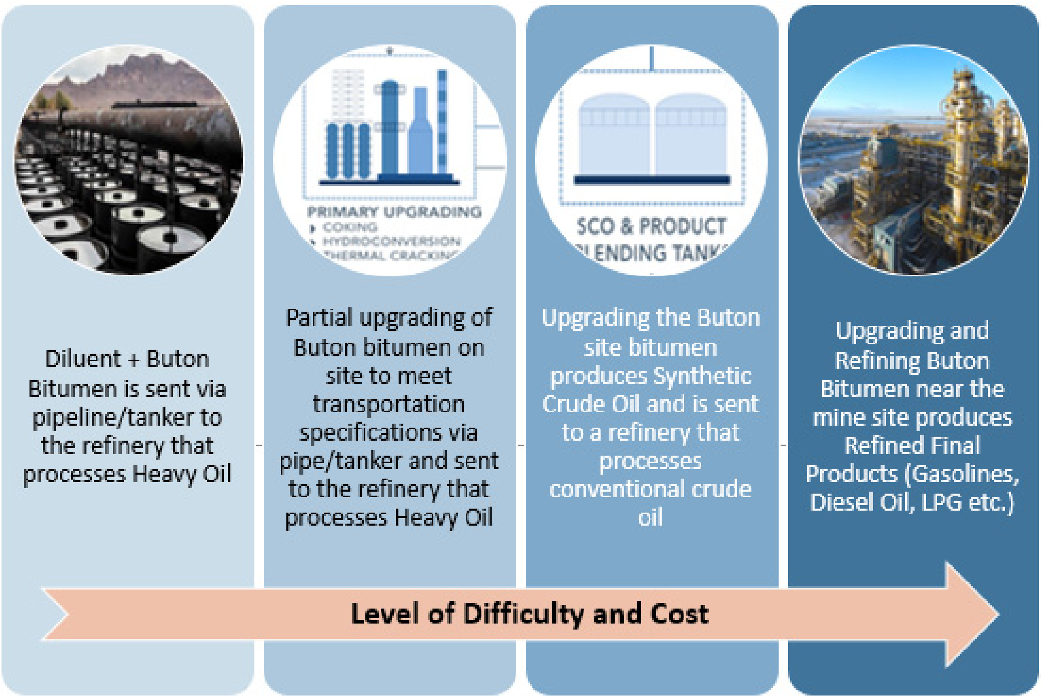

Figure 4
Alternatives to overcome bitumen transportation problems. (https://www.oilsandsmagazine.com).

Bitumen Transportation

Oil sands containing asphalt/bitumen, like the exemplified by substances such as Asbuton, is originate from the biodegradation and water washing of petroleum deposits, which themeselves. Typically, these deposits contain 15% -35% bitumen and the rest is with the remaining composition consisting of carbonate rocks and other constituents. Asbuton harbors contains asphaltenes identified as the heaviest and most polar components in oil and coal. This bitumen is usually poorly soluble exhibits poor solubility in paraffin (usually n-pentane or n-heptane) but soluble in aromatic solvents like toluene. Because it contains due to high asphaltenes content, asbuton bitumen has problems due to its tendency poses challenges, as it tends to cause precipitation in precipitate during oil production, upgrading and processing processes. To be able to market bitumen For successful marketing, the facilitation of course it must be able to be transported. When looking at the bitumen transportation is essential. This necessitates a thorough assessment of piping requirements, it is important to be able to reduce the with efforts focused on reducing specific gravity and viscosity so that it can be pumped to enable smooth pumping and flow through the pipe. Another way is to mix pipelines with water and adopting the wetted line principle to mitigate shear stress. Response to the mentioned requirements above, we can summarize the various alternatives exist for bitumen transportation methods with several alternatives, namely using diluents. These included dilution reducing viscosity with partial upgrading, carrying out full upgrading to directly obtain synthetic crude oil (SCO), and carrying out full ugrading followed by refined production. For diluent applications, bitumen the common practice was to dilute is typically diluted using with fully enhanced natural gas condensate (DilBit) or SCO (SynBit) in order to meet. This was conducted in accordance with pipeline specifications. The amount of diluent required is determined by the pipe's acceptable viscosity specifications. Canadian DilBits in Canada with a diluent type that is generally typically used natural gas condensate with a characteristic specific gravity of 62 °API, sulfur content less than 0.1% sulfur by weight, and a viscosity of 0.6 centistoke (cSt) at 40 °C. While the fully enhanced SCO with an estimated 34°API, less than 0.1 wt% sulfur and a viscosity of 3 cSt at 40°C. Mixing ratio when referring to typical was another common diluent. In DilBit from Athabasca, the typical mixing ratio included a 29 V% condensate. Resulting in a mixture of 21°API, 3.8 wt% sulfur, and 41 wt% residual vacuum. For SynBit, the case at

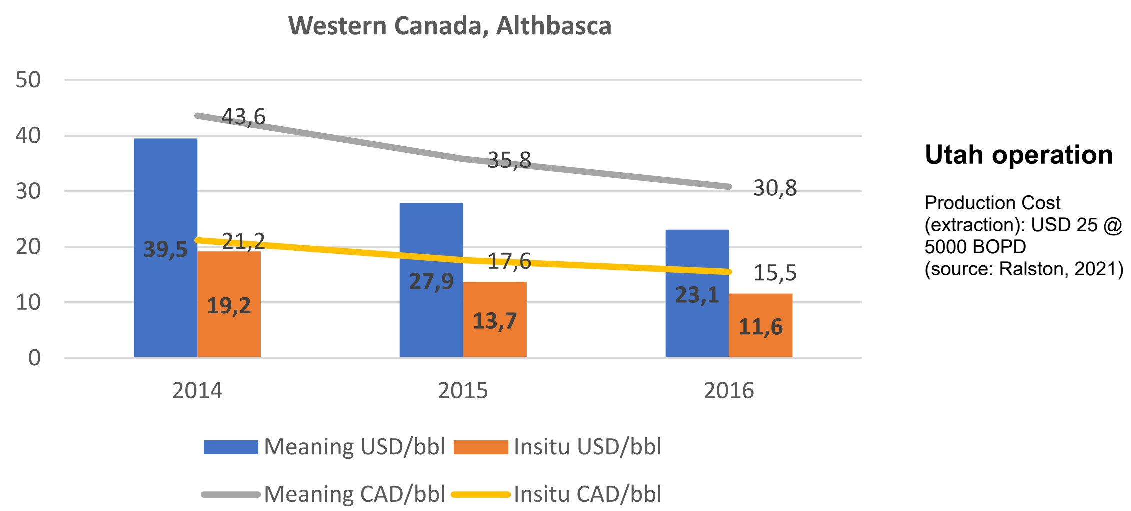

Figure 5
Comparison of asphalt/bitumen production costs originating from in situ extraction and open pit mining on oil sands in Alberta Canada and Utah USA. Note that, oil sands extraction of bitumen in Canada uses the hot water extraction method while the same thing in Utah-USA uses solvents with a closed cycle system. Source: Rystadt Energy (2017).

Table 4
Comparison of asbuton production scenarios.

Scenario	Technical	Financial	Social Impact	Environmental Impact
Scenario 1	vv Relatively easy	vvv Investment in mixing facilities with relative moderate diluent	v (manageable)	v (manageable)
Scenario 2	vv It is risky because *in situ* extraction is a desirable target but is technically reduced by diluent mixing	vv The investment in the *in situ* extraction section is large but offers a significant reduction in production costs and the cost of mixing facilities with a relatively moderate diluent	v (manageable)	v (manageable)

Note: v: good vv: very good vvv: excellent

Athabasca demonstrated the need for approximately. 50% fully enhanced SCO was needed in the mix to meet the pipeline viscosity requirements. This diluent generally contains less raw bitumen than DilBit, and therefore has a much leading to significantly lower residual sulfur and vacuum content as well. Figure 4 presents the implications of the choice of bitumen transportation mode and the accompanying implications.

Upgrading

Both open pit mining and in situ extraction open pit mining and in situ extraction must be diluted of bitumen necessitate a dilution process to achieve the required liquidity for transportation to final processing plants facilitating the production of marketable products. In dilution with light oil and partial upgrading, the blended heavy oil or SCO needs to be in accordance with pipeline specifications. In the case of Althabasca-Canada, products are required to meet specification standards including gravity, viscosity and solids/water values. The upgrading process entails processing heavy crude oil or bitumen through refining operations, such as distillation, coking, thermal cracking, catalytic cracking, hydrocracking, solvent deasphalting, and gasification. Effectively upgrading these heavy oil mandates the conversion of certain secondary treatments (e.g., hydrogen addition, sulfur removal and nitrogen removal) into marketable products.

Heavy oil quality improvement (upgrading) the technology can be divided for enhancing the quality of heavy oil was categorized into 2 main types, namely full and partial upgrading. The full upgrading approach yields finished products suitable for sale, such as gasoline or diesel, or high quality SCO that does not contain devoid of residual vacuum oil. Distillation products of SCO distillation products are treated with were subjected to water and have the same or close to the quality treatment, resulting in a quality comparable to that required for final sale. On the other hand, partial upgrading typically produces SCO containing 5-30% vacuum residue and distillation products that require additional purification (through processes such as hydrotreating).

Field Production Plan

As an As an illustration, temporary production costs were obtained from bitumen from both open pit mining both open -pit mining and in situ extraction operations of bitumen in Canada and Utah-USA. Figure 5 provides an overview of the unit costs per barrel of asphalt/bitumen in Canada and the United States. In the aspect of upgrading costs, both partial and full, various sources and references such as Colyar (2009) can utilized, as well as inference be used. Moreover, valuable insights can be gleaned from the price difference between Western Canadian Select (WCS) heavy oil and West Texas Intermediate (WTI) light oil which typically falls within the price range of USD 10-15 per barrel. The establishment of the assigned field production plan for economic modeling was based regarding information on estimated Asbuton reserves, estimated production schemes, and available technology for extraction technologies, upgrading methods or alternative diluents and transportation, the assigned field production plan for the economics modeling is established through two options. A total of 2 scenarios have been outlined, as shown in Table 4.

Based on the assessments of aspects presented in Table 4, Scenario 1 was considered as the best choice for the initial stage of production while Scenario 2 is chosen later stage, specifically when the potential in situ reserves can be realized for their existence.

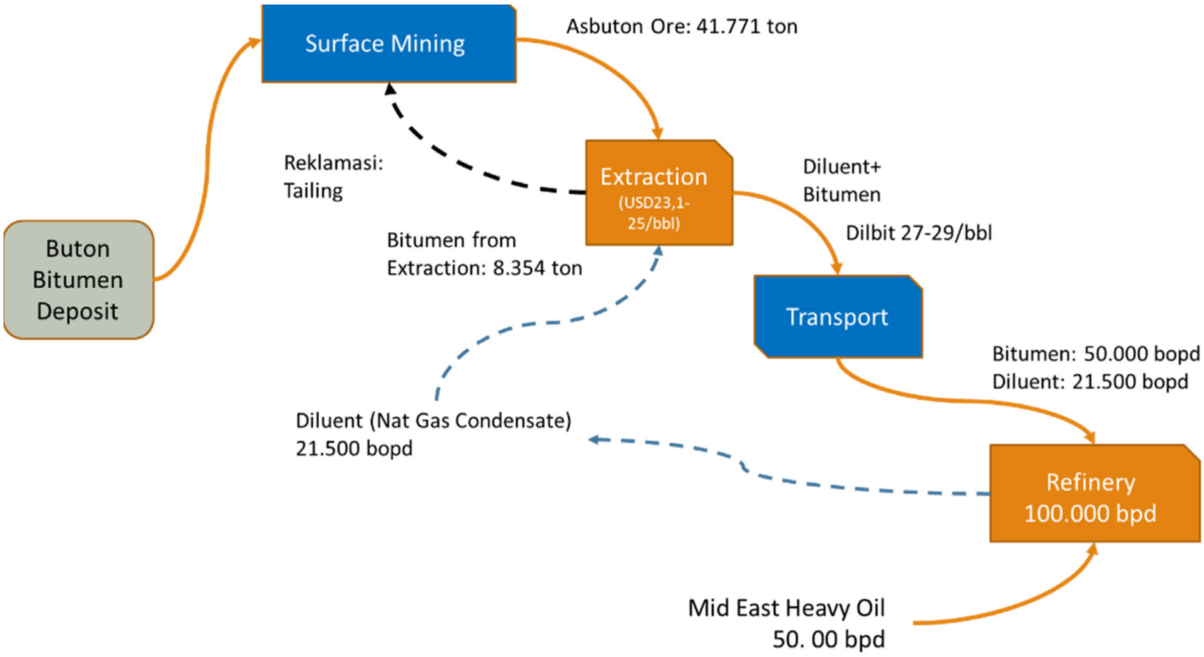

Figure 6
Production schematic of scenario 1.

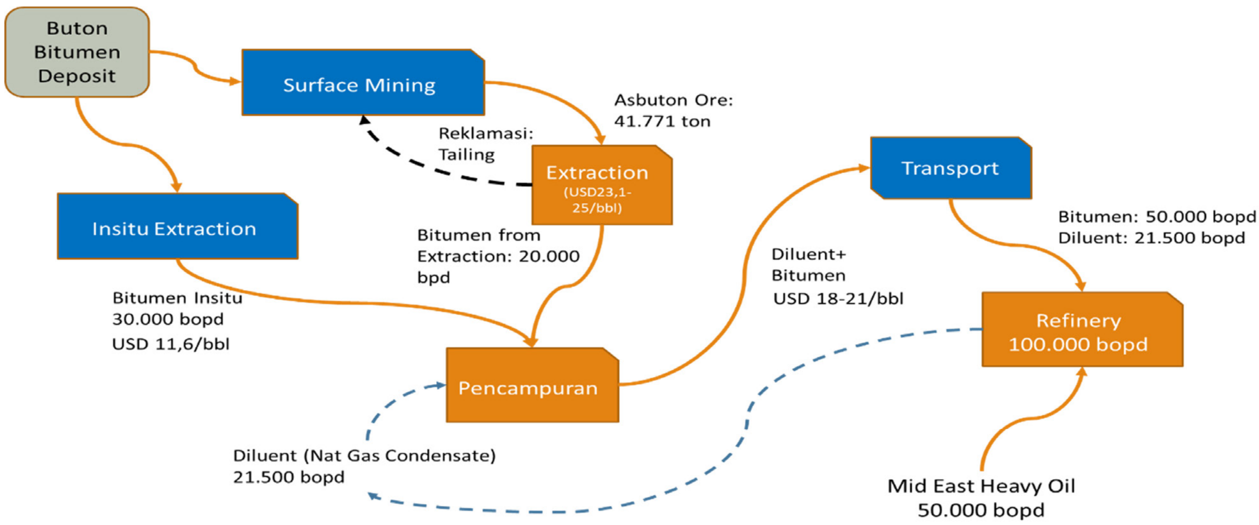

Figure 7
Production schematic of scenario 2.

Scenario 1

All bitumen comes from open-pit mining operations using diluent mixtures for transportation on a base of 50,000 BOPD upgraded bitumen (as shown in Figure 6). The addition of diluent volume was not calculated as an increase in volume assuming that factored into the volume increase, assuming it will be recovered during in the processing process at the refinery. Consequently, the diluent price is not considered in the cost analysis. The cost component in related to the use of diluent usage only included transportation costs of 4 USD 4 per barrel. With the countdown, financing was obtained obtainedThrough careful financial planning, funding has been secure to achieve an upgraded bitumen level (DilBit) within the range of USD 27 – 29 per barrel.

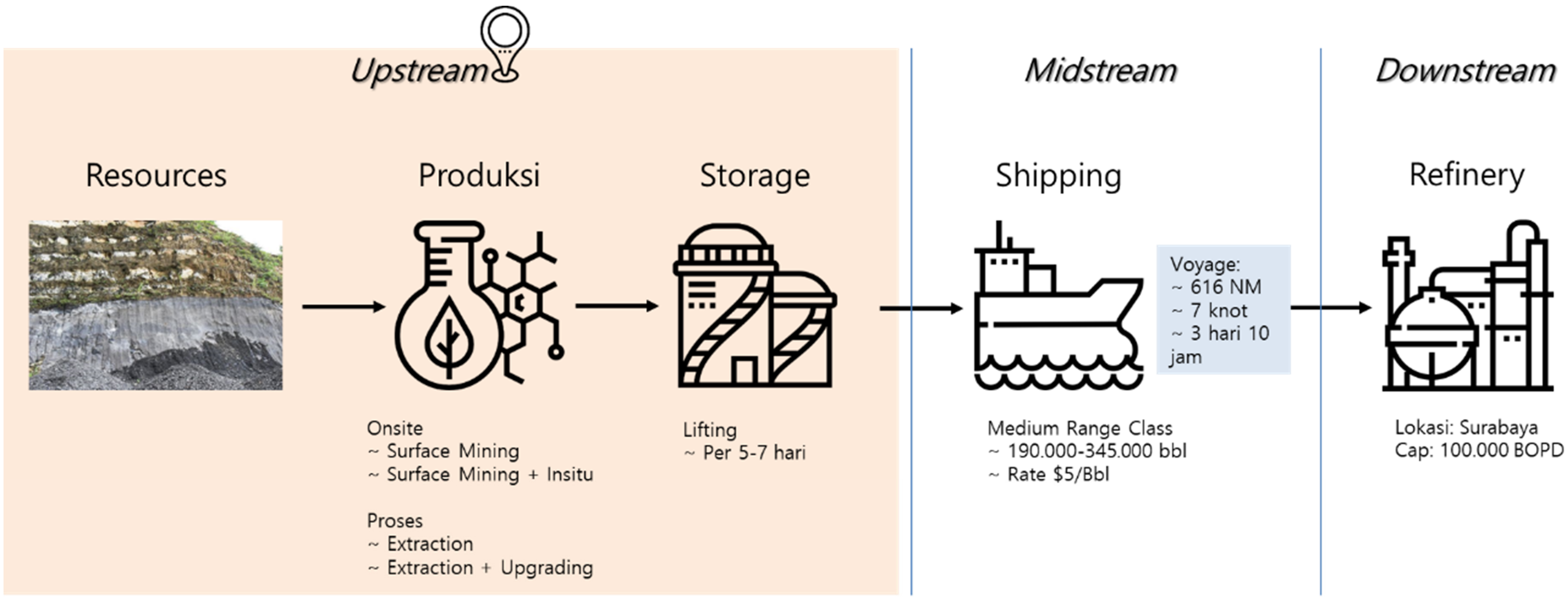

Figure 8
The scope of economic evaluation is marked by a brown box on the left.

Table 5
Assumptions used in economic evaluation.

Gross Prod	SCO/Diluent – Bitument
First Tranche Petroleum (FTP)	10% shareable
Price	USD76.1/Bbl (flat) *)
Contractor Oil Net Share	
Very High Risk	45%
Domestic Market Obligation	25%
DMO Fee	100%
Total Tax	37.6%
Depreciantion	5 years (Declining Balance)
Discount Factor	10%

*) Average price of Western Canada Select (WCS) crude, 2022

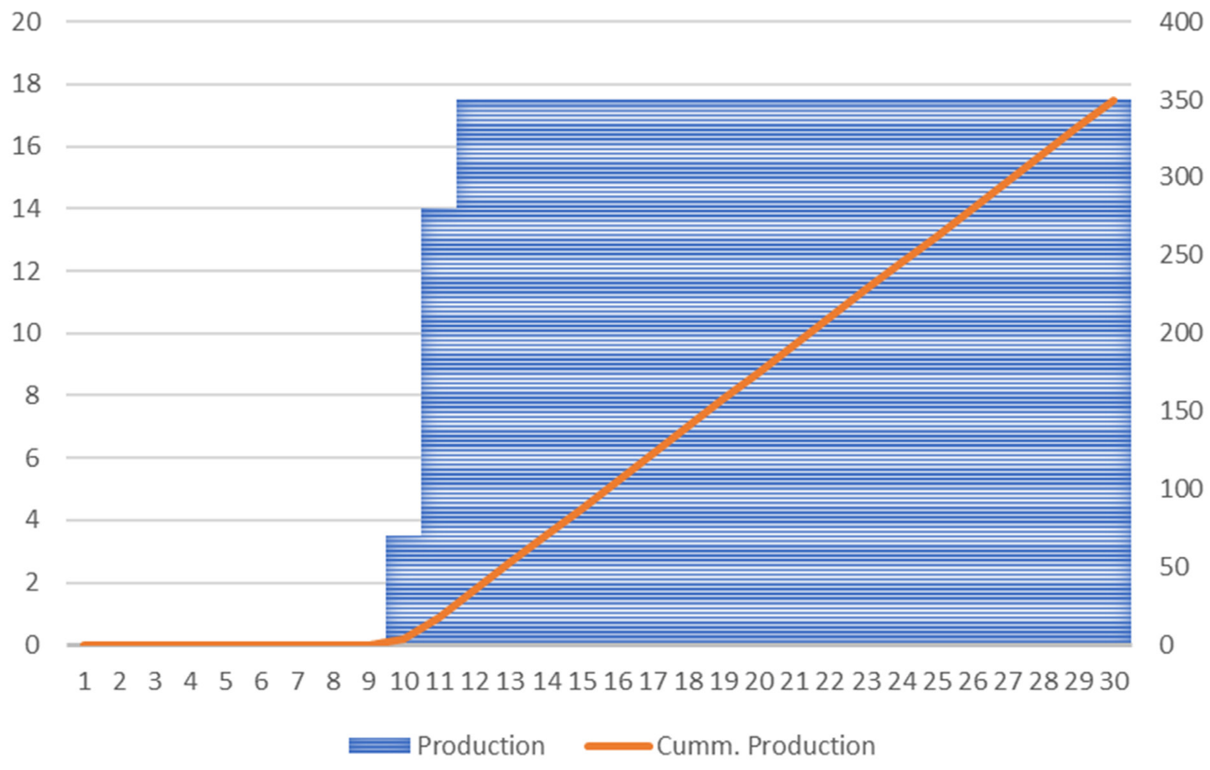

Figure 9
Production profile within 30 years of Working Area contract time. Production begins in the 10th year.

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

Notes:
[a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.
[b] If the range index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

Figure 10
Classification of cost estimates based on AACE International.

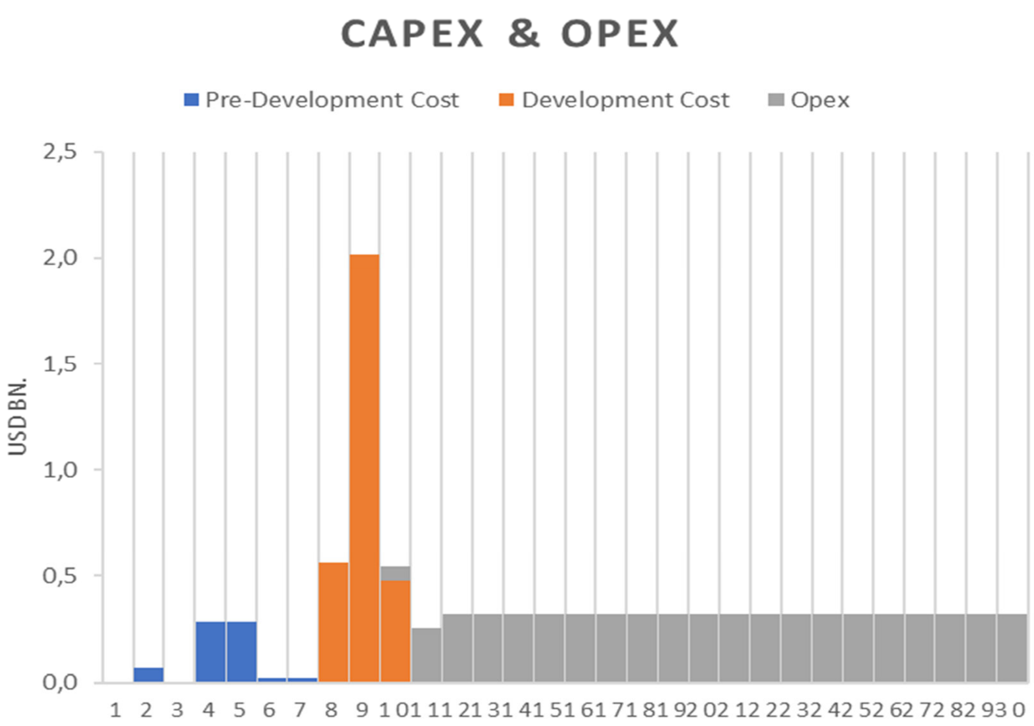

Figure 11
Timeline for CAPEX and OPEX.

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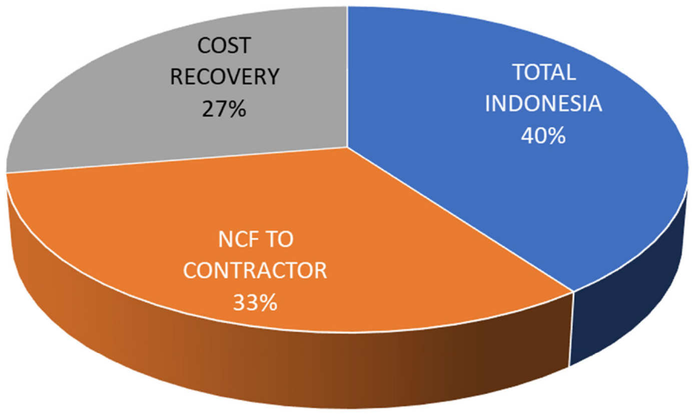

Figure 12
Distribution of revenues for scenario 1.

Table 6
Results of economic evaluation calculations on the two scenarios.
Note that GOI stands for the Government of Indonesia.

Description	Unit	Scenario 1	Scenario 2
Split, GOI: contractor		Very high risk, 55:45	Very high risk, 55:45
Sales, cumulative	million barrel (MMbbl)	350	350
Syncrude/Dilbit price	USD/bbl	76.1	76.1
Costs			
Pre-development	million USD	699	506
Development	million USD	3.056	2.213
Operation+ASR	million USD	6.395	4.631
Gross revenue	million USD	36.850	36.850
Revenue distribution			
GOI take	million USD	14.685	16.225
GOI equity	million USD	7.445	8.226
Tax	million USD	7.240	7.999
GOI takes from gross revenue	%	39.9	44.0
Contractor take	million USD	12.015	13.275
Contractor take from gross revenue	%	32.6	36.0
Cost recovery (CR)	million USD	10.15	7.35
CR from gross revenue	%	27.5	19.9
Contractor economic indicators			
NPV @ 10%	million USD	973.4	1.482.6
IRR	%	15.2	19.6
Payout time	Years	4.7	3.8
CAPEX	USD/bbl	10.7	7.8
OPEX	USD/bbl	18.3	13.2

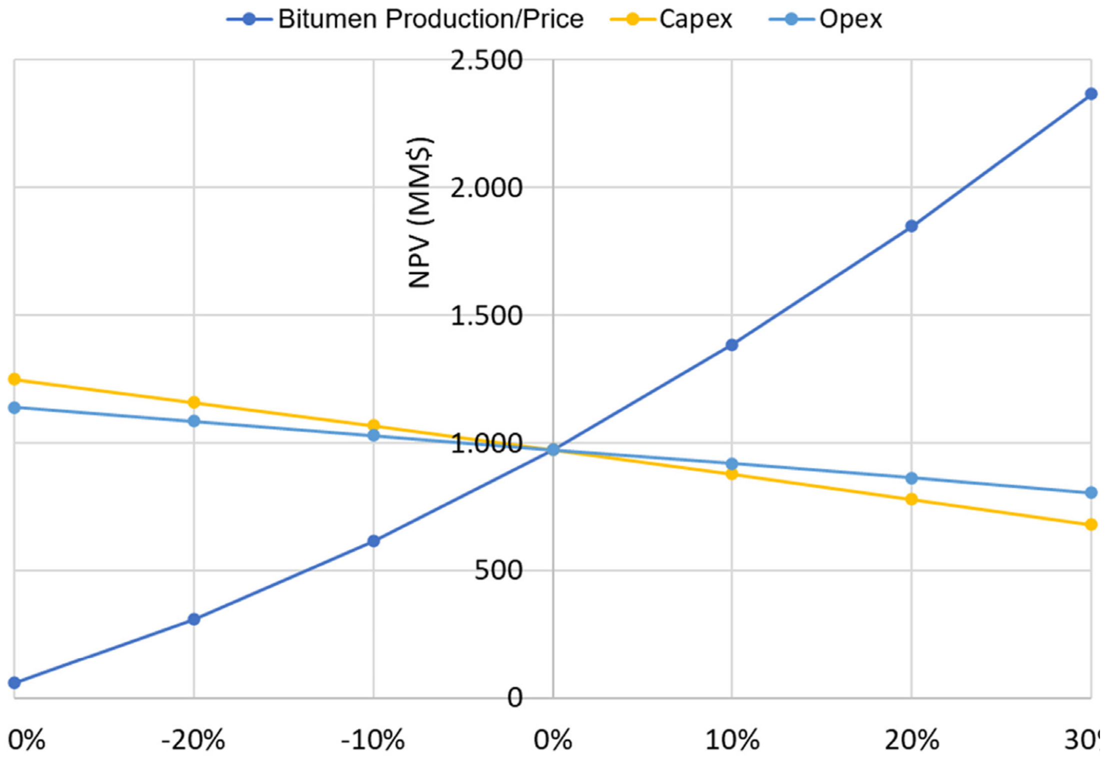

Figure 13
Sensitivity to net present value (NPV) for scenario 1.

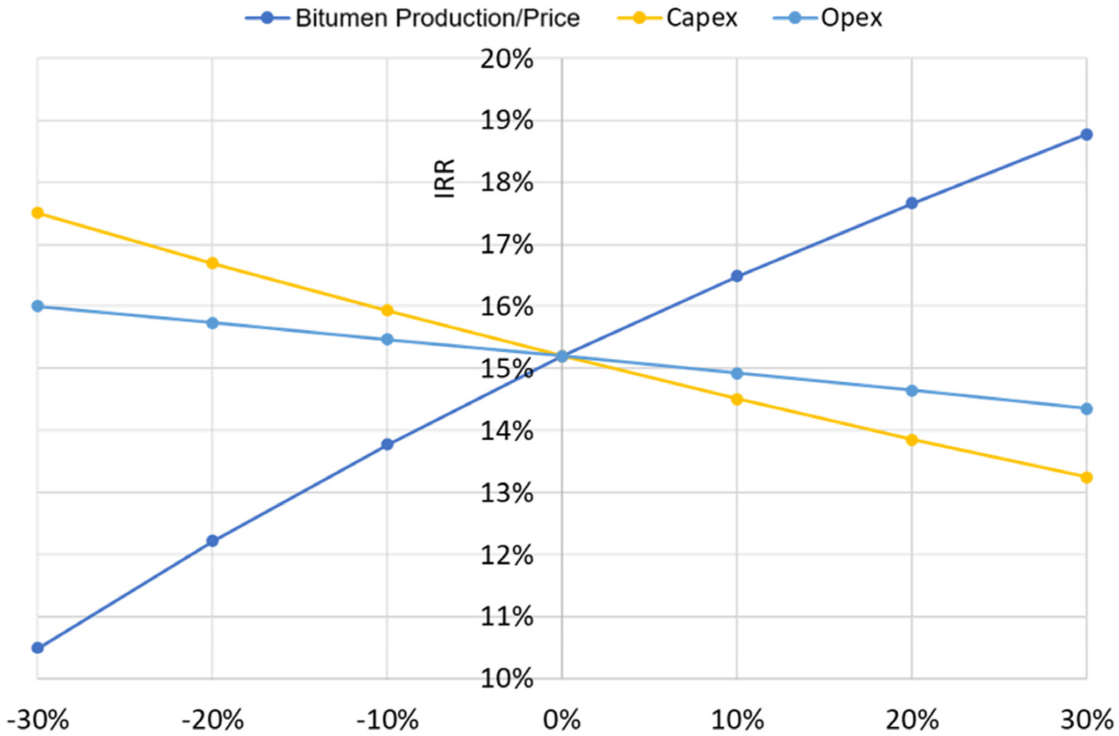

Figure 14
Sensitivity to internal rate of return (IRR) for scenario 1.

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Scenario 2

Scenario 2 includes the production comes from both of bitumen through a combination of open-pit mining (40%) and in situ extraction (60%) with the application of diluent %. Diluent blending is applied in the field for transportation to refineries at a rate of 50,000 BOPD basis of upgraded bitumen. The upgrading process in this scenario mirrors that of scenario is similar with Scenario 1 from the upgrading side. Financing was secured within the countdown, financing was obtained aiming to achieve an upgraded bitumen rate of ranging from USD 18 to 21 per barrel. It is important to note that the cost per barrel is lower than in Scenario 1 because this case stems from the cost more economical nature of in situ extraction per barrel is cheaper than compared to surface extraction (see as presented in Figure 7).

Using a bitumen production scheme for the minimum refinery requirement for bitumen feed equivalent to heavy crude oil of 50,000 BOPD, bitumen is planned for refinery feed obtained by the production scheme entailed extracting Buton asphalt, then asbuton. Subsequently, a partial upgrading is carried out was implemented to reduce viscosity and specific gravity. The upgrading scenario can also be taken by adding incorporates the option of introducing a diluent with a certain ratio, to be. The resulting product is then transported, either via pipeline or tanker to the site of an existing oil refinery and according to its specifications or the refinery to be built.

Techno-economics analysis

The economic evaluation included the determination of scope, profit-sharing schemes, determining assumptions, determining production profiles, cost (CAPEX and OPEX) estimates, making economic models and calculations and verifying calculation results (Stermoleet al., 2018). In this study, the scope of economic evaluation in this paper is limited to the upstream side which consists of identifying resources, production, and storage on Buton Island. The midstream sector in this project consisted of shipping, while the downstream comprised of refinery. An illustration of the scope of economic evaluation is shown by the brown box in Figure 8.

In the upstream oil and gas sector, the economic calculation of SCO and Dilbit production followed the cost recovery Production Sharing Contract (PSC). This PSC, incorporated several distinctive provisions approximately 10% of the gross production was allocated as, the share is referred to as first tranche petroleum (FTP) a portion that can not be used to pay the incurred costs. The existence of FTP served the purpose of securing state revenue, specifically in the early period of production. The remaining 90% of gross production will be used for OPEX cost recovery in the current year. After being taken for cost recovery from the Government, the rest is added deduction of costs by the government, the remaining balance, augmented by FTP is then divided between the government and the contractor. Domestic market obligation (DMO) is the obligation to sell products within the country. According to the prevailing regulations, DMO is determined set at 25% of the contractor's share. Although required for DMO, with a and despite its mandatory nature, this 25% requirement, based on a selling price of 100%, this DMO amount has no effect on does not affect the economic model (PwC, 2023).

The last factor in the PSC economic model is a tax (tax) whose amount is specifically tailored for the upstream oil and gas sector. Within the production scope SCO is subject to a total tax of 37.6%. The calculation assumptions guiding the economic model calculations are shown in Table 5.

Another important factor in economic calculations is the production profile as presented in Figure 9. This production plan was in line with the sales plan and anticipated revenue. The determination of the production profile was subjected to optimization stages to ensure optimal selection. Production was set to commence in the 10th year, after preparation and project construction.

Reviewing the technical aspects that have been previously explained, Scenario 1 involves open-pit mining of bitumen and blending it with diluent for transportation. The diluent volume and price are not counted in the production cost, only the transportation cost. The production capacity is 50,000 BOPD of upgraded bitumen. Scenario 2 involves a mix of open-pit mining (40%) and in situ extraction (60%) of bitumen, with diluent blending in the field. The production capacity is the same as Scenario 1. The cost per barrel is lower than Scenario 1 because in situ extraction is cheaper than surface extraction.

Both scenarios aim to produce bitumen that meets the minimum refinery requirement for heavy crude oil feed. The bitumen is partially upgraded to reduce viscosity and specific gravity, and transported by pipeline or tanker to an existing or new refinery. In order to choosescenario, cost estimates are established in according with class 5 in the International AACE standards as shown in Figure 10. The accuracy resulting from cost estimates is in the range of -20% to -50% for the lowest value (minimum) and +50% to +100% for the highest or maximum value (AACE international, 2020).

The parameters of investment (CAPEX) and operational costs (OPEX) as well as the timing of expenditure are shown on Figure 11. CAPEX is incurred during the pre-development stage and the construction of production facilities. The largest value was recorded in the 9th year, showing ongoing procurement and construction of key production equipment. OPEX was calculated in proportion to the production volume which is assumed to be stable from the 12th year until the end of the production period.

Following the determination of all the necessary data and assumptions, calculations were executed using the established economic model that has been created. Table 6 displays the results of. The outcomes of these economic calculations for the described scenarios are presented in Table 6. Considering that in the initial stages the use of asbuton was expected to rely on the option of completely open mining, a subsequent for the next analysis a scenario is taken was conducted based on the obtained calculation results.

Based on a preliminary economic study of Buton Work Area, which assumes an asphalt/bitumen production rate of 350 million barrels per year for 20 years, Scenario 1 and Scenario 2 are both feasible options. Scenario 1 involves producing all asphalt/ bitumen from open pit mining, which is preferable i the early stages of production. Scenario 2 involves a mix of open mining and in situ extraction, with a ratio of 40% - 60%, which can be adopted later. Under the Production Sharing Contract scheme of 'Very high risk' (PSC Scheme – Very High Risk), these scenarios yield attractive economic indicators, such as a NPV of US$ 973 million and an IRR of 15.2%. The Government also benefits from these scenarios, as it receives a revenue of US$ 14.7 billion during the contract period.

Figure 12 presents the distribution revenue for Scenario 1, which is taken as the example of the two. From the pie chart on the figure, it can be observed that the composition is balanced between the share, of the government and the contractor, as well as the cost recovery. Excluding the cost recovery portion, the share of the government at 40% is still remains higher than that of only the contractor at 33%. Based on the existing PSC scheme, this project still prioritizes state revenues over profit for business entities.

After the economic calculation results for the base case are obtained, the next step is to conduct a sensitivity analysis of the variable values that can change. In this study the analysis aimed to select alternative scenarios. A total of 4 variables that determine the economic level of the project, namely bitumen production volume, bitumen price, CAPEX and OPEX have been chosen with values ranging from plus or minus 30% to the base.

The NPV sensitivity shows that bitumen production and prices have the greatest influence in determining the economic level of the project (as presented in Figure 13). Every 10% change in these parameters results in a $400 million shift in NPV. Meanwhile, CAPEX and OPEX are far below even though exert comparatively less impact, with changes in CAPEX having a greater influence than changes in OPEX. The same thing also happens to this trend is similar in IRR, as shown in Figure 14. A10% change in bitumen price or production caused a 1.5% IRR shift. The same conclusions can be drawn from this figure as those from the NPV conclusions. It is recommended that in further research other analysis. Recommendations include incorporating additional economic parameters can be added in further studies, such as the Profitability Index (PI) to assess project feasibility and the Payback period (payout time, POT) to determine the period for returning capital.

As a critical component of the feasibility study, this tecno-economic analysis should be used as a decision support tool for advancing to the for advancing to the next stage of project implementation such as front end engineering design (FEED). Companies and or contractors need to be aware of all assumptions and considerations made in constructing this analysis to avoid misleading judgments and economic assessments. The FEED process should be supported by techno-economic analysis with more detailed discussion and more accurate estimation. In this phase, technology providers, material suppliers, and other stakeholders should be included during data collection to improve the quality of results that are to be used for decision making that may lead to exploitation of synthetic crude from Buton asphalt.

CONCLUSION

In conclusion, an effort was made to increase oil and gas production producing bitumen from Buton asphalt which could be used as oil refinery feed. Currently, Buton's asphalt reserves, assuming considering a recovery factor (RF) of 95% for open-pit mining operations, mean the estimated ultimate mineable reserves (of Buton's asphalt amounted to an EUR) of 787 million barrels of bitumen. This amount was able to meet the minimum oil refinery feed requirements of 50,000 BOPD. The plan was to conduct bitumen production is planned to be carried out through asphalt extraction, then followed by upgrading to reduce viscosity and specific gravity. Upgrading could also include adding a diluent to allow easy transportation via pipe or tanker to an existing oil refinery location.

In the early stages of production, Scenario 1 was considered the best scenario where all asphalt/bitumen production came from open pit mining. If Supposedly the option of a 40% - 60% ratio between open mining and in situ extraction ratio option of 40% - 60% is taken, was chosen Scenario 2 could be selected as the scenario with the best economic analysis results. The preliminary economic study on the Buton Work Area, based on asphalt/bitumen production of 350 million barrels per year (for 20 years), showed attractive economic indicators with an NPV of US$ 973 million and an IRR of 15.2% under 'Very high risk' PSC. During the contract period, the Government received revenue of US$ 14.7 billion.

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GLOSSARY AND TERMS

Symbol	Definition
AACE	Association for the Advancement of Cost Engineering
API	American Petroleum Institute, used as indicator for oil specific gravity
BOPD	Barrel oil per day
CAPEX	Capital Expenditure
DMO	Domestic market obligation
DTAB	Bromide
NPV	Net present value
IRR	Internal rate of return
SCO	Synthetic crude oil
USD	United States dollar
PSC	Production Sharing Contract
EUR	Estimated ultimate reserves
FTP	First Tranche Petroleum
OPEX	Operating Expenditure
WCS	Western Canadian Select
WTI	West Texas Intermediate

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