King Abdullah Petroleum Studies and Research Center

Placing a Value on Spot Sales from a Joint Oil Stockpiling Facility

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Key Points

With excess supply and reduced transportation costs moving crude oil faster and further than ever before, how can large oil exporting nations compete most effectively in today's crude markets? One possibility is through the commercial use of strategic storage or joint oil stockpiling (JOS) facilities.

The ability to use a JOS facility for commercial purposes presents considerable potential added value to crude oil producers and their marketing companies located far from major consuming markets and refining centers. This added value can be estimated utilizing a quantitative 'real options' style valuation model. Such a model can be designed to combine net present value (NPV) analysis and options modeling techniques, to value the potential for profitable spot crude oil sales from a JOS facility to nearby markets.

The potential added value of conducting spot sales from a well-placed JOS facility can be estimated by calculating how much an industry player would pay to secure the right to purchase crude oil supplies from a distant primary producer at market prices from a JOS close to major markets. That value, in turn, will depend on the price of competing crude oil supplies from other global producers and can be estimated as a simple European spread option.

The upward trajectory of oil prices between June 2014 and mid-2018 resulted in increased competition among major crude producers to secure market share. This, coupled with a general downward trend in oil shipping rates over the same period, enticed producing nations to seek new markets at ever-increasing distances (World Maritime News 2018). The increased competition led many major oil producers – notably from Middle East Gulf nations — to engage in the strategic use and optimization of storage facilities in East Asia, including JOS facilities, and in some cases, of countries' strategic petroleum reserves (SPRs). It should be noted that joint stockpiling or leasing all or part of large third-party commercial storage facilities may be more suitable in this regard, given that the rules for SPRs built and operated by consuming countries tend to be quite restrictive, as outlined in Doshi and Six (2017).

Japan, South Korea, India, with the aid of producers and traders, and China in conjunction with state-run companies, are all reducing their storage and logistics costs and giving sellers faster access to markets by allowing some spot crude sales from their strategic reserves or JOS tanks.

Middle Eastern crude oil producers located far away from consumers in Northeast Asia and Japan tend to favor long-term sales contracts. Producers that are able to participate in the spot market, and take advantage of the potential for temporary increases in spot prices, can benefit from the tactical use of a storage terminal located close to end markets.

This study develops a 'real options' style valuation model, and applies it to a hypothetical case study in Northeast Asia — from the perspective of a crude oil exporter located a considerable distance away from some of its main markets — to determine the potential value of ex-storage spot crude oil sales, using strategically located JOS facilities. The valuation model uses proprietary spread options to capture the value created by volatility in regional spot oil prices.

Our case study demonstrates that the ability to sell spot oil from such a storage facility represents a potential source of added value to 'long distance' crude oil producers and marketers.

Key Points

Our analysis comprises a combination of net present value (NPV) analysis and a ‘real’ options style approach. Based on typical Middle East crude oil production and seaborne transportation costs and a hypothetical 6 million barrel (MMbbl) JOS facility located close to a key market in Northeast Asia, we find that:

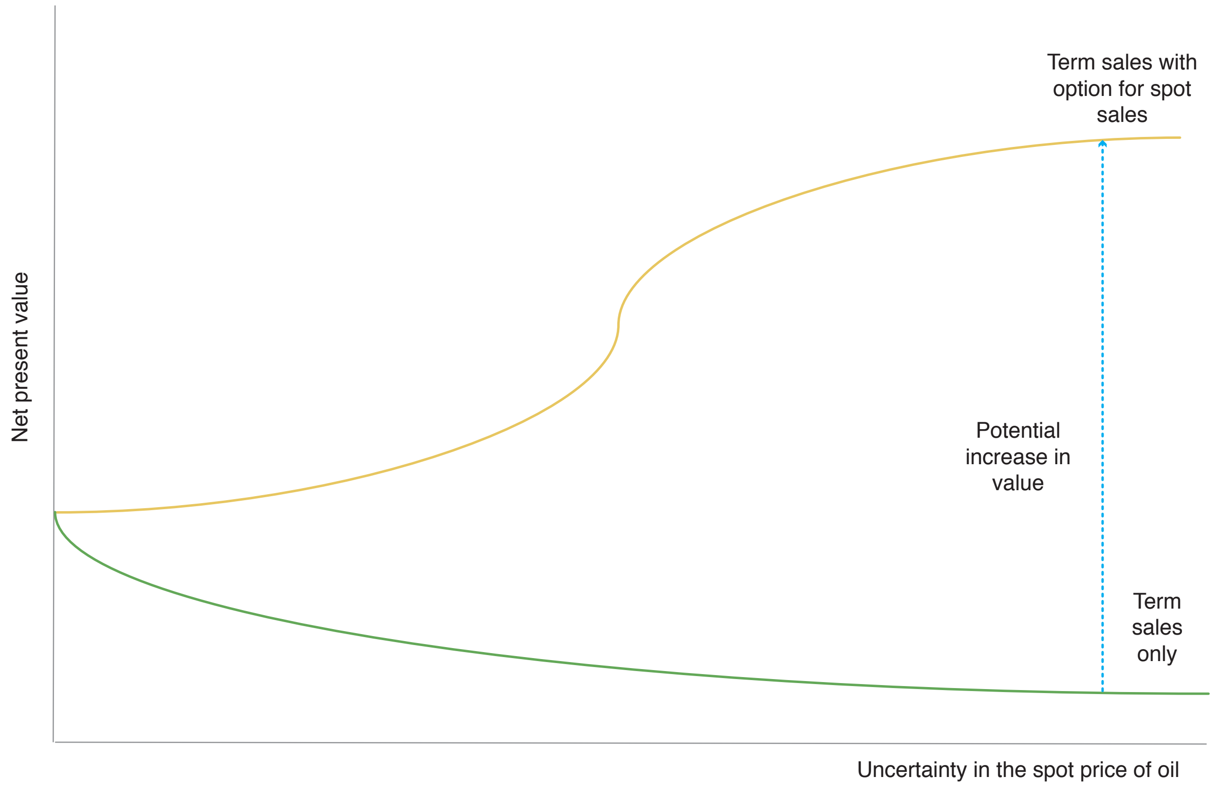
- The option to sell up to 3 MMbbl from one regionally located storage facility per annum has the potential to yield more than 5% additional expected NPV.

- An alternative way of viewing such storage is that it provides a low-cost method of defending market share in highly competitive regions such as Northeast Asia.

Our analysis indicates that if a Middle Eastern producing nation sets up a JOS or agrees on a JOS lease deal with a friendly country located close to the desired end-market, there is a mutually beneficial outcome. The country in which the JOS is located typically gets to use all or some of the stored oil as a strategic crude reserve for use in times of emergency. The producer can capitalize on intermittent spot oil price changes, an option that would not normally be available to such exporters who typically sell the bulk of their oil to Asia on a contract price basis.

Based on the results of the study, a long-distance Middle Eastern supplier can derive clear incremental benefits from the sale of spot crude from a JOS facility located near a major consuming market in China.

Figure 1. Uncertainty can create value.



Source: KAPSARC.

Note: The traditional view holds that because uncertainty reduces the value of a project, it pays to lock into long-term contracts. The real options view is that uncertainty can create value if projects are structured in such a way as to give the decision-maker the right but not the obligation to undertake certain business initiatives, such as the sale of crude oil on the spot market.

Introduction

In this paper, joint oil stockpiling (JOS) refers to a commercial arrangement whereby crude oil, owned and commercially traded by an exporting country, is stored in an importing country in exchange for priority drawdown by the host country in the event of an emergency. It can thus be classified as both commercial and strategic storage (Doshi and Six 2017).

The majority of JOS agreements signed to date have been between the state-owned national oil companies (NOCs) of Middle East oil exporting nations and the governments and/or NOCs of Northeast Asian importers, notably Japan and South Korea.

For the purposes of this study, it is assumed that Saudi Arabian export grade crudes (Arabian Light, Medium, and Heavy) are kept in a storage facility on the east coast of Japan's Okinawa island and sold on the spot market to Chinese independent refiners, through the port of Qingdao in Northeast China, some 1,280 kilometers away.

The use of joint stockpiling agreements for commercial purposes, and projects involving the leasing of parts of national strategic storage facilities, have been gaining popularity with major crude oil producing and trading companies since 2006 (Kilduff 2015). These, in turn, have been used to create regional hubs or distribution centers in the race to capture market share in oil-consuming markets located a long distance from major suppliers, as outlined in 'Joint Oil Stockpiling between Middle East Exporters and Northeast Asian importers' (Doshi and Six 2017).

To cite some examples: In May 2016, South Korea announced plans to construct five new onshore storage tanks in Yeosu, with a combined capacity of 2.5 million barrels (MMbbl) of crude and refined petroleum products. The project was completed in 2017. South Korea uses its storage facilities as international joint stockpiles, with a combined estimated capacity of more than 146 MMbbl (Asghedom 2018). Producers and trading firms lease approximately 24.1 MMbbl of that capacity from the Ulsan Oil Hub project, and an additional 8.2 MMbbl from the onshore tanks at Yeosu. According to Semin Kwon, head of Korea National Oil Corporation's Singapore unit, "The goal is to become the distribution center for not only South Korea, but also other regional players including China and Japan, at a time when they're showing [a] bigger appetite for a wider variety of crude." (Cho 2016). South Korea is planning to double its storage to 60 MMbbl by 2026, with a view to becoming a major regional trading hub.

These deals are not without precedent. The first such agreement between a Middle East oil producer (Kuwait) and an Asian country (South Korea) was agreed in 2006. In 1999, South Korea signed a similar agreement with Norwegian oil company Statoil (now called Equinor).

In early 2016, China was aggressively expanding its strategic petroleum reserves (SPRs) to take advantage of low oil prices which had fallen significantly (from the $109.18 per barrel for West Texas Intermediate [WTI] reported in May 2014 to $36/bbl in February 2016), and issued draft rules in June 2016 permitting local private companies to operate strategic stockpiles. The rules are strict, granting private companies limited rights to fill-in state-run SPRs at selected sites. The 'private' stocks must be held separately from commercial reserves, and compulsory reserves can only be used at the discretion of the state council or cabinet (Wong, Gloystein, and Aizhu 2016).

International Energy Agency SPR commitments

Under the terms of an agreement reached in March 2001, all members of the International Energy Agency (IEA) are committed to maintaining a crude oil reserve equal to 90 days of net oil imports. The terms of the SPR vary across nations, and the situation is slightly different in Japan and South Korea. In Japan, the SPR is composed of three different types of stockpiles: state-controlled reserves, private reserves of petroleum held in accordance with the Petroleum Stockpiling Law, and private reserves of petroleum products. In South Korea, refiners, specific distributors, and importers are obligated to hold 40-60 days of their daily imports, and sales of refined products are based on a lagged 12-month average.

On Jan. 25, 2017, India signed a deal with the Abu Dhabi National Oil Company (ADNOC) to store the latter's crude in a 5.86 MMbbl underground oil storage facility in Mangalore — part of India's strategic petroleum reserve (SPR). According to Sultan Ahmed Al Jabar, the United Arab Emirates (UAE) Minister of State and ADNOC CEO, "We will utilize the Mangalore Facility to not only build on our existing business relationships across India but also to explore new downstream opportunities for ADNOC's expanding range of refined and petrochemical products." (Verma 2017). ADNOC has a similar agreement to store up to 6.29 MMbbl (1 million kilolitres) at the Kiire oil terminal in southern Japan at no cost (Reuters 2017).

Finally, Iraq's State Organization for Marketing of Oil is contemplating the construction of storage facilities in South Korea in an attempt to increase crude sales to Asia (Rasheed 2018).

Spot sales from regional joint stockpiling facilities can enhance major oil companies' (MOCs) market share of local and nearby markets.

This paper develops a methodology to determine the potential incremental value of spot sales from these facilities, from the perspective of a major crude oil producing company located a long distance away from major consuming and refining centers.

Okinawa: An example of a strategic joint stockpiling facility

Okinawa is one of six private bases selected by Japan's Ministry of Economy, Trade and Industry (METI) to facilitate the strategic drawdown of national reserves. In an early stage or pre-emergency, approximately 20 MMbbl of oil would be drawn down from a number of national and private sector bases. The METI order clearly defines the use of a market mechanism to distribute the oil, which will be executed by competitive bidding to successful competitors. The sales bidding is expected to be completed within 13 days of the METI Ministerial Order requesting the drawdown of national reserves in case of an emergency (JNOC 2001). Contracts are awarded to successful bidders over the next seven days of the process.

The response schedule is as follows:

- Day1: METI decides to draw down national reserves
- Day 1-13: A 'Notice of Sale' is issued
- Day 14-20: Contracts are awarded to successful bidders
- Day 21-28: The facility prepares to start drawdown
- Day 21: Crude oil is delivered by tanker to the successful bidder(s) (JNOC 2001).

This paper comprises five sections:

In the first section, ‘Project Assumptions: Calculating the Base Value NPV of Crude Oil Sales from a Joint Stockpiling Leasing Agreement’, a simple net present value (NPV) of term and spot crude oil sales from a joint stockpiling facility in Northeast Asia is calculated from the perspective of a major crude oil producing company in the Middle East. This is the base or reference value of crude oil sales to the Northeast Asian storage facility and the value from which the profits from strategically placed incremental spot oil sales (over and above the reference sales) can be derived, while taking into account the potential implications of a reduction in the general level of crude oil prices resulting from the increase in regional supply.

The second section, ‘The Potential Value of Spot Crude Oil Sales from Joint Stockpiles: A Spread Option,’ formulates and quantifies the problem in terms of a simple European spread option.

In the third section, ‘The Incremental Market Value of Spot Oil Sales from a Joint Stockpiling Leasing Agreement,’ the spread option is modeled and its value is calculated. This value is added to the reference or base case NPV of existing term crude oil sales from a JOS facility.

These first three sections form the basis of analysis for the reference case and assume that the spot sales of crude oil have no impact on world oil prices and that the sale of oil under short-term and long-term contracts to existing customers is unaffected.

In the fourth section, ‘Sensitivity Analysis and Monte Carlo Simulations,’ a number of variables that can significantly change the results of the model are identified. These are selected for sensitivity analysis and modeled in terms of appropriate probability distribution functions. A sensitivity analysis is performed using a Monte Carlo simulation and stepwise multiple regression to determine the regression coefficients of the exogenous variables.

Finally, the paper’s Conclusion outlines some possible areas for further research.

In the Appendices, the project model and assumptions are laid out in detail. These are as follows:

Appendix A: Estimating the Relationship Between Benchmark Dubai Crude and the Three Main Saudi Arabian Export Crude Grades.

Appendix B: The Mathematical Model: A ‘Spread Option’.

Appendix C: Estimating the Relationship between Brent and Saudi Arabian Crudes.

Appendix D: Potential Incremental Value of Spot Sales From the Hypothetical JOS Facility.

Appendix E: Sensitivity Analysis and Monte Carlo Simulation.

Project Assumptions: Calculating the Base Value NPV of Crude Oil Sales From a Joint Stockpiling Leasing Agreement

The reference or base case net present value (NPV) of spot crude oil sales from the leased facilities of a hypothetical joint oil stockpiling (JOS) facility is calculated from the perspective of a major crude oil producing company (MOC) located a long distance away from potentially lucrative market centers. For the purpose of this analysis, the main port of transit (MPT) for a major supplier is located more than 25 days' sailing from key markets in Northeast Asia, such as the Chinese port of Qingdao which services a number of China's independent, or 'teapot', refiners (Finance Insight 2016).

The four assumptions underlying the valuation model are as follows:

1: The MOC can store approximately 6.2 million barrels (MMbbl) of crude oil free of charge throughout the project's lifetime.

2: In return for the free use of storage facilities, the owner of the JOS gets a priority claim on the oil stocks in case of an emergency.

3: The storage facility owner can claim the crude oil storage at the JOS as quasi-government inventory so that about 50% of the oil is counted as part of the host country's national strategic crude oil reserves (Reuters 2016).

4: The value of utilizing a JOS storage facility for commercial purposes derives primarily from its proximity to key markets in Asia. Three days' sailing at average speeds allows the sale of spot crude from the JOS to buyers in the region. From the MOC's perspective, this adds considerable value given that the voyage from a major Middle East oil export port to, for example, Qingdao, China, takes well over 25 days – too long for profitable spot sales to the area.

In our hypothetical case study, a regionally sited JOS (on the island of Okinawa, Japan) provides storage facilities for 6.2 MMbbl crude and refined oil products. Assuming 50% of these volumes are reserved for strategic stockpiles, with 0.99% slippage, about 3 MMbbl can be used for spot sales to Asian markets (any potential slippage is

Hypothetical terms of operation

Under the terms of our hypothetical agreement, the volumes of crude oil supplies are held in storage by the MOC and can be used to supply Asian customers on a term basis, for term sales or long-term deals signed months in advance. Their use for spot sales during times of high oil prices is relatively new and adds considerable value to any such joint storage agreement.

Concerning the effects of an increased supply of crude on the crude oil price, the study assumes liquid forward and futures markets, so that all of these operations can be completed and hedged at the market prices at the time of execution.

Finally, a number of factors leading to tight markets, and supply and demand shocks can contribute to a sudden and short-term increase in spot prices in Asia. For example, independent refiners in China are often caught short at the end of the year as they struggle to meet the provincial government's crude oil import targets (Platts 2016).

due to leaks and errors in the physical drawdown procedure). This value is a conservative minimum approximation. Any major oil producing or marketing company will have the capacity to send very large crude carriers (VLCCs) carrying up to as much as 2.1 MMbbl each and even ultra large crude carriers (ULCCs) carrying up to 3 MMbbl each, rotating between a major port in close proximity to the supply source and a JOS.

Assuming crude oil production costs of $3/bbl, transportation costs from the MPT to the JOS of $1.65/bbl and a sale of 100% Arabian Medium crude, the gross income from these sales, at spot oil prices at time of writing (late 2018), is approximately $98 million per annum, yielding a NPV of $1.45 billion at a 2.5% discount rate (see Table 1).

Table 1. NPV of spot crude oil sales from the JOS.

		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Physical quantities million barrels																
Storage capacity		6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20
Required strategic oil		3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
Slippage	99%															
Percent of strategic oil required	50%															
Physical quantities million barrels																
Storage capacity		6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13
Required strategic oil		3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07
Contract revenue																

Project Assumptions: Calculating the Base Value NPV of Crude Oil Sales From a Joint Stockpiling Leasing Agreement

		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Crude oil futures Dubai ICE		$48.66	$46.96	$50.22	$52.43	$53.59	$41.31	$41.31	$41.31	$41.31	$41.31	$41.31	$41.31	$41.31	$41.31	$41.31
Arab Light		$48.21	$46.43	$49.84	$52.14	$53.36	$40.53	$40.53	$40.53	$40.53	$40.53	$40.53	$40.53	$40.53	$40.53	$40.53
Volume of Arab Light	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Assumed % of Arab Light																
Arab Medium		$46.90	$45.14	$48.53	$50.82	$52.03	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27	$39.27
Volume of Arab Medium	100%	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07	$3.07
Assumed % of Arab Medium																
Arab Heavy		$45.22	$43.48	$46.82	$49.08	$50.27	$37.69	$37.69	$37.69	$37.69	$37.69	$37.69	$37.69	$37.69	$37.69	$37.69
Volume of Arab Heavy	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Assumed % of Arab Heavy																
Total revenue																
Spot sales revenue AL $million		$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
Spot sales revenue AM $million		$143.88	$138.47	$148.85	$155.89	$159.60	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46
Spot sales revenue AL $million		$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
Total revenue		$143.88	$138.47	$148.85	$155.89	$159.60	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46	$120.46

Project Assumptions: Calculating the Base Value NPV of Crude Oil Sales From a Joint Stockpiling Leasing Agreement

NPV	Gross income without option value: EBITDA		Total operating expenses	Other	Operating	Operating expenses	Transportation cost from MPT to JOS	Production costs	Production costs per barrel	Crude oil supplies	Costs of crude oil supplies	Inflation	
							(At $1.65/Bbl)		$3.00			2.5%	
$126.09	$128.61	$-	$15.26	$0.50	$0.50		$5.06	$9.20					**2016**
$244.14	$122.82	$-	$15.65	$0.51	$0.51		$5.19	$9.43					**2017**
$369.30	$132.81	$-	$16.04	$0.53	$0.53		$5.32	$9.67					**2018**
$498.13	$139.45	$-	$16.44	$0.54	$0.54		$5.45	$9.91					**2019**
$627.42	$142.75	$-	$16.85	$0.55	$0.55		$5.59	$10.16					**2020**
$719.05	$103.19	$-	$17.27	$0.57	$0.57		$5.73	$10.41					**2021**
$808.51	$102.76	$-	$17.70	$0.58	$0.58		$5.87	$10.67					**2022**
$895.84	$102.32	$-	$18.14	$0.59	$0.59		$6.02	$10.94					**2023**
$981.07	$101.86	$-	$18.60	$0.61	$0.61		$6.17	$11.21					**2024**
$1,064.26	$101.40	$-	$19.06	$0.62	$0.62		$6.32	$11.49					**2025**
$1,145.42	$100.92	$-	$19.54	$0.64	$0.64		$6.48	$11.78					**2026**
$1,224.61	$100.43	$-	$20.03	$0.66	$0.66		$6.64	$12.07					**2027**
$1,301.87	$99.93	$-	$20.53	$0.67	$0.67		$6.81	$12.38					**2028**
$1,377.21	$99.42	$-	$21.04	$0.69	$0.69		$6.98	$12.69					**2029**
$1,450.69	$98.89	$-	$21.57	$0.71	$0.71		$7.15	$13.00					**2030**

Source: Internal KAPSARC calculations.

Project Assumptions: Calculating the Base Value NPV of Crude Oil Sales From a Joint Stockpiling Leasing Agreement

Arabian Medium is – as the name suggests – the main medium gravity grade crude exported by Saudi Arabia. For physical spot sales it, and most other regional crudes, is priced at a differential to the regional crude benchmark, Dubai, as assessed by the United States (U.S.)-based price reporting agency Platts, a division of S&P Global (Platts 2018).

Table 1 lists the assumptions underlying these projections for sales of Arabian Medium export crude on a free on board (FOB) basis at the MPT, no taxes, or operating expenses for the facility, free lease of crude oil storage, 50% strategic oil requirements and spot sales of 3 MMbbl per year from a regional JOS facility.

We used the futures curve for benchmark Dubai crude to estimate the futures curves for the three main grades of Saudi Arabian export crudes (CME Group 2016). Specifically, the relationship between Arabian Medium and Dubai Mo01 was estimated by simple two-variable regression analyses. Appendix A presents the results of these analyses.

Note: Dubai is the regional crude benchmark; Arabian Light, Medium and Heavy are Saudi Arabia's three main export grades. Mo01 refers to the current month until two calendar days before the end of the month (Platts 2018).

We construct a base case scenario in which we assume 50% of the storage facility's crude oil capacity is available for sale on the spot market once per annum. We also assume that there is a 21-28 day period required between a ministerial order for strategic drawdown and delivery, and a 24-day vessel journey from the MPT to Qingdao port and other similar markets in Northeast Asia. Under these assumptions, there is ample opportunity to make more than one trip per year. Many such trips could be made per year without disrupting the crude oil supplies available for strategic purposes.

The assumed reference level of crude oil sales from the JOS, of 3 MMbbl per year, is a very conservative estimate. Clearly, given the capacity to make numerous deliveries of crude oil to the JOS per year in order to replenish the required volume of strategic oil inventories, the facility holds substantially more capacity for short-term sales than the base value presented in Table 1.

The Potential Value of Spot Crude Oil Sales From Joint Stockpiles: A 'Spread Option'

The potential incremental value of spot crude oil sales from the JOS facility can be estimated by calculating how much a market player would pay to secure the right to purchase crude oil from a NOC delivered to the JOS at market prices (Durrleman and Carmona 2003). That value, in turn, will depend on the price of crude oil from competitors around the world and can be estimated as a simple European spread option.

Spread options derive their value from the difference in prices between two or more assets. They are generally traded over the counter (OTC) rather than on an exchange. In commodity markets spread options are often based on the difference in asset prices between two or more locations, points on the calendar, grades or quality of the energy source, and inputs versus outputs in the production process, such as spark spreads and crack spreads (Carmona and Durrleman 2003). This example is based on location spread or the difference between crude oil prices in two different locations.

The fair value of the spread call option reflects the fair market value of the right, but not the corresponding obligation, to purchase spot crude from the NOC, FOB at the JOS, for final delivery to nearby Asian markets (e.g., Qingdao) at a given exercise price at a future date. The exercise, or strike, price is the cost of transporting the crude oil between the JOS and Qingdao at some future date, *t*.

In short, the potential incremental value of sales of spot crude, in this case Arabian Medium, from the JOS, can be valued as the fair value of a spread call option between two points:

1. Crude deliveries FOB JOS at time *t*.

2. Crude deliveries FOB to Qingdao port, China at time *t*.

Note: The distance from the study's JOS in Naha Okinawa, Japan to Qingdao, China is approximately 736 nautical miles and takes just over three days to complete at an average speed of 10 knots (sea-distances.org and KAPSARC Global Trade Oil Model).

Appendix B specifies the mathematical model for a spread option and provides more detail. However, in summary, the project assumptions specifying the terms of the option are:

1. Type of exercise right: European.

2. Exercise price level: the cost of freight to transport the crude oil from the JOS to Qingdao.

3. Expiration date: two months.

The call spread option is considered to be in the black if the cost of transporting a competing crude to Qingdao, minus the price of Arabian Medium FOB at the JOS, is greater than the cost of transporting the crude from the JOS to Qingdao. The option is out of the money when the cost of getting a competing crude to Qingdao, minus the price of Arabian Medium FOB at the JOS, is less than or equal to the cost of transporting the crude from the JOS to Qingdao.

Once estimated, the option's fair market value will give an excellent approximation of the value of the transportation between the JOS and Qingdao. Or equivalently, the option's value reflects the amount of money a market player would pay to a MOC today — over and above the transportation costs — to reserve the right to buy spot crude for delivery at a future date.

Unsurprisingly, given the volatility of crude oil prices, the level of competition for market share in Asia can be significant and includes a number of shipments from distances exceeding 20 sailing days. To cite one example, China imported crude oil from the U.S. and Canada, including 213,705 bbl transported from the San Francisco area in April 2015 (Bloomberg 2015). Since that time, Chinese imports from the U.S. have continued to increase, exceeding 8 MMbbl of U.S. light crude in February 2017 (Traywick and Tobben 2017).

The price p, or the fair market value of the European spread option, is given by the following equation, detailed in Equations 1-7 in Appendix B:

$$p = e^{-rT} \iint (s_2 - s_1 - K)^+ f_T(s_1 s_2) d_{s_1} d_{s_2}$$

Where:

1. K = The exercise price level: The cost of freight to transport crude from JOS to Qingdao.

2. T = The expiration date: The option is expected to expire two months after the value or settlement date.

3. $S_1(0)$ = The price of crude FOB at Qingdao port.

4. $S_2(0)$ = The price of MOC crude of comparable API FOB at the JOS at time t. (The American Petroleum Industry [API] measure of gravity is the standard industry measure of how light or heavy a petroleum liquid is when compared to water, ie., its density).

5. r = The short-term risk-free interest rate.

Note: The spot price of Arabian Heavy, Medium and Light (as assessed by Platts) plus the cost of sea transportation from the MPT to the JOS, of approximately $1.65/bbl, was estimated using sea-distances.org, and the KAPSARC Global Trade Oil Model, with the total cost estimated using the KAPSARC Global Trade Oil Model (AlKathiri et al. 2017).

A detailed list of the inputs or exogenous variables used in this analysis is presented in Appendix B. Given these assumptions, the solution to the above equation, which is the price or fair market value of the option calculated for three separate grades of crude, is:

1. Arabian Light vs. Minimum Light Grade = $1.14/bbl.

2. Arabian Medium vs. Minimum Medium Grade = $0.00.

3. Arabian Heavy vs. Minimum Heavy Grade = $0.10.

Note: The zero fair market value for Arabian Medium versus the Minimum Medium Grade arises from the spot prices at the time of estimation using the most recent data for 2016. At mid-year 2016 the spot price for Arabian Medium was $46.90/bbl, significantly higher than the minimum price of competing crudes, which averaged $41.83/bbl. (The calculation for the minimum price of competing crudes is described in detail in Appendix B).

In short, given market conditions at the time of valuation, the most value to be derived from the sale of Arabian Medium crude arises from competition with lighter grades, specifically Arabian Light (34 API versus Russian ESPO 34.8 API) plus transportation costs from the Russian far-east port of Kozmino to Qingdao. Given market conditions at the time of estimation, spot sales to this area were highly profitable, and market participants were willing to pay a premium of up to $1.14/bbl simply to reserve the right to purchase Arabian Light at market prices FOB from the JOS for delivery two months from the settlement date. Appendices A, B and C provide a concise description of the mathematical model and estimation techniques used to calculate these values.

> Appendix A: Estimating the Relationship Between Dubai and Arabian Crudes.

> Appendix B: The Mathematical Model: A ‘Spread Option’.

> Appendix C: Estimating the Relationship Between Brent and Arabian Crudes.

The Incremental Market Value of Spot Oil Sales From a Joint Stockpiling Leasing Agreement

As mentioned in earlier sections of this paper, the JOS used in this study provides storage facilities for approximately 6.2 MMbbl of crude. Assuming 50% of these reserves can be freed up for spot sales to Asian markets, and that one delivery per year, approximately 3 MMbbl, will be available for spot sales from the JOS. This is a very conservative estimate given that there will be sufficient time to make numerous trips in a year without disrupting the crude supplies in the JOS reserved for strategic purposes.

It is possible to monetize the value of these transactions through the sale of options reflecting the right, but not the corresponding obligation, to purchase crude oil at market prices FOB from the JOS, for delivery FOB to Qingdao. As seen above, the value or fair market price of such a transaction is equal to the price of a spread option between Arabian Light FOB at the JOS and the minimum cost of light crudes FOB at Qingdao, with a strike or exercise price equal to the cost of transporting the crude from the JOS to Qingdao.

Note: MOCs can deliver crude oil supplies as needed to the hypothetical JOS facility, as they can easily replenish their stocks with weekly, even daily, deliveries from VLCCs. Assuming 16-inch diameter pipes capable of moving 75,000 bbl of crude an hour, it can take 40 hours to offload a 3 MMbbl capacity supertanker (Maslowski 2011). Note: MOCs often own their own fleet of VLCCs and if not are able to get excellent terms on time charter deals.

To forecast the potential value of incremental sales of spot crude from the JOS facility, it is necessary to have some estimate of the futures prices for Arabian crude. The futures curve for Dubai crude was used to estimate the futures curves for Arabian crudes from September 2016 to 2030 (CME Group 2016). The forward curve for Arabian Light, Medium and Heavy were estimated using the relationships defined in Table A1 of Appendix A.

Similarly, the futures curve for Brent crude was used to estimate the futures curves for the minimum price of crude delivered FOB at Qingdao (CME Group 2016). Specifically, the relationships between Brent and the minimum price of light, medium and heavy crudes from competing areas were estimated by a simple two-variable regression analysis. Table C1 of Appendix C presents the results of this analysis.

Appendix D gives a concise description of the mathematical model and estimation techniques.

As before, the price p, or equivalently the fair market value of the European spread option, can be calculated using the equation provided in Appendix B. The solution, the fair market values for the options, and annual options values of the JOS facility are listed in Table D1, Appendix D, for Arabian Light, Medium and Heavy crudes.

The market value of all spot oil sales from the hypothetical JOS storage facility is equal to the NPV of the reference case, plus the options values shown in Appendix D. Given Middle East crude oil production costs of $3/bbl, transportation costs from the MPT to the JOS of $1.65/bbl and assumed spot sales FOB from the JOS of 33% of the available capacity of Arabian Medium, 33% of Arabian Heavy and 33% of Arabian Light crude, the project assumption or reference case gross revenue from these sales is approximately $107 million per annum. This yields an NPV of $1.606 billion at a 2.5% discount rate (see Table 2).

Note: The crude mix assumption reflects the balanced diversification of China's crude oil import portfolio: "By 2010, China's oil import portfolio became remarkably diversified in terms of sulfur contents, thanks to the ongoing large-scale addition of desulfurization capacity." (Kim 2016).

Adding the options value from spot oil sales increases this value significantly by approximately $118 million per annum. If the cash flows are not necessarily periodic, the expected net present value (XNPV) can be calculated for the project and equals approximately $1.775 billion over the 15 years from 2016 to 2030 (see Appendix D and Table 2).

Note: When cash flows are not necessarily periodic, the formula for NPV must be modified slightly to accommodate the actual cash flow. The revised NPV formula, XNPV, is shown in Appendix D.

Table 2. NPV of crude oil sales plus optionality.

		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	XNPV
Physical quantities million barrels																	
Storage capacity		6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	
Required strategic oil		3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	
Slippage	0.99																
Percent of strategic oil required	52%																
Physical quantities million barrels																	
Storage capacity		6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	
Required strategic oil		3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	
Contract revenue																	

The Incremental Market Value of Spot Oil Sales From a Joint Stockpiling Leasing Agreement

Total revenue	Spot sales revenue AL $million	Spot sales revenue AM $million	Spot sales revenue AL $million	Total revenue	Assumed % of Arab Heavy	Volume of Arab Heavy	Arab Heavy	Assumed % of Arab Medium	Volume of Arab Medium	Arab Medium	Assumed % of Arab Light	Volume of Arab Light	Arab Light	Crude oil futures Dubai ICE	
						33%			33%			33%			
$139.18	$44.85	$46.52	$47.81			$0.99	$45.22		$0.99	$46.90		$0.99	$48.21	$48.656	**2016**
$133.95	$43.12	$44.77	$46.05			$0.99	$43.48		$0.99	$45.14		$0.99	$46.43	$46.9586	**2017**
$143.99	$46.43	$48.13	$49.43			$0.99	$46.82		$0.99	$48.53		$0.99	$49.84	$50.2169	**2018**
$150.79	$48.67	$50.40	$51.72			$0.99	$49.08		$0.99	$50.82		$0.99	$52.14	$52.4257	**2019**
$154.39	$49.86	$51.60	$52.92			$0.99	$50.27		$0.99	$52.03		$0.99	$53.36	$53.5922	**2020**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2021**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2022**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2023**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2024**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2025**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2026**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2027**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2028**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2029**
$116.53	$37.39	$38.95	$40.20			$0.99	$37.69		$0.99	$39.27		$0.99	$40.53	$41.3070	**2030**
$1,886.74															**XNPV**

	NPV	Gross income without option value: EBITDA	Total operating expenses	Facilities	Other	Operating	Operating expenses	Transportation cost from MPT to JOS	Production costs	Production costs per barrel	Crude oil supplies	Costs of crude oil supplies	Inflation
						52%		(At 1.67/Bbl)		$3.25			2.50%
2016	$123.52	$123.52	$15.66	$-	$0.50	$0.52		$4.97	9.67				
2017	$241.41	$117.90	$16.05	$-	$0.51	$0.53		$5.09	9.91				
2018	$368.95	$127.53	$16.45	$-	$0.53	$0.55		$5.22	10.16				
2019	$502.88	$133.93	$16.86	$-	$0.54	$0.56		$5.35	10.41				
2020	$639.98	$137.10	$17.28	$-	$0.55	$0.57		$5.48	10.67				
2021	$738.79	$98.81	$17.72	$-	$0.57	$0.59		$5.62	10.94				
2022	$837.17	$98.37	$18.16	$-	$0.58	$0.60		$5.76	11.21				
2023	$935.08	$97.92	$18.61	$-	$0.59	$0.62		$5.91	11.49				
2024	$1,032.53	$97.45	$19.08	$-	$0.61	$0.63		$6.05	11.78				
2025	$1,129.51	$96.97	$19.56	$-	$0.62	$0.65		$6.21	12.08				
2026	$1,225.99	$96.49	$20.04	$-	$0.64	$0.67		$6.36	12.38				
2027	$1,321.98	$95.98	$20.55	$-	$0.66	$0.68		$6.52	12.69				
2028	$1,417.45	$95.47	$21.06	$-	$0.67	$0.70		$6.68	13.01				
2029	$1,512.39	$94.94	$21.59	$-	$0.69	$0.72		$6.85	13.33				
2030	$1,606.80	$94.40	$22.13	$-	$0.71	$0.73		$7.02	13.66				
XNPV		$1,606.09											

The Incremental Market Value of Spot Oil Sales From a Joint Stockpiling Leasing Agreement

	NPV	Gross income: EBITDA	Gross income: EBITDA	Intrinsic value of spot oil sales from JOS	Incremental value of strategic option	Total revenue from strategic options $ million	Percent of storage capacity	Revenue from spot sales of Arab Heavy $/bbl	Revenue from spot sales of Arab Medium $/bbl	Revenue from spot sales of Arab Light $/bbl	Optionality. Spreadoptions ROV
							50%				Options Premium
2016	**$134.82**	$134.82	$134.82	$123.52	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2017	**$264.01**	$129.19	$129.19	$117.90	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2018	**$402.84**	$138.83	$138.83	$127.53	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2019	**$548.07**	$145.23	$145.23	$133.93	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2020	**$696.47**	$148.40	$148.40	$137.10	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2021	**$806.59**	$110.11	$110.11	$98.81	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2022	**$916.26**	$109.67	$109.67	$98.37	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2023	**$1,025.47**	$109.22	$109.22	$97.92	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2024	**$1,134.22**	$108.75	$108.75	$97.45	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2025	**$1,242.49**	$108.27	$108.27	$96.97	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2026	**$1,350.28**	$107.78	$107.78	$96.49	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2027	**$1,457.56**	$107.28	$107.28	$95.98	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2028	**$1,564.33**	$106.77	$106.77	$95.47	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2029	**$1,670.57**	$106.24	$106.24	$94.94	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
2030	**$1,776.28**	$105.70	$105.70	$94.40	$11.30	$11.30	$3.07	$0.95	$0.00	$10.34	
XNPV		$1,775.49	$1,775.49			$169.40					

Source: Internal KAPSARC calculations.

Sensitivity Analysis and Monte Carlo Simulations

It will not surprise readers well-versed in the intricacies of the global crude oil supply chain that a number of the assumptions used in this analysis are extremely conservative. Uncertainty in global commodity markets and geopolitical and fiscal risks have the potential to change the results of the analysis significantly. The use of stochastic modeling techniques can accommodate and model these risks. Appendix E outlines the mathematical models and estimation techniques used in this case study.

In the case of spot oil sales from the JOS facility, the key economic variables subject to commodity and transaction risks include the amount of crude oil required to be maintained at the facility at all times for strategic purposes, commodity prices, costs and the project discount rate. The following variables were selected for sensitivity analysis:

1. Amount of crude oil required in the facility at all times for strategic purposes.
2. Project discount rate.
3. Slippage.
4. Production costs per barrel.
5. Transportation costs from the MPT to the JOS.
6. Brent futures.
7. Dubai futures.

Probability density functions for these variables were estimated using a historical data series. Appendix E describes the estimated distributions in detail (see Equations 9 and 10). Given the probability density functions for the uncertain variables, Monte Carlo simulations were performed utilizing a Mersenne Twister random number generator and Latin hypercube sampling methodology.

The potential value of spot oil sales from the JOS is equal to the XNPV of the assumed 'reference case' crude oil sales, plus the XNPV of the options value, as shown in Table 2. Given the expected value of crude oil forward prices, crude oil production costs of $3/bbl, transportation costs from the MPT to the JOS of $1.65/bbl and assumed spot crude oil sales FOB from the JOS of 33% of the available capacity of Arabian Medium, 33% of Arabian Heavy and 33% of Arabian Light crude, the project yields a 'base case' XNPV of $3.43 billion at a 2.5% discount rate. Note: This value is considerably higher than the value estimated in the previous section due to the higher expected oil price.

Adding the options value increases this amount significantly, by well over 6%, or $221 million. Table E1 of Appendix E compares the results of our analysis with and without additional options value. As might have been expected, adding the optionality of spot oil sales increases the minimum XNPV of gross revenue from total term and spot oil sales from $469 million to $1.54 billion, thereby significantly reducing the price risk or the downside of the project.

A sensitivity analysis was performed to illustrate the effects of economic uncertainty on the value of term and spot crude oil sales, using stepwise multiple regression to estimate the regression coefficients of the exogenous variables (Draper and Smith 1966). Table 3, and Figures 2 and 3 present the results of this regression and the estimated regression coefficients.

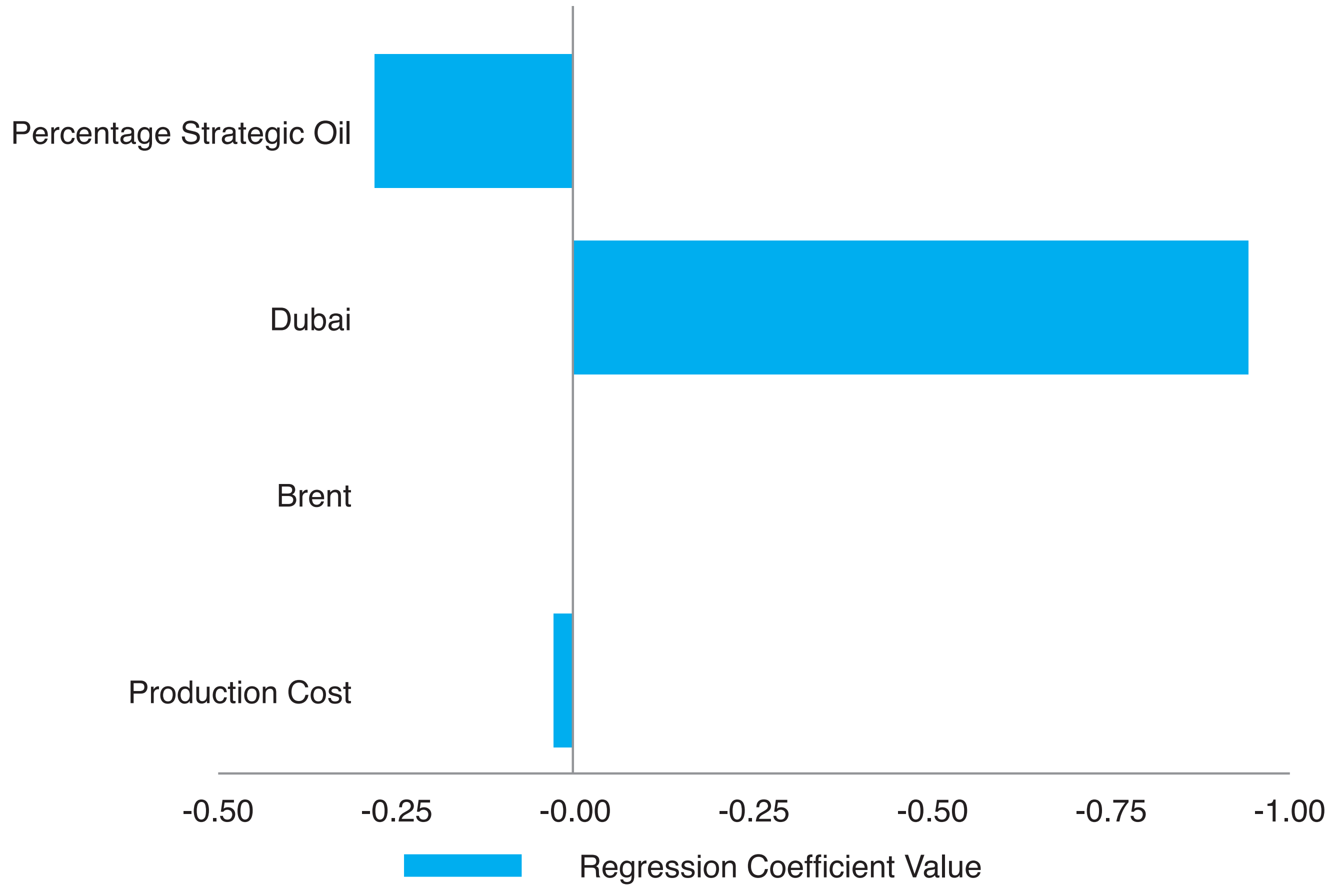
Sensitivity Analysis and Monte Carlo Simulations

The first variable to be considered with a significant impact on the NPV of incremental spot oil sales from the JOS facility is the amount of strategic oil supplies required to remain in the storage tanks at all times for emergency drawdown. A 1% increase in the amount of oil that must remain in storage reduces the potential for commercial spot oil sales, and therefore gross earnings before income and taxes (EBIT) plus the options value, by well over $7 million.

The implications on gross income, or EBIT, for the reference or base case spot crude oil sales from the JOS storage facility is significant. Even without the additional optionality offered by the value placed on the ability to secure safe supplies of MOC crude at market prices, a 1% reduction in the amount of oil that must be reserved for strategic purposes raises the expected income of the project by more than $7.1 million.

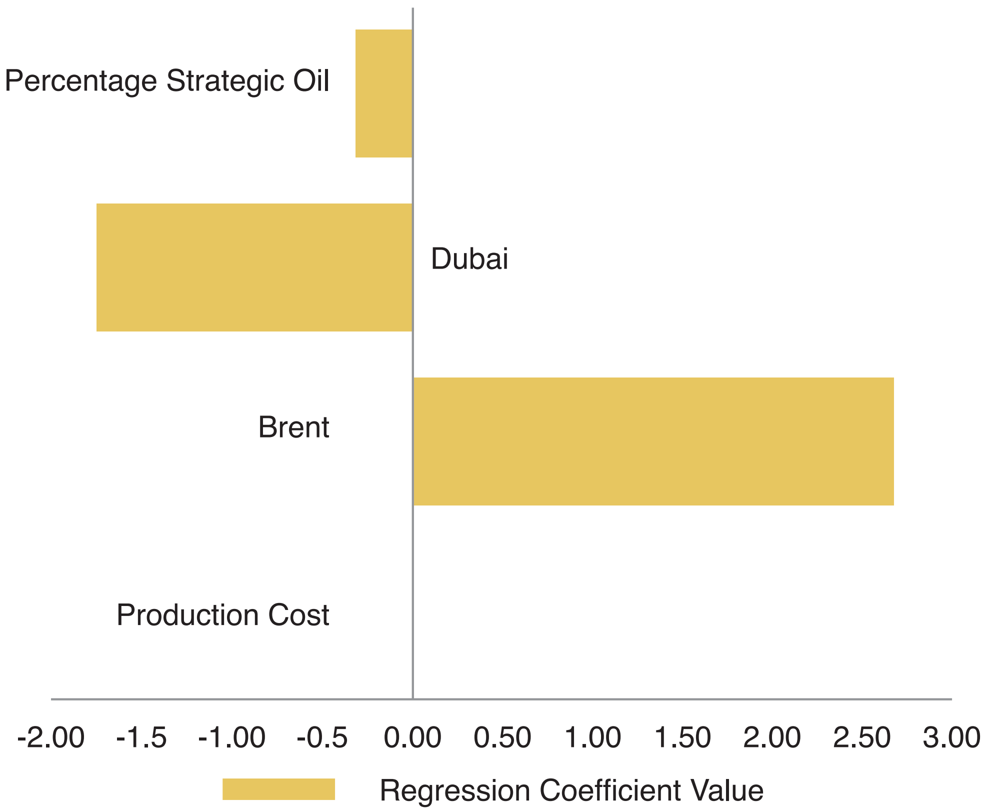
The next variable is the forward curve for Dubai crude. A $1/bbl increase in the price of Dubai increases the value from the reference case crude sales FOB to Qingdao by approximately $46 million (see Table 3).

Figure 2. Regression coefficient sensitivity analysis for gross income assuming no optionality.



Source: Internal KAPSARC calculations.

Figure 3. Regression coefficient sensitivity analysis for gross income plus options value.



Source: Internal KAPSARC calculations.

The final step in the analysis is to measure the implications of a change in crude oil prices on the value of incremental spot oil sales, taking the potential effects on the price received for the base case oil sales from the JOS facility. The regression coefficients for gross income plus the options value of spot crude oil sales depend on the spread — or difference — between spot prices for Arabian crudes FOB at JOS and the minimum price of competing crudes FOB to Qingdao (see Figure 1). In this case, it is the relative movement in prices that determines the market value placed on the ability to reserve the right to purchase MOC crude at spot prices at a future date, in order to hedge or protect against sudden adverse price movements.

An increase in the price of Brent relative to Dubai adds significant value to spot oil sales from the JOS facility. All else being equal, a $1/bbl increase in the price of Brent M1 increases the XNPV of gross income EBIT plus the options value by $121 million. A $1/bbl reduction in the price of Dubai increases the XNPV of the reference case short- and long-term oil sales, plus the incremental spot oil sales from the JOS facility by $80 million. Incremental spot oil sales that increase the differential — Brent minus Dubai — will tend to have positive implications for gross income EBIT for a MOC.

For the purpose of this analysis, the expected value of the real option reflects the amount of money a market player would currently pay to a MOC — over and above the transportation costs — to reserve the right to buy spot crude at JOS for delivery at a future date.

Table 3. Sensitivity analysis.

Sensitivity analysis for gross income EBITDA assuming no optionality			
Variable	**Standard deviation**	**Regression coefficient value**	**Coefficient in original units**
Output variable			
Gross income EBIT	1,261.41		
Input variables			
Percent strategic oil	4.91%	-0.28	(7.20)
Dubai	25.7	0.95	46.63
Brent	26.17		-
Production costs	3.25	-0.03	(11.64)
Volume of Arab Light	0.12	0.01	$1.26
Volume of Arab Heavy	0.12	-0.01	-$1.26
Transportation costs	0.07	0.00	$91.95
Number of cycles	3.46		
Slippage costs	0.69		

Sensitivity analysis for gross income EBITDA assuming no optionality			
Variable	**Standard deviation**	**Regression coefficient value**	**Coefficient in original units**
Output variable			
Gross income EBIT	1,261.41		
Input variables			
Percent strategic oil	4.91%	-0.28	(7.20)
Dubai	25.7	0.95	46.63
Brent	26.17		-
Production costs	3.25	-0.03	(11.64)
Volume of Arab Light	0.12	0.01	$1.26
Volume of Arab Heavy	0.12	-0.01	-$1.26
Transportation costs	0.07	0.00	$91.95
Number of cycles	3.46		
Slippage costs	0.69		

Source: Internal KAPSARC calculations.

Conclusion

The ability to make spot crude oil sales from a JOS located close to major demand centers represents a potential source of value to crude oil producers and marketers. That value can be estimated for a variety of facilities and under a number of different market conditions using the options valuation method developed in this case study. To cite two examples: South Korea's storage facility in Yeosu and India's underground site at Mangalore have been utilized to facilitate spot crude oil sales to established markets.

The potential value from these additional spot sales will depend on a number of factors, including the volatility of crude oil prices and the proximity of alternative suppliers. Under our analysis, the valuation of spot oil sales from a joint oil stockpiling facility follows the 'real options' style approach cited in a number of studies, including Durrleman and Carmona (2003) and Carmona and Durrleman (2003).

Given the ability to make numerous spot sales of crude oil from the JOS facility in any given year, the facility holds substantially more value than a simple NPV calculation would suggest. The incremental or 'options' value of spot oil sales from the JOS facility depends on the price of crude oil from competitors around the world and can be estimated as a simple European spread option.

> The incremental value of spot oil sales from the JOS facility is calculated as the XNPV of a European spread option.

> Given: (i) crude oil production costs of $3/bbl and (ii) transportation costs from a major transportation port to a strategic facility in Northeast Asia, the project yields an incremental expected value XNPV of $221 million at a 2.5% discount rate.

> The additional options value increases the potential value of spot oil sales from the JOS significantly, by well over 6%.

> Incremental spot oil sales that increase the differential — Brent minus Dubai — will tend to have positive implications for gross income EBIT for a major oil producing company.

The capacity to use strategic storage facilities in times of surplus on world oil markets presents considerable potential value to major crude oil producing companies. That value can be estimated utilizing an options valuation model.

Given the framework and model construction, there is considerable potential for further study and analysis, including:

1. Stochastic optimization techniques designed to maximize the options value through the choice of an optimal mix of Arabian Heavy, Medium and Light crudes.

2. Stochastic optimization techniques designed to forecast the sale of spot crudes to select markets in North America, Latin America, Asia and Europe.

3. Further sensitivity analysis investigating the effects of changes in transportation (tankers and rail), production and storage charges.

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Appendix A: Estimating the Relationship Between Benchmark Dubai Crude and the Three Main Saudi Arabian Export Crude Grades

The futures curve for Dubai crude was used to estimate the futures curves for Arabian crudes (CME Group 2016; Platts 2016). Specifically, the relationship between Arabian Light, Medium and Heavy crudes and Dubai Mo01 was estimated by simple two-variable regression analyses. Table A1 presents the results of these analyses. Note: This is a very simple analysis of the differential between Dubai and Saudi crudes. A more detailed analysis would include a more detailed econometric assessment of the price differential, the inclusion of Oman pricing, and adjustment factors for quality analysis, and is a recommended area for future research.

Table A1. Regression results.

Regression equation						
Arab Light = - 2.62482437 + 1.04466961 Dubai Mo01						
Multiple regression for Arab Light	Multiple R	R-square	Adjusted R-square	Std. err. of estimate		
Summary						
	0.9988	0.9977	0.9977	1.469644856		
	Degrees of freedom	Sum of squares	Mean of squares	F	p-value	
ANOVA table						
Explained	1	779305.7339	779305.7339	360813.7453	< 0.0001	
Unexplained	838	1809.959331	2.159856003			

	Coefficient	Standard error	t-value	p-value	Confidence interval 95%	
Regression table					lower	upper
Constant	-2.624824375	0.139083278	-18.87232173	< 0.0001	-2.897816878	-2.351831872
Dubai Mo01	1.044669609	0.001739152	600.6777383	< 0.0001	1.041256004	1.048083214

Regression equation
Arab Medium + (Dubai+Oman)/2 = - 3.63390492 + 1.03867596 Dubai Mo01

Appendix A: Estimating the Relationship Between Benchmark Dubai Crude and the Three Main Saudi Arabian Export Crude Grades

Regression equation

Multiple regression for Arab Medium + (Dubai+Oman)/2	Multiple R	R-square	Adjusted R-square	Std. err. of estimate		
Summary						
	0.9984	0.9968	0.9968	1.724515299		

	Degrees of freedom	Sum of squares	Mean of squares	F	p-value	
ANOVA table						
Explained	1	766770.2355	766770.2355	257828.6312	< 0.0001	
Unexplained	835	2483.250769	2.973953017			

	Coefficient	Standard error	t-value	p-value	Confidence interval 95%	
Regression table					lower	upper
Constant	-3.633904924	0.16334807	-22.24639025	< 0.0001	-3.954526	-3.313283847
Dubai Mo01	1.038675962	0.002045571	507.7682849	< 0.0001	1.034660897	1.042691027

Regression equation

Arab Heavy + (Dubai+Oman)/2 = - 4.58852152 + 1.0236342 Dubai Mo01

Multiple Regression for Arab Heavy + (Dubai+Oman)/2	Multiple R	R-square	Adjusted R-square	Std. err. of estimate		
Summary						
	0.9982	0.9964	0.9964	1.804711746		

	Degrees of freedom	Sum of squares	Mean of squares	F	p-value	
ANOVA table						
Explained	1	744722.8206	744722.8206	228654.0889	< 0.0001	
Unexplained	835	2719.582047	3.256984488			

	Coefficient	Standard error	t-value	p-value	Confidence interval 95%	
Regression table					lower	upper
Constant	-4.588521516	0.17094437	-26.84219148	< 0.0001	-4.924052678	-4.252990354
Dubai Mo01	1.023634203	0.002140698	478.1778842	< 0.0001	1.019432423	1.027835984

Sources: Energy Aspects; Bloomberg.

Appendix B: The Mathematical Model: A 'Spread Option'

For the sake of simplicity, the analysis was restricted to the case of a simple European style spread option between two underlying assets. U.S. options are considerably more difficult to value than European style options because they can be exercised at any time before the expiry date. The analysis can be extended to American style spread options between more than one asset, or even a basket or portfolio of assets (Borokova, Permana, and van der Weide May 2012). Alternatively, Natarajan examines the pricing process for a class of multi-asset European options based on a piecewise linear convex payoff in asset prices (Natarajan 2007). Both of these methodologies can add value to the analysis and are recommended as an area of future research.

Given the compound price index $S_1 = \{S_1(t)\}\ t \geq 0$ and underlying asset price $S_2 = \{S_2(t)\}\ t \geq 0$, the spread will be the difference between the two instruments.

$$S(t) = S_2(t) - S_1(t), t \geq 0 \quad (1)$$

Where:

$S_1(t)$ = The compound price index computed from the aggregation of a number of crude oil prices reflecting the minimum price at time t of all competing crudes FOB to China's Qingdao port.

$S_2(t)$ = The price of Arabian Medium FOB JOS at time t.

Market players are said to be buying the spread if they purchase S_2 and sell S_1. They will make a profit on the transaction if the minimum price that they receive from selling crude FOB to Qingdao port minus the costs of purchasing the crude — Arabian Medium FOB JOS — is greater than the exercise price. The latter is defined as the cost of transportation from JOS to Qingdao.

The purpose of this section is to calculate the 'price' of a simple European call option on the spread between S_1 and S_2. That is the fair market value of the right to purchase the spread, at a fixed exercise, or strike price, which has been set equal to the cost of transportation from JOS to Qingdao. As mentioned above, European call options differ from U.S. options as they can only be exercised at expiry date T. They are defined by the date of expiry, the strike or exercise price and the value of the underlying instruments. (The American option can be exercised at any date prior to expiry, and as a result is considerably more difficult to calculate.)

The payoff of the spread option is given as:

$$(S(T) - K)^+ = (S(T) - K)1_{\{S(T)>K\}} \quad (2)$$

Where:

S(T) is defined in Equation 1.

T = The expiry date of the option.

K = The strike or exercise price of the option. In this case, the exercise price is equal to the cost of transportation from JOS to Qingdao.

Following (Black and Scholes 1973) and (Merton 1973) the price of the European call option *p(t,x)* at time t, when *S(t)* = x is given by the solution to the backward parabolic partial differential equation:

$$\partial_t p(t,x) + \frac{1}{2}\sigma^2 x^2 \partial_{xx}^2 p(t,x) + rx\partial_x p(t,x) - rp(t,x) = 0 \quad (3)$$

and terminal condition: $p(T,x) = (x-K)^{+}$

Where:

r = the short-term risk-free interest rate.

σ = The volatility of the underlying asset

When S(T) has a log-normal distribution:

$$p = E\{e^{-rt}(S(T) - K)^{+}\} \quad (4)$$

This can be solved explicitly for p given values for S(0), T, r and K

$$p = S(0)\emptyset(d_1) - Ke^{-rt}\emptyset(d_2) \quad (5)$$

Where

$$d_1 = \frac{\ln\left(\frac{S(0)e^{-rt}}{K}\right)}{\sigma\sqrt{T}} + \frac{1}{2}\sigma\sqrt{T} \quad and \quad d_2 = d_1 - \sigma\sqrt{T}$$

ø(x) is the cumulative distribution function for the standard normal distribution with mean zero,and standard deviation of 1,N(0,1).

The spread option is the difference between a European call option on asset 1 and a European put option on asset 2, with identical maturity T, and strike price K. It is given by the risk-neutral expectation (Durrleman and Carmona 2003):

$$p = e^{-rt}E\{(S_2(T) - S_1(T) - K)^{+}\} \quad (6)$$

At expiry T:

$$p = e^{-rT}\iint(s_2 - s_1 - K)^{+} f_T(s_1 s_2) d_{s_1} d_{s_2} \quad (7)$$

The solution to the double integral described in Equation 6 is obtained numerically, using Monte Carlo simulation (Rubinstein 1994) and (Garman 1992).

Note: The solution to the spread option defined by equations 6 was solved using (FINCAD 2017).

Given the following assumptions:

1. Type of exercise right: European.
2. Exercise price level: Cost of freight to transport the crude oil from JOS to Qingdao is $0.82/bbl.
3. Expiration date T: The option is expected to expire two months after the value or settlement date.
4. $S_1(0)$ = The compound price index computed from the aggregation of a number of other financial instruments reflecting the minimum price at time t of all competing crudes FOB to China Qingdao port.

- a. The minimum light grade is the Platts daily price of ESPO Mo01 FOB to Qingdao port at time 0.
- b. The minimum medium grade is the minimum of the Platts daily price of Dubai Mo01 and Castilla Blend FOB to Qingdao port at time 0.
- c. The minimum heavy grade is the minimum of the Platts daily price of Cold Lake Blend Hardisty Canada, Kern River, and WCS Hardisty Canada to FOB Qingdao port at time 0.

5. $S_2(0)$ = The price of MOC crude of comparable API FOB JOS at time t.

- a. The price of Arabian Light FOB JOS at time t-0.
- b. The price of Arabian Medium FOB JOS at time t=0.
- c. The price of Arabian Heavy FOB JOS at time t=0.

6. r = 2.5%.

7. The correlation coefficients between the various crude oil prices.

To be more specific:

(i) The minimum light grade is the Platts daily price of ESPO Mo01 FOB to Qingdao port at time 0. Where the price of ESPO FOB to Qingdao is the price of ESPO FOB Kozimoto (Platts) plus the cost of sea transportation to Qingdao of approximately $0.87/bbl estimated by KAPSARC calculations with the distance calculated using sea-distances.org and the KAPSARC Global Trade Oil Model, and the cost estimated using the KAPSARC Global Trade Oil Model,

(ii) The minimum medium grade is the minimum of the Platts daily price of Dubai, Mo01 and Castilla Blend FOB Qingdao port at time 0. Where (a) Dubai Mo01 plus the cost of sea transportation to Qingdao of approximately $1.64/bbl is estimated by KAPSARC calculations, with the distance calculated using sea-distances.org, and the cost estimated using the KAPSARC Global Trade Oil Model; and (b) Castilla Blend FOB Colombia plus KAPSARC calculations of the cost of sea transportation to Qingdao of approximately $2.12/bbl,

(iii) The minimum heavy grade is the minimum of the Platts daily price of Cold Lake Blend Hardisty Canada, Kern River, and WCS Hardisty Canada FOB to Qingdao port at time 0. The minimum price of (a) Kern River plus the cost of transportation to San Francisco port by pipeline is $1.39/bbl, plus KAPSARC calculations of the cost of sea transportation to Qingdao of approximately $1.35/bbl; (b) Cold Lake Blend and WCS Hardisty Canada plus the cost of transportation to a California port by pipeline approximately $12.65/bbl plus KAPSARC calculations of the cost of sea transportation to Qingdao of approximately $4.33 /bbl; and

(iv) The price of MOC crude of comparable API FOB JOS at time t. The price of Arabian Heavy, Medium and Light (Platts) plus the cost of sea transportation from MPT to the hypothetical JOS facility of approximately $1.65/bbl estimated by KAPSARC calculations with the distance calculated using sea-distances.org, and the cost estimated using the KAPSARC Global Trade Oil Model example of shipment to Okinawa.

The fair market values for the options are as follows:

4. Arabian Light vs. Minimum Light Grade = $1.14 US/bbl.

5. Arabian Medium vs. Minimum Medium Grade = $0.00.

6. Arabian Heavy vs. Minimum Heavy Grade = $0.10.

Appendix B: The Mathematical Model: A 'Spread Option'

Table B1. CP - Rates Hardisty to US Gulf Coast (USGC) as of Nov 16, 2016.

Classification	Loading fee $US / car	Loading fee $US / bbl	Manifest train $US / Car	Manifest train $US / bbl	Unit train $US / Car	Unit train $US / bbl	Unloading fee USGC ($US/car)	Unloading fee USGC ($US/bbl)	Brokerage fees ($US/car)	Brokerage fees ($US/Bbl)	Total / car	Total / bbl
Haz	$1,020.00	$1.50	$8,700.00	$12.79	-	-	$1,020.00	$1.50	$34.00	$0.05	$10,774.00	$15.84
Haz	$1,020.00	$1.50	-	-	$6,501.00	$9.56	$1,020.00	$1.50	$34.00	$0.05	$8,591.00	$12.61
Non Haz	$1,020.00	$1.50	$6,960.00	$10.24	-	-	$1,020.00	$1.50	$34.00	$0.05	$9,034.00	$13.29
Non Haz	$1,020.00	$1.50	-	-	$5,568.00	$8.19	$1,020.00	$1.50	$34.00	$0.05	$7,642.00	$11.24

Sources: Personal interviews, Diamond A Ventures, Simba industrial Transload (2016, November 17).

Notes: Hazardous regulated material (crude and LPGs) classification = heavy crudes and LPGs.

Non hazardous non regulated material - this would be medium / lighter crudes classified as fuel oils (Lloydminster crudes).

Crude cars = ~680-720 bbls / car. Note, ~10% minimum of heavy crude is diluent.

Crude manifest trains are trains that haul between 1-70 crude cars.

Crude unit trains are trains that haul ~100 crude cars.

Super unit trains haul 120+ crude cars - limited # of facilities that can take them.

There are also UniFest trains that typically are manifest trains leaving a destination that drop off cargo and pick up additional crude cars to become Unit Trains or can (for some reason) achieve unit train rates.

Appendix C: Estimating the Relationship Between Brent and Saudi Arabian Crudes

We used the futures curve for benchmark Brent crude to estimate the futures curves for the minimum price of crude delivered FOB at Qingdao (CME Group 2016). Specifically, the relationship between Brent and the minimum price of Saudi Arabian export grades of Light, Medium and Heavy crudes was estimated by a simple two-variable regression analysis. The results are presented in Table C1 (Platts 2016). Note: This is a very simple analysis of the differential between Brent and Saudi crudes. A more detailed analysis would include a more detailed econometric assessment of the price differential, the inclusion of adjustment factors, and is recommended as an area for future research.

Table C1. Regression results.

Regression equation
Min Cold Lake WCS Kern @ Qingdao = 3.3559321 + 0.82043253 Brent M1

	Multiple R	R-square	Adjusted R-square	Std. err. of estimate		
Summary						
	0.9509	0.9043	0.9042	7.226804401		
	Degrees of freedom	Sum of squares	Mean of squares	F	p-value	
ANOVA table						
Explained	1	1062343.708	1062343.708	20341.00699	< 0.0001	
Unexplained	2153	112444.0891	52.22670186			
	Coefficient	Standard error	t-value	p-value	Confidence interval 95%	
Regression table					lower	upper
Constant	3.355932099	0.526632549	6.372435777	< 0.0001	2.323170681	4.388693517
Brent M1	0.820432528	0.0057525	142.6219022	< 0.0001	0.809151493	0.831713563

Appendix C:
Estimating the Relationship Between Brent and Saudi Arabian Crudes

Regression equation

min Castilla Dubai @ Qiingdao = - 4.57309702 + 0.95367646 Brent M1

	Multiple R	R-square	Adjusted R-square	Std. err. of estimate
Summary				
	0.9915	0.9830	0.9830	3.390663442

	Degrees of freedom	Sum of squares	Mean of squares	F	p-value
ANOVA table					
Explained	1	1435428.057	1435428.057	124856.7606	< 0.0001
Unexplained	2153	24752.17674	11.49659858		

	Coefficient	Standard error	t-value	p-value	Confidence interval 95%	
Regression table					lower	upper
Constant	-4.573097022	0.247084829	-18.5082064	< 0.0001	-5.057646788	-4.088547255
Brent M1	0.953676456	0.002698951	353.3507615	< 0.0001	0.948383633	0.958969278

Regression equation

ESPO @ Qingdao = 0.03872019 + 1.00762764 Brent M1

	Multiple R	R-square	Adjusted R-square	Std. err. of estimate

Regression equation

Summary					
	0.9973	0.9946	0.9946	1.962826097	
	Degrees of Freedom	Sum of Squares	Mean of Squares	F	p-Value
ANOVA table					
Explained	1	1167486.89	1167486.89	303031.9115	< 0.0001
Unexplained	1650	6356.932375	3.852686288		

	Coefficient	Standard error	t-value	p-value	Confidence interval 95%	
Regression table					lower	upper
Constant	0.038720188	0.170790147	0.226712073	0.8207	-0.296268078	0.373708455
Brent M1	1.007627638	0.001830442	550.4833436	< 0.0001	1.004037405	1.011217872

Sources: Internal KAPSARC estimates, Platts, CME Group.
Estimated by Pallisade Stats Tools.

Appendix D: Potential Incremental Value of Spot Sales From the Hypothetical JOS Facility

Given the following assumptions:

1. Type of exercise right: European.
2. Exercise price level: Cost of freight to transport the crude oil from JOS to Qingdao is $0.82/bbl.
3. Expiration date T: The option is expected to expire two months after the value or settlement date.
4. $S_1(0)$ = The compound price index computed from the aggregation of a number of other financial instruments reflecting the minimum price at time t of all competing crudes FOB to China's Qingdao port.

- a. The minimum light grade is the Platts daily price of ESPO Mo01 FOB Qingdao port at time 0.
- b. The minimum medium grade is the minimum of the Platts daily price of Dubai Mo01 and Castilla Blend FOB Qingdao port at time 0.
- c. The minimum heavy grade is the minimum of the Platts daily price of Cold Lake Blend Hardisty Canada, Kern River, and WCS Hardisty Canada FOB Qingdao port at time 0.

5. $S_2(0)$ = The price of MOC crude of comparable API FOB JOS at time t.

- a. The price of Arabian Light FOB JOS at time t-0.
- b. The price of Arabian Medium FOB JOS at time t=0.
- c. The price of Arabian Heavy FOB JOS at time t=0.

6. r = 2.5%.
7. The forward curves for Brent and Dubai at time t=0.
8. Six sales of options per year.
9. The correlation coefficients between the various crude prices.

Table D1 lists the fair market annual options values for incremental spot oil sales from the JOS facility.

	Arab Light vs Minimum Light Composite	Arab Medium vs Minimum Medium Composite	Arab Heavy vs Minimum Heavy Composite
Asset 1 = S1(0)	$84.94	$83.43	$81.21
Asset 2 = S2(0)	$87.39	$78.10	$74.48
Exercise price	$0.820	0.82	0.82
Expiry date	12-Aug-2018	12-Aug-2018	12-Aug-2018
Value (settlement) date	12-Jun-2018	12-Jun-2018	12-Jun-2018
Volatility of asset 1	52.27%	57.27%	60.46%
Volatility of asset 2	49.11%	58.99%	51.16%
Interest rate - annual - actual/365	2.50%	2.50%	2.50%
Correlation coefficient	0.998	0.995	0.970
Fair value of option	$1.73	$0.0008	$0.16
Delta of asset 1	$(0.85)	$(0.0017)	$(0.07)
Delta of asset 2	$0.86	$0.0018	$0.08
Capacity available	2.98	2.98	2.98
Fair value of real option	$1.7348	$0.0008	$0.16
Volume of Arab crude traded	0.99	0.99	0.99
Fraction of time traded	6.00	6.00	6.00
Option value $ Millions	**$10.34**	**$0.00**	**$0.95**

The options value of the JOS facility is equal to the NPV of the reference case, plus the options value calculated in Table D1. Assuming crude oil production costs of $3/bbl onshore Middle East, transportation costs from MPT to JOS of $1.65/bbl and assumed spot sales FOB JOS of 33% of the available capacity of Arabian Medium, 33% of Arabian Heavy and 33% of Arabian Light crude, the gross revenue from these sales is approximately $94 million per annum. This yields an NPV of $1.61 billion at a 2.5% discount rate (see Table 2).

Adding the options value increases this value significantly, to approximately $118 million per annum. If the cash flows are not necessarily periodic, the XNPV can be calculated for the project and equals approximately $1.775 billion over the 15 years from 2016 to 2030.

$$XNPV = \sum_{i=0}^{T} \frac{P_i}{(1+r_t)^{\frac{d_i - d_0}{365}}} \quad (8)$$

Where:

P_i= the ith payment

d_i= the ith payment date

d_0= 0th payment date

Appendix E:Sensitivity Analysis and Monte Carlo Simulations

The use of stochastic modeling and Monte Carlo simulation to accommodate risks and uncertainties in crude oil projects is well documented (Nahmias 2016); (Ellefsen 2008).

For example, Nischal employed stochastic modeling and Monte Carlo simulation to model a crude oil dispatch plan from a process plant in India (Nischal and Kumar 2010). Kleindorfer used Monte Carlo simulation to minimize commodity procurement risk through hedging tools designed to limit exposure to unanticipated movements in exchange rates and commodity prices (Kleindorfer and Enver 2013).

As mentioned above, in the case of the JOS facility, the key economic variables, subject to commodity and transaction risks, include the amount of crude oil required to be maintained in the facility at all times for strategic purposes, commodity prices, costs and the project discount rate. The following variables were selected for sensitivity analysis:

1. Amount of crude required in the facility at all times for strategic purposes.
2. Project discount rate.
3. Slippage.
4. Production costs per barrel.
5. Transportation costs from MPT to JOS.
6. Brent futures.
7. Dubai futures.

Uniform probability distributions were estimated for assumptions 1-5, where a continuous uniform distribution X is defined as:

$$X \backsim U(a, b) \quad (9)$$

and a = the endpoint of the left interval

b = the endpoint of the right interval

The resulting probability distributions are listed below:

Amount of strategic oil ~ U (0.43,0.6).

Slippage ~ U (0.981,0.998).

Discount rate ~ U (0.04,0.26).

Transportation costs MPT to JOS ~ U (1.55,1.78).

Operating costs ~ U (0.4,0.63).

For the crude oil prices, daily estimates of historical futures prices were used to estimate the probability distributions of Brent and Dubai. Specifically, Platts' estimates of Brent M1 and Dubai Mo01 from Jan. 1, 2008 to Aug. 3, 2016 (Platts 2016). A number of probability distributions were fitted to the data, and the 'best fit' was determined using the Anderson-Darling test statistic, calculated as the average square distance between the empirical cumulative distribution function, and the fitted function, with special attention paid to the tails (Law and Kelton 2001); (Palisade 2012).

The resulting distributions are Kumaraswamy (Y), which is perhaps not surprising given the nature of Platts' data gathering and the data's close association with the distributions, used in the field of hydrology, specifically the estimation of reservoir yield and storage distribution (Fletcher and Kumaraswamy 1996); (Aloui and Jammazi 2015); (Javanshiri, Rad, and Arghami 2015).

Where Y has a continuous uniform distribution:

$$Y \backsim Kw(\alpha, \beta, \gamma, \delta) \quad (10)$$

and α = shape parameter

β = shape parameter

γ =defined minimum

δ = defined maximum

The resulting probability distributions are listed below:

Brent M1~Kw (2.3305,2.4455,16.038,141.55).

Dubai Mo01~Kw (2.0125,2.2961,24.798,146.45).

The distributions were correlated using the 0.999 correlation coefficient estimated with historical data from Platts, Jan. 1, 2008 to Aug. 3, 2016 inclusive.

Given the discounted NPV model presented in Table 2, Monte Carlo simulations were performed utilizing the probability distributions listed above, a Mersenne Twister random number generator (Makoto and Takuji 1998), and Latin hypercube sampling methodology (McKay, Beckman, and Conover 1979). The results of the Monte Carlo simulation are presented in Table E1.

Appendix E:
Sensitivity Analysis and Monte Carlo Simulations

Table 3. Sensitivity analysis.

Total XNPV of gross revenue from spot sales

Statistics		Percentile	
Minimum	$468.67	5%	$1,380.05
Maximum	$7,015.29	10%	$1,702.69
Mean	$3,433.09	15%	$2,045.84
Std Dev	1261.40538	20%	$2,353.64
Variance	1591143.53	25%	$2,499.77
Skewness	0.10	30%	$2,679.02
Kurtosis	2.57	35%	$2,934.93
Median	$3,422.43	40%	$3,077.60
Mode	$3,012.82	45%	$3,258.20
Volume of Arab Heavy	0.12	-0.01	-$1.26
Transportation costs	0.07	0.00	$91.95
Number of cycles	3.46		
Slippage costs	0.69		

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Sources: Internal KAPSARC calculations; Monte Carlo simulations estimated using @Risk Palisade.

Notes

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About the Project

This project intends to assess how the concept of energy security and energy security strategies of suppliers and consumers have evolved following the recent shifts in the global energy markets and balances, and the implications and potential directions of this evolution. The project is focused on the countries of the Gulf Cooperation Council and Northeast Asia and their inter-regional collaboration, with a special emphasis on Saudi Arabia and China. Besides conventional energy security dimensions, we plan to address the following research propositions: How can the magnitude of the changes in energy security be verified and quantified? Are the current energy export/import portfolios of the countries in focus optimal, considering existing and potential risks and diversification costs? Is there a subtle shift from energy security to enterprise and competition?

The goal of this research project is to study the other side of the coin — the security of oil demand from the net-exporter’s perspective. How do large oil exporters trade off risk and rewards in ensuring the security of demand? In the first phase of this research project, a comparative static model of global oil trade is developed to empirically measure the impacts of alternative crude oil market shares across segmented markets; to assess the strategic choice national oil companies (NOCs) have in valuing alternative sales market portfolios in the context of the trade-off along the risk-reward frontier; and to compare international oil company behavior as a benchmark for NOCs.

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